Nuclear Cardiology

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BRUCE Protocol Stress Test

The Bruce protocol is a commonly used treadmill exercise stress test. It was developed as a clinical test to evaluate patients with suspected coronary heart disease, though it can also be used to estimate cardiovascular fitness. Exercise is the preferred stress modality in patients who are able to exercise to an adequate workload (at least 85% of age-adjusted maximal predicted heart rate and five metabolic equivalents).

Indications

- Detection of obstructive coronary artery disease (CAD) in the following:
  (a) Patients with an intermediate pretest probability of CAD based on age, gender, and symptoms.
  (b) Patients with high-risk factors for CAD (e.g., diabetes mellitus, peripheral, or cerebral vascular disease).

- Risk stratification of post-myocardial infarction patients before discharge (submaximal test at 4-6 days), and early (symptom-limited at 14-21 days) or late (symptom-limited at 3-6 weeks) after discharge.

- Risk stratification of patients with chronic stable CAD into a low-risk category that can be managed medically or into a high-risk category that should be considered for coronary revascularization.

- Risk stratification of low-risk acute coronary syndrome patients (without active ischemia and/or heart failure 6-12 hours after presentation) and of intermediate-risk acute coronary syndrome patients 1-3 days after presentation (without active ischemia and/or heart failure symptoms).

- Risk stratification before noncardiac surgery in patients with known CAD or those with high-risk factors for CAD.

- To evaluate the efficacy of therapeutic interventions (anti-ischemic drug therapy or coronary revascularization) and in tracking subsequent risk based on serial changes in myocardial perfusion in patients with known CAD.

Contraindications

Absolute	Relative
• High-risk unstable angina. However, patients with chest pain syndromes at presentation, who are otherwise stable and pain-free, can undergo exercise stress testing. • Decompensated or inadequately controlled congestive heart failure. • Uncontrolled hypertension (blood pressure >200/110 mm Hg). • Uncontrolled cardiac arrhythmias (causing symptoms or hemodynamic compromise). • Severe symptomatic aortic stenosis. • Acute pulmonary embolism. • Acute myocarditis or pericarditis. • Acute aortic dissection. • Severe pulmonary hypertension. • Acute myocardial infarction (<4 days). • Acutely ill for any reason.	• Known left main coronary artery stenosis. • Moderate aortic stenosis. • Hypertrophic obstructive cardiomyopathy or other forms of outflow tract obstruction. • Significant tachyarrhythmias or bradyarrhythmias. • High-degree atrioventricular (AV) block. • Electrolyte abnormalities. • Mental or physical impairment leading to inability to exercise adequately. • If combined with imaging, patients with complete left bundle branch block (LBBB), permanent pacemakers, and ventricular pre-excitation (Wolff-Parkinson-White syndrome) should preferentially undergo pharmacologic vasodilator stress test (not dobutamine stress test).

Patient Preparation

- Nothing to eat 4 hours before the test. Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.

- A large-bore (18- to 22-gauge) intravenous (IV) cannula should be inserted for radiopharmaceutical injection during exercise.

- The electrocardiogram should be monitored continuously during the exercise test and for at least 5 minutes into the recovery phase or until the resting heart rate is <100 beats/minute and/or dynamic exercise-induced ST-segment changes have resolved. A 12-lead electrocardiogram should be obtained at every stage of exercise, at peak exercise, and at the termination or recovery phase.

- The heart rate and blood pressure should be recorded at least every 3 minutes during exercise, at peak exercise, and for at least 5 minutes into the recovery phase.

- All exercise tests should be symptom-limited. Achievement of 85% of maximum, age-adjusted, predicted heart rate is not an indication for termination of the test.

- The radiopharmaceutical should be injected as close to peak exercise as possible. Patients should be encouraged to exercise for at least 1 minute after the radiotracer injection.

- In patients who cannot exercise adequately and are being referred for a diagnostic stress test the patients may be considered for conversion to a pharmacologic stress test.

- Blood pressure medication(s) with antianginal properties (β-blocker, calcium channel blocker, and nitrates) will lower the diagnostic accuracy of a stress test. Generally, discontinuation of these medicines is left to the discretion of the referring physician.

BRUCE Protocol

Procedure: Exercise is performed on a treadmill. The test starts at 2.74 km/hr (1.7 mph) and at a gradient (or incline) of 10%. At three minute intervals the incline of the treadmill increases by 2%, and the speed increases as shown in the table below.

Stage	Speed (km/hr)	Speed (mph)	Gradient
1	2.74	1.7	10
2	4.02	2.5	12
3	5.47	3.4	14
4	6.76	4.2	16
5	8.05	5.0	18
6	8.85	5.5	20
7	9.65	6.0	22
8	10.46	6.5	24
9	11.26	7.0	26
10	12.07	7.5	28

Modifications: The ***Modified*** **Bruce protocol** starts at a lower workload than the standard test and is typically used for elderly or sedentary patients. The first two stages of the Modified Bruce Test are performed at a 1.7 mph and 0% grade and 1.7 mph and 5% grade, and the third stage corresponds to the first stage of the Standard Bruce Test protocol as listed above.

Indications for Early Termination of Exercise

- Moderate-to-severe angina pectoris.
- Marked dyspnea or fatigue.
- Ataxia, dizziness, or near-syncope.
- Signs of poor perfusion (cyanosis and pallor).
- Patient's request to terminate the test.
- Excessive ST-segment depression (>2 mm).
- ST elevation (>1 mm) in leads without diagnostic Q waves (except for leads V1 or aVR).
- Sustained supraventricular or ventricular tachycardia.
- Development of LBBB or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia.
- Drop in systolic blood pressure of >10 mm Hg from baseline, despite an increase in workload, when accompanied by other evidence of ischemia.
- Hypertensive response (systolic blood pressure >250 mm Hg and/or diastolic pressure >115 mm Hg).
- Technical difficulties in monitoring the electrocardiogram or systolic blood pressure.

Pharmacologic Stress Protocols
For Dipyridamole, Adenosine and Regadenoson

Indications

- Patients who cannot achieve an adequate heart rate and blood pressure response with an exercise stress protocol due to a noncardiac physical limitation such as pulmonary, peripheral vascular, or musculoskeletal abnormalities or due to lack of motivation.

- Baseline electrocardiographic (ECG) abnormalities: LBBB, ventricular pre-excitation (Wolff-Parkinson-White syndrome), and permanent ventricular pacing.

- Risk stratification of clinically stable patients into low and high-risk groups very early after acute myocardial infarction (≥1 day) or following presentation to the emergency department with a presumptive acute coronary syndrome.

Contraindications

<table>
<tr><th>DIPYRIDAMOLE</th><th>ADENOSINE</th><th>REGADENOSON</th></tr>
<tr><td colspan="3">• Patients with second or third degree AV block or sinus node dysfunction unless these patients have a functioning artificial pacemaker.
• Patients with bronchospasm.
• Systolic blood pressure <90 mm Hg.
• Methylxanthines such as aminophylline, theobromine in last 24 hours and/or ingestion of caffeinated foods (e.g., chocolate), beverages (e.g., coffee, tea, and sodas) or medications (e.g., Tylenol 2 and 3) within the last 24 hours. Patients should also avoid decaffeinated products, which typically contain some caffeine, as opposed to caffeine-free products, which do not.
• Known hypersensitivity to the pharmacologic stress agent.
• Unstable acute myocardial infarction or acute coronary syndrome.

Relative Contraindications
• Profound sinus bradycardia (heart rates <40/min).</td></tr>
<tr><td>• Asthmatic patients with ongoing wheezing should not undergo dipyridamole stress testing. However, patients with adequately controlled asthma can undergo a dipyridamole stress test and can have pre-treatment with two puffs of albuterol or a comparable inhaler.

• In patients taking oral dipyridamole, IV dipyridamole may be administered safely and efficaciously.</td><td>• Asthmatic patients with ongoing wheezing should not undergo adenosine stress testing. However, patients with adequately controlled asthma can undergo an adenosine stress test and can have pre-treatment with two puffs of albuterol or a comparable inhaler.

• Use of dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) in last 48 hours.</td><td>• Inadequate data exists to confidently use regadenoson in patients with COPD or asthma.

• Use of dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) in last 48 hours.</td></tr>
</table>

Patient Preparation

DIPYRIDAMOLE	ADENOSINE	REGADENOSON
• As with exercise testing, anti-ischemic cardiac medications (including β-blockers, nitrates, and calcium antagonists) have been reported to decrease the diagnostic accuracy of vasodilator stress testing. Generally, discontinuation of these medicines is left to the discretion of the referring physician. • Nothing to eat for at least 4 hours and no caffeine-containing food, beverages or medication at least 24 hours prior to testing. • Methylxanthines such as aminophylline, theophylline, caffeine or theobromine block the effect of adenosine and should be held for at least 24 hours prior to the test. Pentoxifylline (Trental) does not appear to block the effects of adenosine.		
• An infusion pump is preferable, but dipyridamole can also be administered by hand injection or drip.	• An infusion pump is required for adenosine to be administered at a constant infusion rate.	• No infusion pump required.
• In patients taking oral dipyridamole, IV dipyridamole may be administered safely and efficaciously.	• Dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) should be withheld for at least 2 days prior to adenosine administration.	• Dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) should be withheld for at least 2 days prior to regadenoson administration.
• A 22 gauge or larger IV line in a peripheral vein is required for the injection of the dipyridamole and radiotracer.	• A 22 gauge or larger IV line with a dual-port Y-connector or two separate IV lines are required for the adenosine infusion and injection of the radiotracer.	• A 22 gauge or larger IV line in a peripheral vein is required for the injection of the regadenoson and radiotracer.
• Dipyridamole is infused intravenously at 0.56 mg/kg over a 4-minute period (142 mcg/kg/min). The radiotracer is injected 3-5 minutes after the completion of dipyridamole infusion. • For patients deemed to be at a higher risk for complications (borderline hypotension, controlled asthma), dipyridamole is infused intravenously at 0.56 mg/kg over a 6 minute period (95 mcg/kg/min). The radiotracer is injected 2-3 minutes after the completion of dipyridamole infusion.	• Adenosine infusion should be given at a rate of 140 mcg/kg/min for 3 minutes followed by the injection of the radiotracer. The infusion should be continued for another 3 minutes. • For patients deemed to be at a higher risk for complications (borderline hypotension, controlled asthma), adenosine infusion may be started at a lower dose (70-100 mcg/kg/min). If this dose is tolerated well for 1 minute, the infusion rate should be increased to 140 mcg/kg/min and should be continued for 4 minutes. The radiotracer should be injected 1 minute after starting the 140 mcg/kg/min dose.	• Regadenoson (5 mL, containing 0.4 mg of regadenoson) should be given as a rapid (approximately 10 seconds) injection. Administer a 5-mL saline flush immediately after the injection of regadenoson. Administer the radionuclide myocardial perfusion imaging agent 10-20 seconds after the saline flush.
• **Combination of Low-Level Exercise with Dipyridamole Infusion.** Patients who are ambulatory may undergo low-level treadmill exercise (1.7 mph, 0% grade) for 4-6 minutes soon after the completion of dipyridamole infusion. Radiotracer is injected during this low-level exercise, and the exercise continues for two additional minutes to allow for tracer uptake in the myocardium. This significantly reduces the side effects and improves image quality. Low-level exercise supplementation is not recommended for patients with LBBB.	• **Combination of Low-Level Exercise with Adenosine Infusion.** The combination of low-level upright treadmill exercise (1.7 mph, 0% grade) during the adenosine infusion has been found to be safe. Radiotracer is injected at 3 minutes into the low-level exercise/ infusion, and the exercise/infusion continues for three additional minutes to allow for tracer uptake in the myocardium. This significantly reduces the side effects and improves image quality. Low-level exercise supplementation is not recommended for patients with LBBB.	• **Combination of Low-Level Exercise with Regadenoson Infusion - Not Available.**

Patient Preparation, Continued

DIPYRIDAMOLE	ADENOSINE	REGADENOSON
• The electrocardiogram should be monitored continuously during the pharmacologic stress test and for at least 3-5 minutes into the recovery phase or until stable. A 12-lead electrocardiogram will be recorded every minute during the infusion and recovery phase. • Blood pressure should be monitored every minute during infusion and 3-5 minutes into recovery or until stable.		
• Aminophylline (125-250 mg intravenously) is often required to reverse side effects. Aminophylline should also be used in the presence of ischemic ECG changes after dipyridamole. • The half-life of dipyridamole is approximately 30-45 minutes.	• Due to an exceedingly short half-life of adenosine, most side effects resolve in a few seconds after discontinuation of the adenosine infusion, and aminophylline infusion is only very rarely required. • The half-life of adenosine is <10 sec.	• Aminophylline may be administered in doses ranging from 50 to 250 mg by slow intravenous injection (50-100 mg over 30-60 seconds) to attenuate severe and/or persistent adverse reactions to regadenoson. • The half-life of the initial phase is approximately 2-4 minutes. An intermediate phase follows, with a half-life on average of 30 minutes coinciding with loss of the pharmacodynamic effect. The last phase consists of a decline in plasma concentration with a half-life of approximately 2 hours.

Indications for Early Termination of Infusion

DIPYRIDAMOLE	ADENOSINE	REGADENOSON
• Severe hypotension (systolic blood pressure, <80 mm Hg). • Development of symptomatic, persistent second degree or complete heart block. • Wheezing. • Severe chest pain associated with ST depression of 2 mm or greater. • Signs of poor perfusion (pallor, cyanosis, and cold skin). • Technical problems with the monitoring equipment. • Patient's request to stop.		

Dobutamine Protocol Stress Test

Dobutamine infusion results in direct β1 and β2 stimulation with a dose-related increase in heart rate, blood pressure, and myocardial contractility. Dobutamine increases regional myocardial blood flow based on physiologic principles of coronary flow reserve.

Indications

- Dobutamine is a secondary pharmacologic stressor that is recommended only in patients who cannot undergo exercise stress and who also have contraindications to pharmacologic vasodilator stressors (mainly bronchospastic airway disease).

- Dobutamine perfusion imaging has not been studied as extensively as adenosine or dipyridamole perfusion imaging in the evaluation and prognostication of patients with CAD.

Contraindications

- Recent (<1 week) myocardial infarction.
- Unstable angina.
- Hemodynamically significant left ventricular outflow tract obstruction.
- Severe aortic stenosis.
- Atrial tachyarrhythmias with uncontrolled ventricular response.
- Prior history of ventricular tachycardia.
- Uncontrolled hypertension (blood pressure >200/110 mm Hg).
- Patients with aortic dissection or large aortic aneurysm.
- Patients who are on β-blockers the heart rate and inotropic responses to dobutamine will be attenuated.

Patient Preparation

- Nothing to eat for at least 4 hours. Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.

- An infusion pump is necessary for dobutamine administration.

- A 22 gauge or larger IV line with a dual-port Y-connector or two separate IV lines are required for the dobutamine infusion and injection of the radiotracer.

- Dobutamine infusion should start at a dose of 5-10 mcg/kg/min. The dobutamine dose should then be increased at 3-minute intervals up to a maximum of 40 mcg/kg/min. The radiotracer should be injected at 1 minute into the highest dobutamine dose, and dobutamine infusion should be continued for 2 minutes after the radiotracer injection. As with exercise stress, achieving >85% of the predicted heart rate is desirable.

- The addition of atropine is recommended (divided doses of 0.25-0.5 mg up to 1-2 mg) in patients who do not achieve target heart rate with dobutamine alone.

- The electrocardiogram should be monitored continuously during the dobutamine test and for at least 5 minutes into the recovery phase or until the resting heart rate is <100 beats/minute and/or induced ST-segment changes have resolved. A 12-lead electrocardiogram will be recorded every minute during the infusion and recovery phase.

Patient Preparation, Continued

- The heart rate and blood pressure should be recorded at least every 3 minutes during infusion, at peak, and for at least 5 minutes into the recovery phase or until stable.

- In patients with ongoing β blocker treatment a reduced sensitivity for reversible ischaemia has been found even if target heart rate was reached with additional atropine injections, caused by the negative inotropic effect of β blockers. Therefore stopping β blocker treatment 48 hours before the test is useful to increase sensitivity of the test. However, if this may not be possible, patients still can be accepted for dobutamine stress with atropine. In these cases the clinical relevance of the underlying ischaemia should be judged under the given treatment.

- Ischemic ST-segment depression occurs in approximately one-third of patients undergoing dobutamine infusion. Severe side effects may require IV administration of a short-acting β-blocker (esmolol, 0.5 mg/kg over 1 minute).

- The half-life of dobutamine is approximately 2 minutes.

Indications for Early Termination of Dobutamine

The indications for early termination of dobutamine are similar to those for exercise stress. Termination for ventricular tachycardia or ST-segment depression is more likely with dobutamine than with other stressors.

- Moderate-to-severe angina pectoris.
- Marked dyspnea or fatigue.
- Ataxia, dizziness, or near-syncope.
- Signs of poor perfusion (cyanosis and pallor).
- Patient's request to terminate the test.
- Excessive ST-segment depression (>2 mm).
- ST elevation (>1 mm) in leads without diagnostic Q waves (except for leads V1 or aVR).
- Sustained supraventricular or ventricular tachycardia.
- Development of LBBB or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia.
- Drop in systolic blood pressure of >10 mm Hg from baseline, despite an increase in workload, when accompanied by other evidence of ischemia.
- Hypertensive response (systolic blood pressure >250 mm Hg and/or diastolic pressure >115 mm Hg).
- Technical difficulties in monitoring the electrocardiogram or systolic blood pressure.

One Day Gated Rest/Stress
Tc-99m Myocardial Perfusion Imaging Study

Study Description

Myocardial perfusion imaging uses an intravenously administered radiopharmaceutical to depict the distribution of blood flow in the myocardium. Perfusion imaging identifies areas of relatively reduced myocardial blood flow associated with ischemia or scar. The relative regional distribution of perfusion can be assessed at rest, during cardiovascular stress, or both. ^{99m}Tc-labeled radiopharmaceuticals used for myocardial perfusion imaging are Sestamibi or Tetrofosmin.

A one day gated rest/stress protocol includes a low radiopharmaceutical dose rest study which is followed by an exercise or a pharmacological stress protocol and a high radiopharmaceutical dose stress study.

Patient Preparation

- Patients should be NPO at least 4 hours prior to Myocardial Perfusion Imaging (MPI). Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.
- Blood pressure medication(s) with antianginal properties (β-blocker, calcium channel blocker, and nitrates) will lower the diagnostic accuracy of a stress test. Generally, a 48 hour discontinuation of these medicines is recommended and left to the discretion of the referring physician.
- Remind patients to bring a list of all their medications and to record all medication doses and times for the 48 hours prior to the stress SPECT study, including the time off beta-blockers, calcium channel blockers and long acting nitrates.
- Patients should discontinue long acting nitrates for at least 12 hours prior to the stress test.
- Patients should not smoke at least 4 hours prior to MPI.
- Patients should bring comfortable clothes and footwear for their treadmill exercise test.
- A large-bore (18- to 22-gauge) intravenous (IV) cannula should be inserted for radiopharmaceutical injection.
- If this is a follow-up study, make sure to use the same camera, camera parameters, radionuclide doses and medication doses that were used for the baseline study for the follow-up studies.
- Record all the information on the worksheets.

Patient Preparation, Continued

Patients who cannot exercise adequately and are being referred for an exercise stress test may be considered for conversion to a pharmacologic stress test. To facilitate the conversion, patients should abstain from the following:

- Patients should not have any caffeine, caffeine containing foods, beverages or medications for 24 hours prior to the dipyridamole, adenosine or regadenoson stress study.
- Methylxanthines such as aminophylline, theophylline, caffeine or theobromine block the effect of adenosine and should be held for at least 24 hours prior to the test. Pentoxifylline (Trental) does not appear to block the effects of adenosine.
- Dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) should be withheld for at least 2 days prior to the pharmacologic stress test.

Nitroglycerine (NTG) Administration

- In patients with a history of myocardial infarction or severe coronary disease, it may be advisable to administer nitroglycerin sublingually (one spray of 0.4 mg) about 3-5 minutes before the resting injection of the radiopharmaceutical.
- Erectile dysfunction medications (e.g. Viagra, Cialis or Levitra) use in the last 24 hours is a contraindication to the sublingual nitroglycerin administration.
- The patient should be advised not to use erectile dysfunction medications for an additional 24 hours post nitroglycerin administration.
- If a patient is already wearing a NitroDur patch, remove the patch, wait 5 minutes, and administer the sublingual nitroglygerin.

Tc-99m Sestamibi / Tetrofosmin Doses

- Patients greater than 113 Kg (250 lbs) or 30 BMI should be switched to a Two Day Protocol.
- Using standard tracer injection techniques inject the ^{99m}Tc radiopharmaceutical into a peripheral arm vein and image after an appropriate time delay. If there is excessive infiltration of the tracer the study should be rescheduled for another day.
- For patients with poor veins an intravenous catheter may need to be inserted into a peripheral vein and used to inject both the rest and stress radiopharmaceutical.

Tc-99m Sestamibi / Tetrofosmin Doses, Continued

Prepare and inject an adequate tracer amount of ^{99m}Tc Sestamibi / Tetrofosmin according to the following dose schedule:

Subject Weight		Rest Dose		Stress Dose	
		mCi	MBq	mCi	MBq
	<70 Kg	7.2	268	21.7	803
≥ 70 Kg	<80 Kg	7.8	287	23.3	860
≥ 80 Kg	<90 Kg	8.8	325	26.4	975
≥ 90 Kg	<100 Kg	9.8	363	29.5	1090
≥ 100 Kg	<110 Kg	10.9	401	32.6	1204
≥ 110 Kg	<120 Kg	11.9	440	35.7	1319

Stress injection dose based on 0.31 mCi/Kg according to ASNC guidelines.
Rest injection dose based on 0.103 mCi/Kg according to ASNC guidelines.

- Image the patient after an appropriate time delay for the imaging protocol.

Protocol and tracer specific image delay times:

Protocol	Time to Imaging (Minutes)	
	Sestamibi	Tetrofosmin
Rest	45-60	30-45
Exercise	15-20	10-15
Dipyridamole	60	45
Dipyridamole with Low-Level Exercise	15-20	10-15
Adenosine	60	45
Adenosine with Low-Level Exercise	15-20	10-15
Regadenoson	60	45
Dobutamine	15-20	10-15

There is minimal redistribution with these radiopharmaceuticals, longer delays of up to 2 hours between radiotracer injection and imaging may be used when needed.

ECG Gating Setup

- Electrode Placement:

  Prepare skin for optimal contact with electrodes using an alcohol prep and abrasive pad. Use 3 electrodes, 2 subclavicular (1 on each side) and 1 below left ribcage.

  If small R wave: 1) Switch lead output on the gating box
  2) Move left ribcage electrode to right side
  3) Move subclavicular electrodes closer together

- If there are >30% PVC's or you cannot gate, document and continue acquisition un-gated

Rest and Stress Acquisition Parameters

- Patients should be imaged supine with arms extended over the head, out of the field of view of the camera. All jewellery should be removed from around the neck area. For female patients: no bra and record bra and cup size. Patients should be instructed to relax and breathe normally (no talking, sleeping, heavy breathing or coughing). Inform them of the effects of motion. Use pillows and blankets to make patients comfortable.

Position:	Supine	
Energy window:	15%-20% symmetric window over the 140 keV photopeak	
Angular Range:	180° (45° RAO to 45° LPO)	
Angular Step:	3°	
Time/ Angular Step:		
Rest Study	25 sec	***Note:*** For patients >102 kg (225 lbs) increase time/angular step by 5 seconds.
Stress Study	20 sec	
Matrix Size:	64 x 64	
No. of projections:	60-64	
Collimator:	LEHR	
Orbit:	Circular or non-circular	
Acquisition type:	Step-and-shoot (preferred) or continuous	
Zoom:	Adjust for a pixel size of 6.4mm/pix ± 0.4mm	
ECG gating:	Yes	
Frames/cycle	8	
R-to-R window	100% (±50 %)	

- Acquisitions should be started at the right anterior oblique position and proceed 180° to the left posterior oblique position.

- For attenuation correction purposes, acquire the low dose CT transmission images after the emission study is complete and has been reviewed for artifacts. Do not allow the patient to move in between the emission and transmission acquisitions.

Quality Assurance (QA) of Projection Data

All projection data should be reviewed immediately post-acquisition for quality assurance.

- Post acquisition, the raw tomographic data is reviewed, in cine mode, for possible artifacts due to patient and/or heart motion, "upward creep," breast shadow due to attenuation, diaphragmatic attenuation, and superimposed abdominal visceral activity.

- For gated studies, the cine is reviewed for gating errors due to arrhythmias demonstrated by an intermittent flashing of the images.

Look for:	**Solve by:**
Motion	Repeat scan
Upward Creep	Repeat scan
Bad Gate (flashing)	Fix gate, then repeat scan
Liver Hot or Bowel Too Close to Heart	Repeat 1 hour later
Poor Counts	Check for infiltration. If none: Repeat scan with a longer acquisition time.

- If using attenuation correction, before reconstructing the attenuation corrected emission data, the transmission data is to be checked for artifacts and corrected for misalignment in between the emission and transmission data.

Please archive your data.

Two Day Gated Stress/Rest
Tc-99m Myocardial Perfusion Imaging Study

Study Description

Myocardial perfusion imaging uses an intravenously administered radiopharmaceutical to depict the distribution of blood flow in the myocardium. Perfusion imaging identifies areas of relatively reduced myocardial blood flow associated with ischemia or scar. The relative regional distribution of perfusion can be assessed at rest, during cardiovascular stress, or both. ^{99m}Tc-labeled radiopharmaceuticals used for myocardial perfusion imaging are Sestamibi or Tetrofosmin.

To improve the quality of the myocardial perfusion images for patients greater than 113 Kg (250 lbs) a two day gated stress/rest protocol is followed. On day one, an exercise or a pharmacological stress protocol is carried out, an injection of a radiopharmaceutical is given and a stress study is acquired. If the stress study is equivocal or abnormal than, on day two, a rest study is required to resolve the problem and characterize the abnormality as to whether it is fixed or reversible. If the stress study is normal than no further testing is required.

Patient Preparation: Day One/Stress Study

- Patients should be NPO at least 4 hours prior to Myocardial Perfusion Imaging (MPI). Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.
- Blood pressure medication(s) with antianginal properties (β-blocker, calcium channel blocker, and nitrates) will lower the diagnostic accuracy of a stress test. Generally, a 48 hour discontinuation of these medicines is recommended and left to the discretion of the referring physician.
- Remind patients to bring a list of all their medications and to record all medication doses and times for the 48 hours prior to the stress SPECT study, including the time off beta-blockers, calcium channel blockers and long acting nitrates.
- Patients should discontinue long acting nitrates for at least 12 hours prior to the stress test.
- Patients should not smoke at least 4 hours prior to MPI.
- Patients should bring comfortable clothes and footwear for their treadmill exercise test.
- A large-bore (18- to 22-gauge) intravenous (IV) cannula should be inserted for radiopharmaceutical injection.
- If this is a follow-up study, make sure to use the same camera, camera parameters, radionuclide doses and medication doses that were used for the baseline study for the follow-up studies.
- Record all the information on the worksheets.

Patient Preparation: Day One/Stress Study Continued

Patients who cannot exercise adequately and are being referred for an exercise stress test may be considered for conversion to a pharmacologic stress test. To facilitate the conversion, patients should abstain from the following:

- Patients should not have any caffeine, caffeine containing foods, beverages or medications for 24 hours prior to the dipyridamole, adenosine or regadenoson stress study.

- Methylxanthines such as aminophylline, theophylline, caffeine or theobromine block the effect of adenosine and should be held for at least 24 hours prior to the test. Pentoxifylline (Trental) does not appear to block the effects of adenosine.

- Dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) should be withheld for at least 2 days prior to the pharmacologic stress test.

Patient Preparation: Day Two/Rest Study

If the stress MPI study is equivocal or abnormal than a rest study is required to resolve the problem and characterize the abnormality as to whether it is fixed or reversible.

- Patients should be NPO at least 2 hours prior to the resting MPI study. Patients scheduled for later in the morning may have a light (cereal, fruit) breakfast.

- Patients should not smoke at least 4 hours prior to the resting MPI study.

- If this is a follow-up study, make sure to use the same camera, camera parameters, radionuclide doses and medication doses that were used for the baseline study for the follow-up studies.

- Record all the information on the worksheets.

Day Two/Rest Study: Nitroglycerine (NTG) Administration

- In patients with a history of myocardial infarction or severe coronary disease, it may be advisable to administer nitroglycerin sublingually (one spray of 0.4 mg) about 3-5 minutes before the resting injection of the radiopharmaceutical.

- Erectile dysfunction medications (e.g. Viagra, Cialis or Levitra) use in the last 24 hours is a contraindication to the sublingual nitroglycerin administration.

- The patient should be advised not to use erectile dysfunction medications for an additional 24 hours post nitroglycerin administration.

- If a patient is already wearing a NitroDur patch, remove the patch, wait 5 minutes, and administer the sublingual nitroglycerin.

Tc-99m Sestamibi / Tetrofosmin Doses

- Using standard tracer injection techniques inject the ^{99m}Tc radiopharmaceutical into a peripheral arm vein and image after an appropriate time delay. If there is excessive infiltration of the tracer the study should be rescheduled for another day.

- For patients with poor veins an intravenous catheter may need to be inserted into a peripheral vein and used to inject both the rest and stress radiopharmaceutical.

- Prepare and inject an adequate tracer amount of ^{99m}Tc Sestamibi / Tetrofosmin according to the following dose schedule:

Stress Dose		Rest Dose	
mCi	MBq	mCi	MBq
30	1110	30	1110

- Image the patient after an appropriate time delay for the imaging protocol.

Protocol and tracer specific image delay times:

Protocol	Time to Imaging (Minutes)	
	Sestamibi	Tetrofosmin
Rest	45-60	30-45
Exercise	15-20	10-15
Dipyridamole	60	45
Dipyridamole with Low-Level Exercise	15-20	10-15
Adenosine	60	45
Adenosine with Low-Level Exercise	15-20	10-15
Regadenoson	60	45
Dobutamine	15-20	10-15

There is minimal redistribution with these radiopharmaceuticals, longer delays of up to 2 hours between radiotracer injection and imaging may be used when needed.

ECG Gating Setup

- Electrode Placement:

  Prepare skin for optimal contact with electrodes using an alcohol prep and abrasive pad. Use 3 electrodes, 2 subclavicular (1 on each side) and 1 below left ribcage.

  If small R wave: 1) Switch lead output on the gating box
  2) Move left ribcage electrode to right side
  3) Move subclavicular electrodes closer together

- If there are >30% PVC's or you cannot gate, document and continue acquisition un-gated

Rest and Stress Acquisition Parameters

- Patients should be imaged supine with arms extended over the head, out of the field of view of the camera. All jewellery should be removed from around the neck area. For female patients: no bra and record bra and cup size. Patients should be instructed to relax and breathe normally (no talking, sleeping, heavy breathing or coughing). Inform them of the effects of motion. Use pillows and blankets to make patients comfortable.

Position:	Supine
Energy window:	15%-20% symmetric window over the 140 keV photopeak
Angular Range:	180° (45° RAO to 45° LPO)
Angular Step:	3°
Time/ Angular Step:	
Rest Study	30 sec
Stress Study	25 sec
Matrix Size:	64 x 64
No. of projections:	60-64
Collimator:	LEHR
Orbit:	Circular or non-circular
Acquisition type:	Step-and-shoot (preferred) or continuous
Zoom:	Adjust for a pixel size of 6.4mm/pix ± 0.4mm
ECG gating:	Yes
Frames/cycle	8
R-to-R window	100% (±50 %)

- Acquisitions should be started at the right anterior oblique position and proceed 180° to the left posterior oblique position.

- For attenuation correction purposes, acquire the low dose CT transmission images after the emission study is complete and has been reviewed for artifacts. Do not allow the patient to move in between the emission and transmission acquisitions.

Quality Assurance (QA) of Projection Data

All projection data should be reviewed immediately post acquisition for quality assurance.

- Post acquisition, the raw tomographic data is reviewed, in cine mode, for possible artifacts due to patient and/or heart motion, "upward creep," breast shadow due to attenuation, diaphragmatic attenuation, and superimposed abdominal visceral activity.

- For gated studies, the cine is reviewed for gating errors due to arrhythmias demonstrated by an intermittent flashing of the images.

Look for:	**Solve by:**
Motion	Repeat scan
Upward Creep	Repeat scan
Bad Gate (flashing)	Fix gate, then repeat scan
Liver Hot or Bowel Too Close to Heart	Repeat 1 hour later
Poor Counts	Check for infiltration. If none: Repeat scan with a longer acquisition time.

- If using attenuation correction, before reconstructing the attenuation corrected emission data, the transmission data is to be checked for artifacts and corrected for misalignment in between the emission and transmission data.

Please archive your data.

Tl-201 Stress/Redistribution

Study Description

Myocardial perfusion imaging uses an intravenously administered radiopharmaceutical to depict the distribution of blood flow in the myocardium. Perfusion imaging identifies areas of relatively reduced myocardial blood flow associated with ischemia or scar. The relative regional distribution of perfusion can be assessed at rest, during cardiovascular stress, or both.

Tl-201 is an analog of potassium, with a physical half-life of 73.1 hours, decay by electron capture to Hg-201 with principal emission of 68-80 keV x-rays, high first-pass extraction (85%), active membrane transport into the myocyte, rapid clearance from the intravascular space, and mono exponential washout (redistribution) which starts 10-15 minutes after injection. Washout depends on initial tracer concentration in the myocyte and on myocardial blood flow. Clearance occurs via the kidneys. The whole body effective dose for Tl-201 is approximately 6.3 mSv per mCi of Tl-201 injected.

A single dose of 3-4 mCi of Tl-201 is injected prior to peak exercise stress or at peak pharmacologic vasodilation, and the stress imaging starts at 10-15 minutes later. Redistribution imaging is done 3-4 hours later. In cases where standard stress-redistribution imaging shows a fixed or minimally reversible perfusion abnormality, myocardial viability can be furthered assessed with a redistribution image at 18-24 hours.

Patient Preparation

- Patients should be NPO at least 4 hours prior to Myocardial Perfusion Imaging (MPI). Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.
- Blood pressure medication(s) with antianginal properties (β-blocker, calcium channel blocker, and nitrates) will lower the diagnostic accuracy of a stress test. Generally, a 48 hour discontinuation of these medicines is recommended and left to the discretion of the referring physician.
- Remind patients to bring a list of all their medications and to record all medication doses and times for the 48 hours prior to the stress SPECT study, including the time off beta-blockers, calcium channel blockers and long acting nitrates.
- Patients should discontinue long acting nitrates for at least 12 hours prior to the stress test.
- Patients should not smoke at least 4 hours prior to MPI.
- Patients should bring comfortable clothes and footwear for their treadmill exercise test.
- A large-bore (18- to 22-gauge) intravenous (IV) cannula should be inserted for radiopharmaceutical injection.
- If this is a follow-up study, make sure to use the same camera, camera parameters, radionuclide doses and medication doses that were used for the baseline study for the follow-up studies.
- Record all the information on the worksheets.

Patient Preparation, Continued

Patients who cannot exercise adequately and are being referred for an exercise stress test may be considered for conversion to a pharmacologic stress test. To facilitate the conversion, patients should abstain from the following:

- Patients should not have any caffeine, caffeine containing foods, beverages or medications for 24 hours prior to the dipyridamole, adenosine or regadenoson stress study.
- Methylxanthines such as aminophylline, theophylline, caffeine or theobromine block the effect of adenosine and should be held for at least 24 hours prior to the test. Pentoxifylline (Trental) does not appear to block the effects of adenosine.
- Dipyridamole, dipyridamole-containing medications (e.g., Aggrenox) should be withheld for at least 2 days prior to the pharmacologic stress test.

201-Thallous Chloride Doses

Prepare an adequate tracer amount of ^{201}Thallous Chloride according to the following dose schedule:

Subject Weight		^{201}Tl Dose mCi	MBq
	<70 Kg	3	110
≥ 70 Kg	<90 Kg	3.0-3.2	110-120
≥ 90 Kg	<115 Kg	3.2-3.5	120-130
≥ 115 Kg	<135 Kg	3.5-3.8	130-140
≥ 135 Kg		3.8-4.0	140-150

- Using an intravenous catheter inject the ^{201}Thallous Chloride into a peripheral vein at peak exercise stress or at peak pharmacologic vasodilation and image after a 10-15 minute time delay.

Image delay times:

201-Tl Protocol	Time to Imaging
Stress	10-15 Minutes
Redistribution	3-4 Hours
24 Hour Study	18-24 Hours

ECG Gating Setup

- Electrode Placement:

  Prepare skin for optimal contact with electrodes using an alcohol prep and abrasive pad. Use 3 electrodes, 2 subclavicular (1 on each side) and 1 below left ribcage.

  If small R wave: 1) Switch lead output on the gating box
  2) Move left ribcage electrode to right side
  3) Move subclavicular electrodes closer together

- If there are >30% PVC's or you cannot gate, document and continue acquisition un-gated

Stress/Redistribution and 24 Hour Acquisition Parameters

- Patients should be imaged supine with arms extended over the head, out of the field of view of the camera. All jewellery should be removed from around the neck area. For female patients: no bra and record bra and cup size. Patients should be instructed to relax and breathe normally (no talking, sleeping, heavy breathing or coughing). Inform them of the effects of motion. Use pillows and blankets to make patients comfortable.

Position:	Supine
Energy window:	30% symmetric window over the 70 keV photopeak 20% symmetric window over the 167 keV photopeak
Angular Range:	180° (45° RAO to 45° LPO)
Angular Step:	3° (preferred) or 6°
Time/ Angular Step:	
Stress Study	40 sec (32 fr), 25 sec (64 fr)
3-4 Hr Redistribution	40 sec (32 fr), 25 sec (64 fr)
24 Hr Redistribution	45 sec (32 fr), 30 sec (64 fr)
Matrix Size:	64 x 64
No. of projections:	32-64
Collimator:	LEAP (preferred) or LEHR
Orbit:	Circular or non-circular
Acquisition type:	Step-and-shoot or continuous
Zoom:	Adjust for a pixel size of 6.4mm/pix ± 0.4mm
ECG gating:	Stress study only
Frames/cycle	8
R-to-R window	100% (±50 %)

Note: For a LEHR collimator increase time/angular step by 5 seconds.

- Acquisitions should be started at the right anterior oblique position and proceed 180° to the left posterior oblique position.

- For attenuation correction purposes, acquire the low dose CT transmission images after the emission study is complete and has been reviewed for artifacts. Do not allow the patient to move in between the emission and transmission acquisitions.

- Before releasing the patient, have a physician review the stress/redistribution study in case further redistribution imaging at 18-24 hours is required.

Quality Assurance (QA) of Projection Data

All projection data should be reviewed immediately post-acquisition for quality assurance.

- Post acquisition, the raw tomographic data is reviewed, in cine mode, for possible artifacts due to patient and/or heart motion, "upward creep," breast shadow due to attenuation, diaphragmatic attenuation, and superimposed abdominal visceral activity.

- For gated studies, the cine is reviewed for gating errors due to arrhythmias demonstrated by an intermittent flashing of the images.

Look for:	**Solve by:**
Motion	Repeat scan
Upward Creep	Repeat scan
Bad Gate (flashing)	Fix gate, then repeat scan
Poor Counts	Check for infiltration. If none: Repeat scan with a longer acquisition time.

- If using attenuation correction, before reconstructing the attenuation corrected emission data, the transmission data is to be checked for artifacts and corrected for misalignment in between the emission and transmission data.

Please archive your data.

Tl-201 Rest/Redistribution Viability Protocol

Study Description

Myocardial perfusion imaging uses an intravenously administered radiopharmaceutical to depict the distribution of blood flow in the myocardium. Perfusion imaging identifies areas of relatively reduced myocardial blood flow associated with ischemia or scar. The relative regional distribution of perfusion can be assessed at rest, during cardiovascular stress, or both.

Tl-201 is an analog of potassium, with a physical half-life of 73.1 hours, decay by electron capture to Hg-201 with principal emission of 68-80 keV x-rays, high first-pass extraction (85%), active membrane transport into the myocyte, rapid clearance from the intravascular space, and mono exponential washout (redistribution) which starts 10-15 minutes after injection. Washout depends on initial tracer concentration in the myocyte and on myocardial blood flow. Clearance occurs via the kidneys. The whole body effective dose for Tl-201 is approximately 6.3 mSv per mCi of Tl-201 injected.

A single dose of 3-4 mCi of Tl-201 is injected prior to a rest/redistribution study, and the rest imaging starts at 10-15 minutes later. Redistribution imaging is done 3-4 hours later. In cases where standard rest-redistribution imaging shows a fixed or minimally reversible perfusion abnormality, myocardial viability can be furthered assessed with a redistribution image at 18-24 hours.

Patient Preparation

- Patients should be NPO at least 2 hours prior to Myocardial Perfusion Imaging (MPI). Patients scheduled for later in the morning may have a very light (cereal, fruit) breakfast.
- Remind patients to bring a list of all their medications and to record all medication doses and times for the 48 hours prior to the stress SPECT study, including the time off beta-blockers, calcium channel blockers and long acting nitrates.
- Patients should not smoke at least 4 hours prior to MPI.
- If this is a follow-up study, make sure to use the same camera, camera parameters, radionuclide doses and medication doses that were used for the baseline study for the follow-up studies.
- Record all the information on the worksheets.

201-Thallous Chloride Doses

- Using standard tracer injection techniques inject the 201-Thallous Chloride into a peripheral arm vein and image after a 10-15 minute time delay. If there is excessive infiltration of the tracer the study should be rescheduled for another day.

- For patients with poor veins an intravenous catheter may need to be inserted into a peripheral vein and used to inject the 201-Thallous Chloride.

Prepare and inject an adequate tracer amount of 201-Thallous Chloride according to the following dose schedule:

Subject Weight		^{201}Tl Dose mCi	MBq
	<70 Kg	3	110
≥ 70 Kg	<90 Kg	3.0-3.2	110-120
≥ 90 Kg	<115 Kg	3.2-3.5	120-130
≥ 115 Kg	<135 Kg	3.5-3.8	130-140
≥ 135 Kg		3.8-4.0	140-150

- Image the patient after an appropriate time delay.

Image delay times:

201-Tl Protocol	Time to Imaging
Rest	10-15 Minutes
Redistribution	3-4 Hours
24 Hour Study	18-24 Hours

ECG Gating Setup

- Electrode Placement:

  Prepare skin for optimal contact with electrodes using an alcohol prep and abrasive pad. Use 3 electrodes, 2 subclavicular (1 on each side) and 1 below left ribcage.

  If small R wave: 1) Switch lead output on the gating box
  2) Move left ribcage electrode to right side
  3) Move subclavicular electrodes closer together

- If there are >30% PVC's or you cannot gate, document and continue acquisition un-gated

Rest/Redistribution and 24 Hour Acquisition Parameters

- Patients should be imaged supine with arms extended over the head, out of the field of view of the camera. All jewellery should be removed from around the neck area. For female patients: no bra and record bra and cup size. Patients should be instructed to relax and breathe normally (no talking, sleeping, heavy breathing or coughing). Inform them of the effects of motion. Use pillows and blankets to make patients comfortable.

Position:	Supine
Energy window:	30% symmetric window over the 70 keV photopeak 20% symmetric window over the 167 keV photopeak
Angular Range:	180° (45° RAO to 45° LPO)
Angular Step:	3° (preferred) or 6°
Time/ Angular Step:	
Rest Study	40 sec (32 fr), 25 sec (64 fr)
3-4 Hr Redistribution	40 sec (32 fr), 25 sec (64 fr)
24 Hr Redistribution	45 sec (32 fr), 30 sec (64 fr)
Matrix Size:	64 x 64
No. of projections:	32-64
Collimator:	LEAP (preferred) or LEHR
Orbit:	Circular or non-circular
Acquisition type:	Step-and-shoot or continuous
Zoom:	Adjust for a pixel size of 6.4mm/pix ± 0.4mm
ECG gating:	Rest study only
Frames/cycle	8
R-to-R window	100% (±50 %)

Note: For a LEHR collimator increase time/angular step by 5 seconds.

- Acquisitions should be started at the right anterior oblique position and proceed 180° to the left posterior oblique position.

- For attenuation correction purposes, acquire the low dose CT transmission images after the emission study is complete and has been reviewed for artifacts. Do not allow the patient to move in between the emission and transmission acquisitions.

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Quality Assurance (QA) of Projection Data

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- For gated studies, the cine is reviewed for gating errors due to arrhythmias demonstrated by an intermittent flashing of the images.

Look for:	**Solve by:**
Motion	Repeat scan
Upward Creep	Repeat scan
Bad Gate (flashing)	Fix gate, then repeat scan
Poor Counts	Check for infiltration. If none: Repeat scan with a longer acquisition time.

- If using attenuation correction, before reconstructing the attenuation corrected emission data, the transmission data is to be checked for artifacts and corrected for misalignment in between the emission and transmission data.

Please archive your data.