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2015 (Resolution 44)*

ACR–NASCI–SPR–STR PRACTICE PARAMETER FOR THE PERFORMANCE OF CARDIAC SCINTIGRAPHY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable

1 Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard’s stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that “published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation” even though ACR standards themselves do not establish the standard of care.
course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the North American Society for Cardiovascular Imaging (NASCI), the Society for Pediatric Radiology (SPR), and the Society of Thoracic Radiology (STR).

It is intended to guide physicians performing and interpreting cardiac scintigraphy in adults and children [1,2]. Properly performed imaging with radiopharmaceuticals that localize in either the myocardium or the blood pool is a sensitive means of detecting and quantitatively assessing various conditions involving the heart. As with all other scintigraphic techniques, maximum diagnostic accuracy is achieved by correlation with clinical findings, imaging with other radiopharmaceuticals not discussed in this practice parameter, and other diagnostic tests.

Application of this practice parameter should be in accordance with the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals [3], with particular attention paid to the prescribing and handling of radiopharmaceuticals.

The first part of this practice parameter addresses myocardial perfusion imaging, and the second part covers gated cardiac blood-pool imaging and first-pass cardiac imaging including left-to-right shunt evaluation.

The primary goals of cardiac scintigraphy are to evaluate myocardial perfusion and/or ventricular function, to detect physiologic and anatomic abnormalities of the heart, and to stratify cardiac risk.

PART I
MYOCARDIAL PERFUSION IMAGING

II. INDICATIONS AND CONTRAINDICATIONS

Myocardial perfusion imaging encompasses single photon emission computed tomography (SPECT) or planar techniques, stress and/or rest, gated or ungated. Indications for these examinations include, but are not limited to, the following [4]:

1. Detecting the presence, location, and extent of ischemic coronary artery disease in conjunction with stress testing
2. Evaluating the physiologic significance or sequelae of coronary artery stenosis
3. Monitoring the effects of treatment of coronary artery disease, including revascularization and medical therapy
4. Detecting myocardial infarction
5. Evaluating the viability of dysfunctional myocardium (hibernating myocardium)
7. Stratifying the risk after myocardial infarction
8. Evaluating ventricular function and measuring ventricular volumes using gated images

For information on radiation risks to the fetus, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [6].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals [3].
IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for cardiac scintigraphy should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state’s scope of practice requirements. (ACR Resolution 35, adopted in 2006)

1. Radiopharmaceutical
   a. Technetium-99m sestamibi and Technetium-99m tetrofosmin
      Sestamibi and tetrofosmin are taken up by the myocardium proportional regional myocardial perfusion. Unlike thallium, very little redistribution occurs. Measurement of regional myocardial perfusion during stress and rest requires 2 separate intravenous injections. Imaging is usually begun 15 to 120 minutes after administration of the radiopharmaceutical. Numerous imaging protocols have been described (eg, 1-day rest/stress, 2-day stress/rest, and rest thallium-stress sestamibi or other dual-radiopharmaceutical technique). The protocol chosen should reflect the needs of the patient and the logistics of the institution. One-day total administered activity of up to 44 mCi (1,630 MBq) of sestamibi or tetrofosmin may be used in most patients. One-day rest/stress protocols typically use a 1:3 ratio for the rest-and-stress injected activities. The stress injection should be given 1 to 2 minutes prior to cessation of exercise. Patients may require larger total administered activity based upon body habitus to obtain diagnostic image quality. In stress/rest protocols, if the stress examination is normal, the rest study does not need to be performed [7,8].
   b. Thallium-201 (thallous chloride)
      Thallium-201 has significantly higher radiation exposure than the technetium-99m-labeled radiopharmaceuticals, and it should not be used routinely unless there are specific reasons for its use. Due to its redistribution, thallium-201 is recommended when the purpose of the examination is to assess for myocardial viability. Thallium is injected intravenously in administered activity of 2.0 to 4.0 mCi (74 to 148 MBq). For an exercise examination, radiopharmaceutical injection should occur 1 minute prior to cessation of stress. Imaging is routinely started within 10 minutes after injection. Redistribution images are obtained 3 to 4 hours after injection, with or without the additional reinjection of 1.0 mCi (37 MBq) of thallium. If reinjection of 1.0 mCi of thallium is planned prior to redistribution imaging, the administered activity used for stress imaging may be limited to 3 mCi. When assessing myocardial viability, additional information may be gained by obtaining 24-hour delayed images. Other protocols, such as rest and delayed redistribution imaging, may also give useful information about myocardial viability.

2. Patients
   Patients should be evaluated prior to the examination for their ability to undergo physical or pharmacologic stress safely. Patients who are unable to exercise may be stressed pharmacologically. If a patient is unable to tolerate physical stress for cardiac reasons, pharmacologic stress may also be contraindicated. All patients undergoing stress should have intravenous access and should wear comfortable clothing and shoes. External attenuating objects should be removed, if possible. Patients should fast for at least 4 hours prior to exercise or pharmacologic stress. They may have sugar-free beverages prior to the redistribution phase of a thallium examination but otherwise should remain fasting and not exercise more than is absolutely necessary.
3. **Stress**

Stress may be performed by physical or pharmacologic means. A brief summary of the level and method of stress should be included in the imaging report.

a. **Physical**

For patients who are physically able to exercise, the desired endpoint is a heart rate of at least 85% of the age-predicted maximum predicted heart rate (MPHR) or a workload of at least 5 metabolic equivalents (METS). One hundred percent of MPHR is calculated as 220 minus the patient’s age in years; 1 MET = amount of energy expended at rest or 3.5 mL oxygen per kg per minute; carrying out activities of daily living requires 5 METS, achieved by walking at 1.7 mph (2.7 km/hour) up a 10% incline. The patient must be monitored closely by a physician or other qualified personnel experienced in cardiac stress testing. For further information see the ACR Nuclear Medicine and PET Accreditation Program Requirements. With development of angina, stress may be discontinued and the reason so noted. If exercise is terminated prior to the achievement of 85% of the age-predicted MPHR due to noncardiac limitations such as musculoskeletal, neurological, or pulmonary symptoms, abnormalities associated with coronary stenosis may be underestimated or missed. Beta-blocking and calcium channel-blocking medications often prevent the patient from achieving the desired heart rate and may reduce the sensitivity of the examination [9]. Depending on the clinical necessity or the clinical question, these medications may need to be discontinued by the patient’s physician prior to examination for a time sufficient to obviate their pharmacologic effect. Alternatively, pharmacologic stress may be used.

b. **Pharmacologic**

The heart may be stressed using one of a variety of pharmaceutical medications (eg, dipyridamole, adenosine, regadenoson, or dobutamine). Depending on the clinical necessity or the clinical question, beta-blocking and calcium channel-blocking medications may need to be discontinued by the patient’s physician prior to examination for a time sufficient to obviate their pharmacologic effect.

i. **Dipyridamole**

Dipyridamole is infused intravenously in a dosage of 0.14 mg/kg/min for 4 minutes (total dosage = 0.56 mg/kg). Its duration of action is between 30 minutes and 1 hour. The radiopharmaceutical should be injected 2 to 4 minutes after the end of the dipyridamole infusion. Dipyridamole has numerous side effects, including chest pain, headache, dizziness, hypotension, nausea, flushing, and dyspnea. Severe reactions have included fatal and nonfatal myocardial infarctions and severe bronchospasm. Aminophylline (1 to 2 mg/kg) must be immediately available for intravenous injection and should be given to reverse significant side effects. Because all xanthines (eg, caffeine and theophylline) interfere with the pharmacologic effect of dipyridamole, they must be discontinued for 24 to 48 hours prior to the examination. Patients who have unstable angina, bronchospastic airway disease, and second-degree heart block are at increased risk for complications of dipyridamole administration, and these conditions should be considered relative contraindications to use of the medication. As with physical stress, clinical, blood pressure, and electrocardiographic monitoring are mandatory during the dipyridamole infusion and for a period of time following the infusion.

ii. **Adenosine**

Adenosine may also be given intravenously in a dosage of 0.14 mg/kg/min over 6 minutes (3 minutes prior to injection of the radiopharmaceutical and continued for 3 minutes thereafter). Shorter infusion protocols (4 to 5 minutes) have been used successfully with adenosine. While using shorter infusion protocols, the radiopharmaceutical should be injected at least 2 to 2.5 minutes prior to termination of adenosine infusion. Because of the extremely short duration of the pharmacologic action of adenosine, injection of the radiopharmaceutical must occur during the adenosine infusion. Side effects are similar to those of dipyridamole but are very short-lived, often eliminating the need for aminophylline. Adenosine is vulnerable to the same interference from xanthine-containing foods, beverages, and medications as is dipyridamole, so all must be discontinued for 24 to 48 hours prior to examination. Hemodynamic, electrocardiographic, and clinical monitoring must be carried out as with any other form of stress.

iii. **Regadenoson**

Regadenoson is an A2A adenosine receptor agonist administered as a rapid intravenous injection in a dosage of 0.4 mg over 20 seconds; there is no dosage adjustment for body weight/body mass index. It should not be administered to patients with a second-degree or third-degree
atrioventricular block or sinus node dysfunction who do not have a functioning artificial pacemaker.

iv. Both dipyridamole and adenosine can be combined with simultaneous low-level exercise in patients who are ambulatory to reduce the side effects of these agents, reduce subdiaphragmatic radiopharmaceutical uptake, and improve image quality. While using dipyridamole, exercise should start after the completion of dipyridamole infusion and should last 4 to 6 minutes. While using adenosine, exercise should be simultaneous with the adenosine infusion. Its duration of effect is short (biologic half-life of approximately 2 minutes). Low-level exercise such as the first 2 stages of the modified Bruce protocol suffices.

v. Dobutamine is infused intravenously. A number of protocols are available. One involves the graduated infusion of increasing amounts of dobutamine over time, beginning with 5 to 10 mcg/kg/min over 3-minute increments, rising by 5 to 10 mcg/kg/min each step, with a maximum dosage rate of 40 mcg/kg/min. Atropine may be needed to achieve the target heart rate. The endpoint is 85% of MPHR or side effects similar to those listed in sections IV.3.a. and IV.3.b.i. Beta blockers and calcium-channel blockers must be withdrawn far enough in advance of the test to eliminate their effect. Dobutamine stress is an alternative in patients who have obstructive pulmonary disease. Dobutamine is associated with an increased incidence of cardiac arrhythmia and should be given with extreme caution in patients prone to arrhythmias or in the postmyocardial infarction period.

4. Safety
When exercise or pharmacologic stress is performed or when hemodynamically unstable patients are studied, life support instruments, medications, and appropriately trained personnel (advanced cardiac life support [ACLS] or pediatric advanced life support [PALS]) must be available in the immediate vicinity of the stress laboratory. Baseline blood pressure measurement and electrocardiographic tracing should be obtained before performing either a stress test using exercise or a pharmacologic stimulation. Electrocardiographic and blood pressure monitoring must be performed during stress and recovery.

5. Imaging
For most applications, SPECT or SPECT/CT should be performed [10,11]. Planar imaging may be performed when the patient is unable to undergo SPECT (eg, body habitus, claustrophobia, or inability to lie recumbent or remain immobile).

a. SPECT or SPECT/CT
The patient is placed supine on the imaging table and should be instructed to stay as motionless as possible. Care should be taken to provide for his/her comfort. It is possible to image with the patient prone, especially in those patients with suspected inferior wall attenuation defects, but this may introduce anterior wall artifacts. The left arm (both arms for some multihead systems) should be raised above the head to reduce attenuation, permit a smaller radius of rotation, and prevent inadvertent contact with the detector. In rare instances strapping the arm over the head can result in nerve or dialysis shunt injury. Patients should wear similar, loose-fitting clothing for both sets of images. To avoid inconsistent attenuation artifacts in a woman, special care should be taken to position the woman’s breasts as identically as possible between the stress and rest images.

The imaging and reconstruction protocol should be chosen for optimum quality and should be used consistently from patient to patient.

Patient motion and attenuation artifacts may create defects on the reconstructed tomographic filtered images. Cinematic raw data (projection files) should be reviewed to evaluate the examination for overall quality, patient motion, and attenuation artifacts during image acquisition. Attenuation correction is available on some commercial SPECT or SPECT/CT systems; both the attenuation-corrected and the non–attenuation-corrected images should be reviewed when available [12]. Other
useful quality control images are the sinogram and summed projection images. Improper reconstruction techniques can also produce artifacts [13,14]. When attenuation-correction is used, care should be taken to ensure correct alignment of the SPECT and CT data sets.

With the high count rates achievable with technetium-99m-based radiopharmaceuticals, gated acquisition of images should be carried out routinely. Gated images can be used to calculate ejection fraction and end-diastolic and end-systolic volumes and to assess regional wall thickening and wall motion.

New technology instrumentation such as solid state detectors, specialized cardiac collimators, or wide beam reconstruction techniques may allow for more rapid acquisitions or lower administered activities than described elsewhere in this document [15-17]. In such cases, manufacturers’ suggested protocols should be followed [10-12].

b. Planar
At a minimum, images should be obtained in the anterior, shallow left anterior oblique, and left lateral and/or steep left anterior oblique (LAO) projections. When stress and rest/redistribution images are obtained, each pair of images should be as closely matched in positioning as possible.

6. Quantification
A number of strategies are available for quantitative analysis of planar and SPECT myocardial perfusion studies. Quantitative analysis requires comparison with a normal database. Whether the database is commercially supplied or developed from one’s own experience, the interpreting physician is responsible for ensuring the quality of the database. Quantitative analysis only supplements a careful visual analysis of the raw images and reconstructed images.

V. EQUIPMENT SPECIFICATIONS

1. Planar
For technetium-99m sestamibi or tetrofosmin, a high-resolution collimator may be used, and up to 1,000,000 counts per view may be achieved quite easily. Imaging may be started as soon as is convenient after heart rate and respirations slow adequately (to avoid motion artifacts), although a delay of 30 minutes may improve images by allowing clearance of hepatic activity.

For thallium-201, a gamma camera with a detector size of 250 to 400 mm and a low-energy all-purpose (LEAP) collimator may be used. A high-resolution collimator may improve resolution, but longer imaging times will be required to obtain the same number of counts. For thallium-201, imaging is routinely started within 10 minutes after injection. Images should be acquired for 6 to 10 minutes per view. This represents the best compromise between image quality and the need to acquire the images before redistribution occurs. Redistribution images obtained 3 to 4 hours after injection should be acquired for duration of time similar to that for poststress views. Cardiac and respiratory motion reduces the spatial resolution of cardiac examinations.

Currently, planar imaging has largely been replaced by SPECT imaging. Planar imaging is only used in cases where SPECT imaging cannot be carried out.

2. SPECT
SPECT acquisition parameters depend on the radiopharmaceutical and instrument [10,11]. For single-head cameras, LEAP/general all-purpose (GAP) collimators and a circular orbit are acceptable. When thallium-201 is used, LEAP/GAP collimators should be used. With sestamibi and tetrofosmin, high-resolution collimators enhance image quality. With dual-radiopharmaceutical imaging, the same collimator should be used for both radiopharmaceuticals. At a minimum, 32 images in a 180° arc, from right anterior oblique to left posterior oblique (LPO), should be obtained.
For multidetector systems, data can be acquired from either a 180° or a 360° arc, and images can be reconstructed from the complete orbit (whether circular or ellipse) or from the 180° arc. Two-detector camera systems in which the detectors may be positioned at approximately 90° angles allow efficient acquisition of data over a 180° arc. Smaller imaging intervals (3° rather than 6°) are feasible with triple-head systems and two-head 90° systems.

Multihead camera systems are the preferred imaging systems. They decrease image acquisition time compared to single-head systems, which helps to improve patient comfort and reduce patient motion.

SPECT/CT cameras are being used more frequently. In addition to attenuation correction, the CT images may detect the presence of coronary artery calcification, which may be clinically significant and should be reported [18-20].

PART II
GATED BLOOD-POOL IMAGING AND FIRST-PASS CARDIAC IMAGING, INCLUDING LEFT-TO-RIGHT SHUNT EVALUATION

VI. INDICATIONS AND CONTRAINDICATIONS

Cardiac scintigraphy includes gated cardiac blood-pool imaging (rest and/or stress), first-pass cardiac imaging, and left-to-right shunt evaluation. Indications for these examinations include, but are not limited to, the following:

A. Gated Cardiac Blood-Pool Imaging

Quantifying parameters of ventricular function (eg, ejection fraction, wall motion, ventricular volume, cardiac output, diastolic function), including monitoring cardiac effects of chemotherapy

B. First-Pass Cardiac Imaging Including Left-to-Right Shunt Evaluation

1. Calculating left and right ventricular ejection fractions
2. Quantifying left-to-right cardiac shunts

Note: Detecting and quantifying right-to-left shunts using radiolabeled particles are covered in the ACR–SPR–STR Practice Parameter for the Performance of Pulmonary Scintigraphy [21].

VII. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals [3].

VIII. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for cardiac scintigraphy should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately
licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state’s scope of practice requirements. (ACR Resolution 35, adopted in 2006)

A. Gated/Multigated Acquisition, MUGA Cardiac Blood-Pool Imaging (Radionuclide Angiocardiography or Ventriculography)

1. Radiopharmaceutical [22-25]
   Technetium-99m-labeled autologous red blood cells, labeled by the in-vivo, in-vivo/in-vitro, or in-vitro technique, are most commonly used. The adult administered activity is usually 15 to 25 mCi (555 to 925 MBq) administered intravenously, and the examination may commence immediately thereafter. Administered activity for children should be determined based on body weight and should be as low as reasonably achievable for diagnostic image quality. For children, the recommended administered activity for a gated blood-pool examination including left-to-right shunt is 5 to 20 mCi (185 to 740 MBq) [1,2]. If a patient has received a recent blood transfusion, is in renal failure, or is on heparin or doxorubicin, the in-vivo technique may result in unacceptably high levels of unbound technetium-99m. Other medications may have similar effects.

2. Patient
   Except for those patients undergoing stress-gated ventriculography, few restrictions apply. Patients requiring exercise should be evaluated for their ability to undergo the physical stress safely.

3. Stress
   Exercise, when performed, usually consists of graded levels of work performed on a bicycle ergometer with simultaneous acquisition of gated images. These are commonly obtained for 2 to 3 minutes during each level of exercise by imaging after heart rate equilibration, which usually occurs in 1 to 2 minutes. The endpoint may be achievement of a desired predefined work level or percentage of MPHR, anginal symptoms, significant ST segment depression or other electrocardiogram abnormality, or physical inability to continue.

4. Safety
   When hemodynamically unstable patients are studied or when exercise is performed, life support instruments, medications, and appropriately trained personnel (ACLS or PALS) must be available in the immediate vicinity of the stress laboratory. Baseline blood pressure measurement and electrocardiographic tracing should be obtained before performing a stress test using exercise. Electrocardiographic and blood pressure monitoring must be performed during stress and recovery.

5. Imaging
   a. Rest
      At least 16 frames per R-R interval are needed for accurate measurement of the ejection fraction. The electrocardiographic tracing on the monitor should be inspected before imaging starts to be certain that the R wave is properly triggering the acquisition. The angle for the LAO view should be chosen to obtain the best separation of the right and left ventricles. The anterior view should be obtained at an angle that is 45° shallower than the LAO (best septal) view. The left lateral view should be obtained at an angle that is 45° steeper than the LAO view. A LPO view may be substituted for, or can be obtained in addition to, the left lateral view. Caudal angulation (up to 30° if using a slant-hole collimator) may help to separate the ventricular blood pool from the atrial blood pool. The matrix size should be 64 x 64. Each set of images should be acquired for at least 5 minutes or 300,000 counts per frame, whichever occurs first. Recent advances in hardware and software allow SPECT acquisition of gated blood-pool images. SPECT acquisition allows a more detailed evaluation of left and right ventricular regional wall motion and calculation of both right and left ventricular ejection fractions.
   b. Stress
      Patients should exercise at each new level of exercise for 1 to 2 minutes to achieve a stable heart rate. Once a stable heart rate is obtained, 2-minute to 3-minute images are acquired using the best septal
view and approximately 16 frames per cardiac cycle. One examination should be acquired at the maximum level of exercise. Studies at other levels of exercise can also be obtained.

6. Quantification
   a. R-wave histogram (“beat histogram”)
      Inspection of the R-wave histogram provides information on the regularity of the cardiac rhythm during the acquisition. Because the gated examination averages hundreds of heartbeats, wall-motion evaluation and ejection fraction calculations are optimal with a regular rhythm. Less than 10% of beats rejected is optimal. If more than 30% of beats are rejected, quantitative results may be unreliable.
   b. Wall motion
      Wall motion can be assessed quantitatively or qualitatively. Functional images such as stroke volume, paradox, regional ejection fraction, amplitude, and phase images may be helpful.
   c. Left ventricular ejection fraction
      All computer programs calculate an ejection fraction using the difference between background-corrected end-diastolic counts and background-corrected end-systolic counts divided by background-corrected end-diastolic counts. The background region of interest should avoid the stomach or the spleen, which can result in erroneously low or high ejection fractions, respectively. Manual, semiautomatic, or fully automatic algorithms for calculating ejection fractions are available. In addition to the R-wave histogram, region of interest and the ejection fraction curve should be inspected to be certain the quantitative results are consistent with the acquired data. The user of these programs should have a quality control program in place to maximize the precision of the measurement. The user should understand the strengths and limitations of the algorithms used. Computer-generated left ventricular ejection fractions should be compared with the visual estimation of ejection fractions to ensure reliability.

B. First-Pass Cardiac Imaging (First-Pass Ventriculography), Including Left-to-Right Shunt Evaluation

1. Radiopharmaceutical [22-25]
   If the examination is performed in conjunction with a gated blood-pool examination, technetium-99m-labeled red blood cells in an administered activity of 15 to 25 mCi (555 to 925 MBq) may be used. Other technetium-99m-labeled radiopharmaceuticals (eg, pertechnetate, diethylene-triamine penta-acetic acid, or sestamibi) may be used if the study is done alone or with another unrelated examination. Administered activity for children should be determined based on body weight and should be as low as reasonably achievable for diagnostic image quality. For children, the recommended administered activity for first-pass cardiac imaging including left-to-right shunt is 5 to 20 mCi (185 to 740 MBq). Injection technique is critically important. Rapid injection of a small volume of the radiopharmaceutical into a large proximal vein (eg, external jugular) or through a large-gauge intravenous access in an antecubital vein followed by an instantaneous saline flush is necessary for optimal results, especially when measuring left-to-right shunts. If the bolus is suboptimal, the results may not be valid. Bolus adequacy can be measured by superior vena cava (SVC) bolus analysis.

2. Patient
   No patient preparation is required unless the procedure is performed as part of an exercise examination.

3. Imaging
   Depending on the information desired, the imaging device is positioned over the patient’s chest in the anterior or right anterior oblique projection. Data are acquired in list or fast-frame mode for up to 1 minute. A 64 x 64 matrix is preferred. A low-energy all-purpose/general all-purpose (LEAP/GAP) or high-sensitivity collimator is used.
4. Quantification of right and left ventricular ejection fraction(s)
   The user must understand the limitations of the quantitative techniques used to avoid errors. A quality control program should be in place to maximize the value of this examination.

5. Evaluation of left-to-right shunt
   The size of cardiac and extracardiac left-to-right shunts also may be measured by assessing first transit pulmonary time-activity curves. The technique is used more commonly in children than in adults. The injection technique must ensure delivery of the radiopharmaceutical in as tight a bolus as possible. Computer programs, such as gamma variate analysis, are applied to pulmonary curves to determine the pulmonary-to-systemic blood-flow ratio (QP/QS).

Note: Right-to-Left Shunt Detection: For further information see the ACR–SPR–STR Practice Parameter for the Performance of Pulmonary Scintigraphy [21].

IX. EQUIPMENT SPECIFICATIONS

A. Gated Cardiac Blood-Pool Imaging
   
   A gamma camera equipped with a LEAP/GAP collimator is required, although a high-resolution collimator provides sharper images on a rest examination if the count rate is adequate. An electronic cardiac monitor with an R-wave trigger signal compatible with the camera/computer system used is required. Recently, gated SPECT imaging has been used quite successfully in place of planar imaging for gated blood-pool imaging. With the wider availability of appropriate software and computer programs for SPECT blood-pool imaging, this is likely to be used increasingly in future.

B. First-Pass Cardiac Imaging, Including Left-to-Right Shunt Evaluation
   
   Any standard gamma camera may be used. A LEAP/GAP collimator or a high-sensitivity collimator is recommended.

X. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [26].

The report should include the radiopharmaceutical used, the administered activity, route of administration, as well as any other pharmaceuticals administered, including their dose and route of administration.

XI. RADIATION SAFETY [27,28]

Radiologists, medical physicists, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, “as low as reasonably achievable” (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization, and the use of dose reference levels). Please consult http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals and that they are adhered to in accordance with ALARA. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by
state and/or other regulatory agencies. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol.

Nationally developed guidelines, such as the ACR Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Additional information regarding patient radiation safety in imaging is available at the Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Regular auditing of patient dose indices should be performed by comparing the facility’s dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States, or the Conference of Radiation Control Program Director’s National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006—revised in 2009, 2013, Resolution 52).

XII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education on the ACR website (http://www.acr.org/guidelines).

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Medical Nuclear Physics Performance Monitoring of Gamma Cameras [29].

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12 / Cardiac Scintigraphy
REFERENCES


*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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