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ACR PRACTICE GUIDELINE FOR THE PERFORMANCE OF CARDIAC SCINTIGRAPHY

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They 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 cautions against the use of these guidelines 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 physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, 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 the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations on available resources or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines 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. It should be recognized; therefore, that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable 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 these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline has been developed by the American College of Radiology (ACR) to guide physicians performing cardiac scintigraphy in adults and pediatric patients. Properly performed imaging with radiopharmaceuticals that localize in either the myocardium or the blood pool is a sensitive means of detecting and quantitatively assessing numerous conditions involving the heart. As with all other scintigraphic techniques, maximum diagnostic accuracy is achieved by correlation with clinical findings, imaging with other radiotracers not discussed in this guideline, and other diagnostic modalities, both imaging and nonimaging.

Application of this guideline should be in accordance with the [ACR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#), with particular attention

paid to the prescription and handling of radiopharmaceuticals.

II. GOAL

The goal of cardiac scintigraphy is to evaluate myocardial perfusion and/or function to detect physiologic and anatomic abnormalities of the heart.

III. INDICATIONS

Five major classes of cardiac scintigraphy are included in this guideline: myocardial perfusion imaging (single-photon-emission computed tomography [SPECT] or planar, stress and/or resting, gated or ungated), gated cardiac blood-pool imaging (resting and/or stress), first-pass cardiac imaging, myocardial infarction imaging, and right-to-left shunt evaluation. Indications for these studies include, but are not limited to, the following:

A. Myocardial Perfusion Imaging

1. Detecting the presence, location, and extent of coronary artery disease.
2. Evaluating the physiologic significance or sequelae of known or suspected coronary artery stenosis.
3. Monitoring the effects of treatment of coronary artery disease, including revascularization and medical therapy.
4. Detecting acute myocardial infarction.
5. Evaluating the viability of dysfunctional myocardium.
6. Stratifying risk of myocardial events.
7. Evaluating ventricular function (using gated images).
8. Determining prognosis after myocardial infarction.

B. Gated Cardiac Blood-Pool Imaging

1. Quantifying parameters of ventricular function (e.g., ejection fraction, wall motion, ventricular volume, cardiac output, and diastolic function).
2. Detecting the presence, location, and extent of coronary artery disease.
3. Assessing whether congestive heart failure is due to ischemic or nonischemic causes.
4. Evaluating potential cardiotoxic effects of chemotherapy.
5. Evaluating the effects of valvular abnormalities.

C. First-Pass Cardiac Imaging

1. Calculating left and right ventricular ejection fractions.
2. Assessing wall motion abnormalities.
3. Quantifying left-to-right cardiac shunts.

4. Measuring cardiac output and absolute ventricular chamber volumes.

D. Myocardial Infarction Imaging

Diagnosing and assessing the location and extent of acutely infarcted myocardium.

E. Right-to-Left Shunt Evaluation

Detecting and quantifying right-to-left shunts using radiolabeled particles.

IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#).

V. SPECIFICATIONS OF THE EXAMINATION

A. Myocardial Perfusion Imaging

1. Radiopharmaceutical

a. Thallium-201 (thallous chloride)

Thallium is injected intravenously in administered activity of 2.0-4.0 millicuries (74-148 MBq). When stress is used, injection should precede cessation of stress by 1 minute. Most experts recommend thallium-201 when the purpose of the study is to assess myocardial viability because it redistributes. Imaging is routinely started within 10 minutes after injection. Redistribution images are obtained 2-4 hours after injection, with or without the additional reinjection of 1.0 millicurie (37 MBq) of thallium. When assessing myocardial viability, additional information may be gained by obtaining 24-hour delayed images. Other sequences, such as rest and delayed redistribution imaging, may also give useful information about myocardial viability.

b. Technetium-99m sestamibi

Sestamibi distributes according to regional myocardial perfusion. Unlike thallium, very little redistribution occurs. Measurement of regional myocardial perfusion during stress and rest requires two separate intravenous injections. Imaging is usually begun 15-120 minutes after administration of the radiopharmaceutical. Numerous imaging protocols have been described (e.g., rest-stress 1 day, stress-rest 2 days, and resting thallium-stress sestamibi). The protocol

chosen should reflect the needs of the patient and the logistics of the institution. One-day total administered activity of up to 40 millicuries (1,480 MBq) of sestamibi may be used. The stress injection should be given 1 to 2 minutes prior to cessation of exercise. Gated perfusion SPECT imaging can be performed.

- c. Technetium-99m tetrofosmin
Tetrofosmin distributes according to regional myocardial blood flow. Procedures are the same as those described for technetium-99m sestamibi in Section V.A.1.b, above. One-day total administered activity of up to 40 millicuries (1,480 MBq) may be used.

2. Patient

Patients should be evaluated prior to the study 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 study but otherwise should remain NPO 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 mets. The patient must be monitored frequently for abnormal change in blood pressure, marked ST changes on the electrocardiogram, development of serious arrhythmias, or severe chest pain. With development of angina, stress may have to be discontinued and the reason so noted. If exercise is

terminated prematurely, abnormalities associated with coronary stenosis may not be detected. Beta-blocking and calcium-channel-blocking medications often prevent the patient from achieving the desired heart rate and may reduce the sensitivity of the test. Depending on the clinical necessity or the clinical question, these agents may need to be discontinued by the patient's physician prior to examination for a time sufficient to obviate their pharmacologic effect.

b. Pharmacologic

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

- i. Dipyridamole (Persantine™) is infused intravenously in an administered activity 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 2-4 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 (1-2 mg/kg) must be immediately available for intravenous injection and should be given to reverse significant side effects. Because all xanthines (e.g., caffeine and theophylline) interfere with the pharmacologic effect of dipyridamole, they must be discontinued for 24-48 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 drug. 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 may also be given intravenously in an administered activity of 0.14 mg/kg/min over 6 minutes (3 minutes prior to injection of the radiopharmaceutical and continued for 3 minutes thereafter). Because of the extremely short duration of 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 24-48 hours prior to examination. Hemodynamic, electrocardiographic, and clinical monitoring must be carried out the same as with any other form of stress.
- iii. Dobutamine is infused intravenously. Its duration of effect is short (biologic half-life of approximately 2 minutes). A number of protocols are available. One involves the graduated infusion of increasing amounts of dobutamine over time, beginning with 5-10 mcg/kg/min over 3-minute increments, rising by 5-10 mcg/kg/min each step, with a maximum dose rate of 40 mcg/kg/min. Atropine may be needed to achieve target heart rate. The endpoint is 85% of MPRH or side effects similar to those listed in Sections V.3.a. and V.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 post-myocardial infarction period.

4. Safety

When exercise or pharmacologic stress is performed or 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

Planar and/or SPECT imaging may be performed. For most applications, SPECT, if available, is preferred. Planar imaging may be performed when the patient is unable to undergo SPECT (e.g., extreme obesity, claustrophobia, or inability to lie recumbent or remain immobile).

a. 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.

b. SPECT

The patient may be placed supine on the imaging table and should be instructed to stay as motionless as possible. Care should be given to provide for his/her comfort. It is possible to image with the patient prone, 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. Strapping the arm over the head can, in rare instances, result in nerve or dialysis shunt injury. Patients should wear similar, loose-fitting clothing for both the immediate and delayed 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 resting views.

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

Because patient motion and attenuation artifacts may create defects on the reconstructed tomographic filtered image, the cinematic raw data (projection files) should be reviewed. Attenuation correction is available on some commercial SPECT

systems, and both the attenuation-corrected and the non-attenuation-corrected images should be reviewed when available. Other useful quality control images are the sinogram and summed projection images. Improper reconstruction techniques may produce artifacts.

With the high count rates achievable with technetium-99m-based radiopharmaceuticals, another option is gated acquisition of data. This may be used to estimate ejection fraction, to estimate stroke volume, and to assess wall thickening and motion.

6. Quantification

A number of strategies are available for quantification of planar and SPECT myocardial perfusion studies. If quantification and comparison with a normal database are performed, their validity depends on using similar acquisition and processing protocols on similar patients with similar equipment upon which the indications and normal database were established. 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. Quantification results should be reported only after full review of images and data quality to assure concordance.

B. Gated Cardiac Blood-Pool Imaging (Gated Ventriculography)

1. Radiopharmaceutical

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 15-25 millicuries (555-925 MBq) administered intravenously, and the examination may commence immediately thereafter. Administered activity in children should be reduced according to body surface area or weight. The minimum pediatric administered activity should be as low as practically achievable for appropriate image quality. If a patient has received a recent blood transfusion, is in renal failure, or is on heparin or adriamycin, 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 2-3 minutes during each level of exercise by imaging after heart rate equilibration, which usually occurs in 1-2 minutes. The endpoint may be achievement of a desired predefined work level or percentage of M_{PHR}, anginal symptoms, significant ST 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 either a stress test using exercise or a pharmacologic stimulation. Electrocardiographic and blood pressure monitoring must be performed during stress and recovery.

5. Imaging

a. Resting

At least 16 frames per R-R interval are needed for accurate measurement of ejection fraction. The electrocardiographic tracing on the monitor should be inspected prior to commencement of imaging to be certain that the R wave is properly triggering acquisition. A larger number of frames (up to 32) may be needed for measuring diastolic parameters. The angle for the left anterior oblique (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 left posterior oblique (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 bloodpool. 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.

b. Stress

Patients should exercise at each new level of exercise for 1-2 minutes to achieve a stable heart rate. Once a stable heart rate is obtained, 2-3 minute studies are acquired using the best septal view and approximately 16 frames per cardiac cycle. One study 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

Inspection of the R wave histogram provides information on the regularity of cardiac rhythm during the acquisition. Because the gated study averages hundreds of heartbeats, wall motion evaluation and ejection fraction calculations are optimal with a regular rhythm. Fewer 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, regions 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 that are used. Computer generated left ventricular ejection fractions should be compared with the visual estimation of ejection fractions to ensure reliability.

C. First-Pass Cardiac Imaging (First-Pass Ventriculography)

1. Radiopharmaceutical

If the study is performed in conjunction with a gated blood-pool examination, technetium-99m-labeled red blood cells in adult administered activity of 15-20 millicuries (555-740 MBq) may be used. Other technetium-99m-labeled radiopharmaceuticals (e.g., pertechnetate, diethylenetriamine pentaacetic acid, or sestamibi) may be used if the study is done alone or with another unrelated examination. Administered activity in children should be reduced according to body surface area or weight. The minimum pediatric administered activity should be as low as practically achievable for appropriate image quality. Injection technique is critically important. Rapid injection of a small volume of the radiotracer into a large proximal vein (e.g., external jugular) or through 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 preparation is required, unless the procedure is performed as part of an exercise study.

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 test.

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 adults. The injection technique must ensure delivery of the agent 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).

D. Myocardial Infarction (Infarct Avid) Imaging

1. Radiopharmaceutical

Technetium-99m pyrophosphate, in administered activity of 15-25 millicuries (555-925 MBq), is injected intravenously.

2. Patient

Maximum sensitivity of this procedure for acute myocardial infarction occurs at 3-6 days after the event. Studies obtained as soon as 12 hours after an infarction may be positive. Activity in the infarcted area may persist for variable amounts of time.

3. Imaging

Imaging is usually conducted 1.5-3 hours after injection. Patients with poor cardiac output or poor renal function may clear tracer from the blood pool more slowly. Immediate or delayed imaging may help differentiate infarct from blood pool in such patients. At least three images (anterior, LAO, and left lateral) are acquired on a scintillation camera equipped with a LEAP/GAP or high-resolution collimator. For small field cameras (≈ 250 mm) 300,000-500,000 counts per image are needed. For large field circular and rectangular detector cameras (400-500 mm), 500,000-1,000,000 counts should be acquired. SPECT imaging may also be performed.

E. Right-to-Left Shunt Detection

Right-to-left shunt detection may be assessed with technetium-99m-labeled macroaggregated albumin (MAA). The usual adult administered activity is 1.0-4.0 millicuries (37-148 MBq). Administered activity in children should be reduced as stated in Section V.C.1. Although no untoward clinical effects related to systemic distribution of MAA have been reported, it may be prudent to limit the number of particles injected, e.g., one-quarter to one-half reduction. Under normal circumstances, this agent will not pass into the systemic circulation. If a right-to-left shunt is present, activity will appear in systemic organs such as the brain, spleen, and kidneys. It is possible to estimate the severity of the shunt by comparing pulmonary with systemic counts. This is accomplished by performing a total body image after the intravenous administration of MAA. Imaging should be started within 2 minutes after injecting the radiotracer. The fraction of systemically shunted tracer is determined by dividing systemic counts (i.e., total-body counts minus total-lung counts) by total body counts. The number is converted to a percentage of right-to-left shunt by multiplying by 100.

VI. EQUIPMENT SPECIFICATIONS

A. Myocardial Perfusion Imaging

1. Planar

For thallium-201, a scintillation camera with a detector head size of 250-400 mm with a 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 6-10 minutes per view. This represents the best compromise between image quality and the need to acquire the images before redistribution occurs. Redistribution images obtained 3-4 hours after injection should be acquired for a duration of time similar to that for poststress views. Cardiac and respiratory motion reduces the spatial resolution of cardiac studies.

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 some clearance of hepatic activity.

For scintillation cameras with a field of view of ≈ 400 mm or greater, a high-resolution collimator may be preferable. A software magnification of 1.2-1.6 should be used, and the data density acquired should be similar to that of the smaller field-of-view cameras.

2. SPECT

As with planar imaging, acquisition parameters depend on the radiopharmaceutical and instrument. For single-head cameras, LEAP/GAP collimators and a circular orbit are acceptable. High-resolution collimators and contoured (elliptical) orbits may improve image quality, although these orbits may also result in some artifacts. When thallium-201 is used, LEAP/GAP collimators should be used. With sestamibi and tetrofosmin, high-resolution collimators enhance image quality. With dual-isotope imaging, the same collimator should be used for both isotopes. At a minimum, 30-32 images in a 180° arc from right anterior oblique to LPO should be obtained.

For multihead systems, data can be acquired from either a 180° or a 360° arc, and images can be reconstructed from the complete circle (ellipse) or the 180° arc. Two-head camera systems in which the heads 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.

B. Gated Cardiac Blood-Pool Imaging

A scintillation camera equipped with a LEAP/GAP collimator is required, although a high-resolution collimator provides sharper images on a resting study 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.

C. First-Pass Cardiac Imaging

Any standard scintillation camera may be used. A GAP/LEAP collimator is recommended.

D. Myocardial Infarction (Infarct Avid) Imaging

Any scintillation camera may be used. A LEAP/GAP or high-resolution collimator should be used.

E. Right-to-Left Shunt Detection

Any standard scintillation camera may be used. A LEAP/GAP collimator is recommended.

VII. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication: Diagnostic Radiology](#).

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

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 Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

Equipment performance monitoring should be in accordance with the [ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of Nuclear Medicine Imaging Equipment](#).

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