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ACR PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF CARDIAC COMPUTED TOMOGRAPHY (CT)

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. Therefore, it should be recognized 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

Cardiac computed tomography (CT) is an evolving modality that includes a variety of examinations to assess the anatomy and pathology of the central great vessels and pericardium as well as the function of the heart and cardiac valves. CT is a proven and useful procedure for detecting and characterizing cardiac and pericardial masses and pericardial effusion. With the development of multidetector CT (MDCT) scanners with increasing number of detector rows, narrow section thickness, increasing scanner speed, ability for electrocardiogram (ECG) gating, and radiation dose modulation, CT can also assess the coronary arteries and veins and can evaluate cardiac function. This guideline attempts to maximize the probability of detecting cardiac abnormalities with cardiac CT.

Cardiac CT involves the exposure of patients to ionizing radiation and should only be performed under the supervision of a physician with the necessary training in radiation protection to optimize examination safety. Medical physicists and trained technical staff must be available.

Cardiac CT should be performed only for a valid medical indication and with the minimum radiation exposure that provides diagnostic image quality.

While important abnormalities of the heart and associated structures can be detected on chest CT performed for other reasons, these guidelines are written specifically for dedicated examinations designed to detect cardiac pathology.

For further information on CT imaging of other structures within the chest and of the noncardiac vasculature see the ACR Practice Guideline for the Performance of Computed Tomography (CT) for the Detection of Pulmonary Embolism in Adults, the ACR Practice Guideline for the Performance of Pediatric and Adult Thoracic Computed Tomography (CT), and the ACR Practice Guideline for the Performance and Interpretation of CT Angiography (CTA).

II. DEFINITIONS

A. Cardiac CT

Cardiac CT is a chest CT performed primarily for the morphologic evaluation of the cardiac chambers, valves, ventricular myocardium, coronary arteries and veins, aortic root, central pulmonary arteries and veins, and pericardium. However, noncardiac structures are included and must be evaluated.

B. Unenhanced Cardiac CT

Unenhanced cardiac CT is a dedicated chest CT performed primarily for evaluating cardiac calcification, i.e., the coronary arteries (coronary calcium scoring), cardiac valves, pericardium, and cardiac masses. ECG gating reduces motion artifact and is required for calcium detection, scoring, and localization.

C. Contrast-Enhanced Cardiac CT

1. Contrast-enhanced cardiac CT is performed after intravenous (IV) administration of iodinated contrast to optimize evaluation of the cardiac chambers, myocardium, valves, and pericardium.
2. CT coronary arteriography is performed to characterize the origin and course of the coronary arteries and/or bypass grafts and to assess stenosis, and/or atherosclerotic plaque formation.
3. CT cardiac venography is performed to assess the cardiac or pulmonary veins.

III. INDICATIONS

Unenhanced ECG-gated cardiac CT may be indicated for detecting and quantifying coronary artery calcium ("calcium scoring"). While the role of coronary artery calcium scoring is currently being refined, data support its use for risk stratification and therapeutic decision making in select patients with intermediate risk for a significant ischemic cardiac event. An additional indication is the localization of myocardial and pericardial calcium.

Indications for contrast-enhanced cardiac CT include, but are not limited to, the diagnosis, characterization, and/or surveillance of:

1. Arterial and venous aneurysms.
2. Atherosclerotic disease.
3. Traumatic injuries of arteries and veins.
4. Arterial dissection and intramural hematoma.
5. Arterial and venous thromboembolism (also see the ACR Practice Guideline for the Performance of Computed Tomography (CT) for the Detection of Pulmonary Embolism in Adults).
6. Vascular congenital anomalies and variants.
7. Vascular interventions (percutaneous and surgical, e.g., angioplasty, coronary stenting, coronary bypass grafts [CABGs], ablation therapy for cardiac dysrhythmia, valve surgery, aortic root replacement, pacemaker placement planning,).
8. Vascular infection, vasculitis, and collagen vascular diseases.
9. Sequelae of ischemic coronary disease (myocardial scarring, ventricular aneurysms, thrombi).
10. Cardiac tumors and thrombi.
11. Pericardial diseases.
12. Cardiac functional evaluation, especially in patients in whom cardiac function may not be assessed by magnetic resonance imaging (automatic implantable defibrillator, pacemaker, general MRI contraindications, etc.) or echocardiography (e.g., poor acoustic window).

All imaging facilities should have policies and procedures to reasonably attempt to identify pregnant patients prior to the performance of any diagnostic examinations involving ionizing radiation. If the patient is known to be pregnant, the potential radiation risk to the fetus and clinical benefits of the procedure should be considered before proceeding with the study. 1995, 2005 (Res. 1a)

IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) and the ACR Practice Guideline for the Performance and Interpretation of CT Angiography (CTA) for physician qualifications to interpret general CT examinations and CTA, and for qualifications of the Qualified Medical Physicist and the Radiologic Technologist. The requirements set forth below will become applicable by July 1, 2008.

A. Physician

The physician shall have the responsibility for all aspects of the study including, but not limited to, reviewing all indications for the examination, specifying the imaging sequences to be performed, specifying the methods of image reconstruction, specifying the use and dosage of contrast and pharmacologic agents, interpreting images, generating an official interpretation,[1] and assuring the quality of the images and the interpretation.

1. Physician with prior qualifications in general and/or thoracic CT interpretation.

   The radiologist or other physician who meets the qualifications of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) has substantial knowledge of radiation biology, the physics of CT scanning, the principles of CT image acquisition and postprocessing including use of diagnostic workstations, and the design of CT protocols including rate and timing of contrast administration. The physician also will have substantial experience in CT interpretation, including CT of extracardiac thoracic structures that will be included on the cardiac CT examination, and experience with CT angiography of other regions of the body. Some of these physicians will also have substantial experience in other methods of cardiac imaging, assessment of cardiac function, and/or experience specifically in cardiac CT. These physicians are qualified to interpret coronary artery calcium scoring based on their prior experience. However, in order to achieve competency in all aspects of cardiac CT imaging, many physicians will require additional education in cardiac anatomy, physiology, pathology, and/or cardiac CT imaging.

   The supervising and interpreting physician with prior qualifications in general and/or thoracic CT interpretation should also meet one of the following requirements:

   a. Training in cardiac CT in an Accreditation Council for Graduate Medical Education (ACGME) or an American Osteopathic Association (AOA) approved training program to include:
      i. Education in cardiac anatomy, physiology, pathology, and cardiac CT imaging for a time equivalent to at least 30 hours of CME.

         and

      ii. The interpretation, reporting, and/or supervised review of at least 50 cardiac CT examinations in the last 36 months. Coronary artery calcium scoring does not qualify as meeting these requirements.

      or

   b. Completion of at least 30 hours of Category I CME in cardiac imaging, including:
      i. Cardiac CT, anatomy, physiology, and/or pathology, or documented equivalent supervised experience[2] in a center actively performing cardiac CT.

         and

      ii. The interpretation, reporting, and/or supervised review of at least 50 cardiac CT examinations in the last 36 months. Coronary artery calcium scoring does not qualify as meeting these requirements.

2. Physician who does not have prior qualifications in general and/or thoracic CT interpretation.

   The radiologist or other physician who does not meet the qualifications of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) or who meets these qualifications only for a specific anatomic area outside of the thorax requires more extensive training and experience in CT scanning with an emphasis on the thorax and specific experience in cardiac CT scanning. In addition to specific training in imaging interpretation, this training must include knowledge of the principles of CT image acquisition and postprocessing including use of diagnostic workstations and the design of CT protocols including rate and timing of contrast administration. The physician must also meet the same requirements, or document equivalent training, as those delineated in the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT) with regard to knowledge of the physics of CT scanning and radiation biology. Some physicians

[1] The ACR Medical Legal Committee defines official interpretation as that written report (and any supplements or amendments thereto) that attach to the patient's permanent record. In healthcare facilities with a privilege delineation system, such a written report is prepared only by a qualified physician who has been granted specific delineated clinical privileges for that purpose by the facilities governing body upon the recommendation of the medical staff.

[2] Documented equivalent supervised experience is defined as supervision at a center where the proctoring physician meets these criteria to independently interpret cardiac CT.

will also require additional education in cardiac anatomy, physiology, and pathology.

The supervising and interpreting physician without prior qualifications in general and/or thoracic CT interpretation should meet the following requirements:

a. Completion of sufficient training and experience to meet the qualifications of the ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography (CT). For a physician who assumes responsibilities for CT imaging exclusively in a specific anatomical area such as cardiac CT, this includes:
   i. Completion of an ACGME approved training program in the specialty practiced plus 200 hours of Category I CME in the performance and interpretation of CT in the subspecialty where CT reading occurs.

      and

   ii. Supervision, interpretation, and reporting of 500 cases, at least 100 of which must be a combination of thoracic CT or thoracic CT angiography during the past 36 months in a supervised situation. Coronary artery calcium scoring does not qualify as meeting these requirements.

   and

b. Included in the above, completion of at least 30 hours of Category I CME in cardiac imaging, including
   i. Cardiac CT, anatomy, physiology, and/or pathology, or documented equivalent supervised experience[3] in a center actively performing cardiac CT.

      and

   ii. The interpretation, reporting, and/or supervised review of at least 50 cardiac CT examinations in the last 36 months. Coronary artery calcium scoring does not qualify as meeting these requirements.

3. Administration of pharmacologic agents

Physicians administering pharmacologic agents as part of cardiac CT imaging should be knowledgeable about the administration, risks, and contraindications of the pharmacologic agents used and should be capable of monitoring the patient throughout the procedure.

4. Maintenance of competence

All physicians performing cardiac CT examinations should demonstrate evidence of continuing competence in the interpretation and reporting of those examinations. If competence is assured primarily on the basis of continuing experience, performance and interpretation of a minimum of 75 examinations every 3 years is recommended in order to maintain the physician's skills.

5. Continuing medical education

The physician's continuing medical education should be in accordance with the ACR Practice Guideline for Continuing Medical Education (CME) of 150 hours of approved education every 3 years, and should include CME in cardiac CT as is appropriate to the physician's practice needs.

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The ACR considers that certification and continuing education in the appropriate subfield(s) demonstrate that an individual is competent to practice one or more of the subfields in medical physics, and to be a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR) or for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

The appropriate subfields of medical physics for this guideline are Therapeutic Radiological Physics, Diagnostic Radiological Physics, Medical Nuclear Physics, and Radiological Physics.

The continuing education of a Qualified Medical Physicist should be in accordance with the ACR Practice Guideline for Continuing Medical Education (CME). 2006 (Res. 16g)

C. Radiologist Assistant

A radiologist assistant is an advanced level radiographer who is certified and registered as a radiologist assistant by the American Registry of Radiologic Technologists (ARRT) after having successfully completed an advanced academic program encompassing an ACR/ASRT (American Society of Radiologic Technologists) radiologist assistant curriculum and a radiologist-directed clinical preceptorship. Under radiologist supervision, the radiologist assistant may perform patient assessment, patient management and selected examinations as delineated in the Joint Policy Statement of the ACR and the ASRT titled "Radiologist Assistant: Roles and

[3] Documented equivalent supervised experience is defined as supervision at a center where the proctoring physician meets these criteria to independently interpret cardiac CT.

Responsibilities" and as allowed by state law. The radiologist assistant transmits to the supervising radiologists those observations that have a bearing on diagnosis. Performance of diagnostic interpretations remains outside the scope of practice of the radiologist assistant. 2006 (Res. 34)

D. Radiologic Technologist

The technologist should participate in assuring patient comfort and safety, in preparing and positioning the patient for the CT examination including proper positioning of the ECG leads, and in obtaining the CT data in a manner suitable for interpretation by the physician. The technologist's continuing education credits should include continuing education in cardiac CT performance as is appropriate to the technologist's practice needs. Basic life support (BLS) and automatic defibrillator (AED) training is recommended.

V. SPECIFICATIONS OF THE CONTRAST-ENHANCED CARDIAC CT EXAMINATION

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

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). The provision of 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 scope of practice requirements. 2006 (Res. 35)

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with CT, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing CT interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the CT examination.

Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

A. Patient Selection and Preparation

The appropriate guidelines for patient selection for a contrast-enhanced cardiac CT examination will continue to evolve with the introduction of new scanner technology with higher temporal and spatial resolution. The availability of specific scanner technology (16 vs 64 MDCT for example) may impact patient selection for contrast-enhanced cardiac studies as the positive and negative predictive values will vary based on available hardware configurations. Patients scheduled for CT coronary arteriography must have adequate peripheral venous access and be able to cooperate with breath holding and the administration of medication as needed (i.e., beta blockers or nitroglycerin/nitrates). Patients referred for cardiac CT should be first evaluated by an appropriate health care provider knowledgeable of risk factors for cardiac and vascular disease.

Based on the results reported in recent publications, selection for CT coronary arteriography may include patients with:

1. Unexplained or atypical chest pain when an aberrant origin of the coronary artery is considered possible.
2. Unexplained or atypical chest pain with low to intermediate likelihood of coronary artery disease based on gender, age, and risk factors.
3. Typical or atypical chest pain with normal or equivocal stress test and normal or equivocal ECG findings.
4. Unexplained severe chest pain in the acute setting without a clinical history of coronary artery disease. Cardiac CT may be used as a rapid triage method to evaluate for the presence of coronary artery disease, and to exclude pulmonary embolism or aortic dissection.

Additional indications for coronary CT arteriography include patients with CABG surgery:

1. With new or recurrent symptoms of chest pain or chest pain equivalent to confirm graft patency or detect graft stenoses.
2. Who are scheduled for additional cardiac surgery (e.g., aortic valve replacement) when preoperative definition of anatomic detail, including the bypass grafts, is critical.

Cardiac CT should be used selectively in patients with a high pretest probability of significant coronary artery disease based on clinical, laboratory or other imaging studies, including stress testing. These higher risk patients are more likely to need invasive coronary catheter studies and interventions. CT should be used with caution in patients with borderline or compromised renal function since if the patient requires an invasive procedure, the contrast load will be significantly increased by performing the CT which could result in even a greater chance of renal impairment.

Patients should have a liquid only diet for 3 hours and abstain from caffeine for at least 6 hours before the study. When a patient has a relative contraindication to the administration of IV iodinated contrast media, measures to reduce the possibility of contrast media reactions or nephrotoxicity should be followed as defined in the ACR Practice Guideline for the Use of Intravascular Contrast Media. A physician should also be available to treat adverse reactions to IV contrast media.

A 20-gauge or larger right antecubital IV catheter is the preferred administration route of iodinated contrast media for CT coronary arteriography. To minimize the risk of contrast media extravasations, all catheters used for cardiac CT angiography should first be tested with a rapidly injected bolus of sterile saline to insure that the venous access is secure and effective. Trained medical personnel should monitor the injection site for signs for IV extravasation. Departmental procedures for treating IV extravasations should be documented.

Because faster heart rates tend to degrade image quality, patients may need to be medicated with beta-blockers, unless contraindicated, prior to or during the cardiac CT arteriogram. Nitroglycerin/nitrates may also be administered in conjunction with the study. Physicians performing CT coronary arteriography should be knowledgeable of the administration, risks, and contraindications of these drugs. Blood pressure and heart rate should be monitored.

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate or “conscious” sedation may enable achievement of the examination. If moderate sedation is necessary, refer to the ACR Practice Guideline for Adult Sedation/Analgesia or the ACR Practice Guideline for Pediatric Sedation/Analgesia.

B. Examination Technique

An initial unenhanced CT acquisition may be needed to depict calcification of the arteries, valves, pericardium, and myocardium to detect mural or extravascular hemorrhage or to localize an anatomic structure. The section thickness may vary but should not exceed 5 mm.

Because of substantial variations in the time required for an IV contrast media injection to reach the targeted vascular anatomy, an assessment of patient-specific circulation time is required in protocols that include the administration of IV contrast media. Circulation timing can be performed using two techniques:

1. Test bolus technique. IV injection of a small bolus (e.g., 10-15 ml) of contrast media at the rate and via the IV site to be used during the examination. Sequential stationary CT images are acquired at the anatomic level of interest during the test bolus. The timing of the contrast delivery and ensuing attenuation of the vascular lumen of interest are then plotted to create a time-density curve. The time of the peak of vascular enhancement is used to determine the scanning delay.
2. Bolus track and trigger technique. Following the initiation of the full dose of contrast media injection, automated triggering CT software monitors the attenuation within the cardiac structure of interest. The CT is automatically started when the enhancement in the monitored vessel or structure reaches a predetermined operator selected level.

A right arm injection is preferable to avoid artifacts from undiluted contrast media in the left brachiocephalic vein. A bolus of saline following the iodinated contrast media injection may reduce the volume of contrast media required to achieve adequate vascular opacification and reduce artifacts from high concentration of contrast media in the superior vena cava and right atrium. Contrast injection parameters should be modified on an individual patient basis whenever possible. The administration of iodinated contrast media for the contrast-enhanced cardiac CT should ideally be performed with a minimum flow rate of 3 ml per second in any patient weighing 50 or more kilograms. Higher flow rates of 5 ml per second or greater are frequently required for larger patients, and in general are required for shorter acquisition scan times. In children, contrast media dosing should be scaled by body weight with injection rate scaled similarly. Preferably the contrast is delivered via powered injection. The volume of contrast media should be selected in consideration of the patient’s weight and comorbidities that might increase the risk of nephrotoxicity.

The contrast-enhanced cardiac CT acquisition should be performed with a section thickness of $\leq$ 1.50 mm depending on the cardiac structure to be assessed. Calcium scoring typically has been performed using 3 mm section thickness, but thinner sections may be used. The field of view (FOV) should span from below the tracheal carina through the apex of the heart. If the patient has had a CABG, the FOV should span from the top of the clavicular heads to the apex of the heart, to include the entire length of internal mammary grafts using breath holding and retrospective cardiac gating. Multisector reconstruction associated with lower pitch values may improve temporal resolution of the reconstructed images, depending on the heart rate and the CT scanner.

For CT coronary arteriography, the use of oral and/or IV beta-blockers, if not contraindicated, may be used during the scan, to obtain a stable heart rate of approximately 50-70 beats per minute. The scan data should be reconstructed at various phases of the cardiac cycle with overlapping sections at a maximum slice increment of 50% of the effective section thickness and a FOV of approximately 25 cm. Thin section reconstruction during the most optimal temporal window is recommended to improve conspicuity of the structures of interest. Thick section reconstructions that span the entire cardiac cycle can be performed to assess cardiac contractility. When recording to film, display settings of window width and level should be customized to clearly delineate the enhanced vascular lumen from mural calcification and myocardium.

Postprocessing of the cardiac CT data should be performed by physicians, registered radiology technologists, or other experienced personnel knowledgeable of cardiovascular anatomy and pathophysiology. The data may be formatted and presented using various display techniques, including multiplanar reformations (MPRs), maximum intensity projections (MIPs), 3D volume renderings (VR), 3D shaded surface displays, and/or 4D dynamic reconstructions.

Images are to be labeled with the following: a) patient identification, b) facility identification, c) examination date, and d) the side (right or left) of the anatomic site imaged. Postprocessed images should be recorded and archived in a manner similar to the source CT sections.

C. Interpretation

Cardiac CT data should be interpreted on a computer workstation that displays axial, reformatted, and postprocessed images. Interpretation of the CT coronary arteriogram includes assessment of intraluminal plaques, to include segmental vascular location, attenuation characteristics, and degree of luminal narrowing; vascular anomalies; and abnormalities of the cardiac chambers, myocardium, and pericardium. Frequently, reconstruction from different phases of the cardiac cycle may be required to fully interpret the examination. For functional cardiac assessment, multiples phases should be examined. Interpretation of the noncardiac portion of the examination should include use of proper windowing and leveling for adequate visualization of the soft tissue, mediastinum, pulmonary, and bony portions of the chest. Comparison with previous chest CT images should be performed if appropriate.

VI. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Guideline for Communication of Diagnostic Imaging Findings. In addition to examining the cardiac structures of interest, the CT sections should be examined for extracardiac abnormalities that may have clinical relevance. These abnormalities should also be described in the formal report of the examination.

VII. EQUIPMENT SPECIFICATIONS

For diagnostic quality cardiac CT, the CT scanner should meet or exceed the following specifications:

1. Contrast-enhanced cardiac CT by MDCT, including CT coronary arteriography, a scanner capable of achieving in-plane spatial resolution $\leq$ 0.5 x 0.5 mm axial, z-axis spatial resolution $\leq$ 1 mm longitudinal, and temporal resolution $\leq$ 0.25 sec.
2. Non-contrast-enhanced MDCT for coronary artery calcium scoring may be adequately performed on a scanner with a temporal resolution of $\leq$ 0.50 second using retrospectively gated volume-series acquisition or a prospectively triggered "stop and shoot" sequential acquisition.
3. Tube heat capacity that allows for a single $\geq$ 20 second acquisition.
4. Minimum section thickness: no greater than 3 mm; no greater than 1.5 mm for CT coronary arteriography.

To maximize the CT interpretation, any CT scanner used for cardiac CT must allow display and interpretation of the full 12 bits (from -1,000 to 3,095 Hounsfield Units) of attenuation information. Additionally the display FOV must be sufficient to assess the vasculature region of interest, the end-organ, and adjacent structures.

For adequate contrast-enhanced cardiac CT, including CT coronary arteriography, a power injector capable of delivering a programmed volume of a contrast agent at a steady flow rate of at least 3 cc per second for delivery of $\geq$ 300 mg of iodine/ml is necessary. A dual chambered power injector is preferred if a saline flush will be administered immediately after the intravenous contrast material injection.

A workstation capable of creating straight or curved multiplanar reformations, maximum intensity projections, volume renderings that can be compared across multiple cardiac phases and 4D dynamic reconstructions should be available for coronary CTA and for other applications as appropriate.

Appropriate emergency medication and resuscitation equipment must be readily available to treat adverse contrast reactions, an acute coronary syndrome, and cardiac arrest. Resuscitation equipment should be monitored on a routine basis in compliance with institutional policies.

VIII. RADIATION SAFETY IN IMAGING

Radiologists, radiologic technologists, and all supervising physicians have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This is the concept "As Low as Reasonably Achievable (ALARA)".

Facilities, in consultation with the medical physicist, should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active or manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. Patient radiation doses should be periodically measured by a medical physicist in accordance with the appropriate ACR Technical Standard. 2006 (Res. 17)

IX. 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 Physics Performance Monitoring of Computed Tomography (CT) Equipment.

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