Revised 2021 (Resolution 45)*

ACR–NASCI–SPR PRACTICE PARAMETER FOR THE PERFORMANCE AND INTERPRETATION OF CARDIAC COMPUTED TOMOGRAPHY (CT)

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[1]. 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 considering 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 variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and 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 course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing 831 N.W.2d 826 (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.

I. INTRODUCTION

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

Cardiac computed tomography (CT) is a well-established noninvasive cross-sectional imaging modality most commonly used to assess coronary arteries. It provides comprehensive information on the anatomy, function, and pathology of the cardiac structures, and pericardium. With advances in technology, such as CT perfusion and CT-derived fractional flow reserve, it can also provide hemodynamic information on coronary artery disease [1-24].

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 (for more information, see Section IV.A). A qualified medical physicist and trained technical staff must be available [25].

Cardiac CT should be performed only when appropriate, and with the minimum radiation exposure that provides diagnostic image quality, following the as low as reasonably achievable (ALARA) principle.

Although important abnormalities of the heart and associated structures can be detected on chest CT performed for other reasons, these practice parameters 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, the reader should see the ACR–SCBT-MR–SPR–STR Practice Parameter for the Performance of Thoracic Computed Tomography (CT) [26].

A. Cardiac CT

Cardiac CT is performed primarily for the morphologic evaluation of the coronary arteries and veins, cardiac chambers, valves, ventricular myocardium, aortic root, central pulmonary arteries and veins, and pericardium. However, noncardiac structures included in the field of view (FOV) must be evaluated and reported [27-38].

B. Noncontrast Cardiac CT

Noncontrast cardiac CT is performed primarily for detecting and evaluating calcification, such as that of the coronary arteries (coronary calcium scoring), ascending aorta, cardiac valves, pericardium, or cardiac masses. Electrocardiogram (ECG) synchronization reduces motion artifact and is required for coronary calcium quantification [27,28,32,35]. It may also be performed for cardiac surgical planning in preoperative patients [39].

C. Contrast-Enhanced Cardiac CT

1. Contrast-enhanced ECG-synchronized_cardiac CT is performed with intravenous (IV) administration of iodinated contrast to allow evaluation of the cardiac chambers, myocardium, valves, pericardium, and central vessels. These studies include assessment of pulmonary veins or coronary veins.
2. Coronary CT angiography (CTA) is an ECG-synchronized contrast-enhanced CT performed to characterize the origin and course of the coronary arteries and/or stents and/or bypass grafts and to assess atherosclerotic plaque, stenosis, and/or aneurysm.
3. CT cardiac venography with or without ECG synchronization is performed to assess the pulmonary veins, the coronary veins, and systemic veins.

II. INDICATIONS [30,33,37,38,40]

Noncontrast ECG-synchronized cardiac CT may be indicated for detecting and quantifying coronary artery calcium ("calcium scoring"). Although the role of coronary artery calcium scoring continues to be refined, data support its use for risk stratification and therapeutic decision making in select patients with intermediate risk or selected adults with borderline-risk for atherosclerotic cardiovascular disease [41]. An additional indication is the localization of myocardial, valvular, aortic, and pericardial calcium. Quantification of aortic valve calcium is also useful in grading the severity of low-gradient aortic valve stenosis.

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

1. Coronary atherosclerotic and nonatherosclerotic disease
2. Cardiac and vascular congenital anomalies and variants
3. Follow-up of corrected or palliated congenital heart disease and assessment of postoperative complications (shunt/conduit stenosis, thrombosis, pseudoaneurysms) in children and adults
4. Coronary interventions (endovascular and surgical, eg, angioplasty, coronary stenting, coronary artery bypass grafts [CABGs], pulmonary vein ablation therapy for cardiac dysrhythmia, valve replacement, aortic root replacement, planning for aortic endovascular valve replacement, pacemaker placement planning)
5. Other cardiac interventions (eg, myocardial ablation for hypertrophic cardiomyopathy, pulmonary vein isolation with left atrial appendage imaging for atrial dysrhythmia, transcatheter left atrial appendage occlusion, pacemaker placement and lead extraction planning, ventricular tachycardia ablation with contraindications for cardiac magnetic resonance imaging (MRI), atrial septal defect/patent foramen ovale (ASD/PFO) closure, ventricular assist devices) [42]
6. Cardiac valvular disease in patients in whom transcatheter treatment is planned (transcatheter aortic, pulmonary, mitral, or tricuspid replacement/repair)
7. Complications of open surgical or transcatheter valve repair/replacement (pannus formation, leaflet thrombosis, root abscess, pseudoaneurysms, paravalvular leak) [43]
8. Sequelae of ischemic coronary disease (myocardial scarring, ventricular aneurysms/pseudoaneurysms, thrombi)
9. Cardiac masses including thrombi pericardial diseases
10. Intracardiac thrombi
11. Cardiac trauma and iatrogenic injury

Specific congenital cardiovascular anomalies and variants may include the following:
1. Coronary artery anomalies
2. Systemic and pulmonary venous anomalies
3. Aortic and pulmonary anomalies
4. Right-sided cardiac obstructive disorders
5. Left-sided cardiac obstructive disorders
6. Atrial and ventricular septal defects
7. Other complex structural disorders of the cardiac chambers, morphology, and valves, including heterotaxy.

For additional indications see the Cardiac Imaging section of the ACR Appropriateness Criteria® [44].

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [45]. For additional information on contrast media and contrast reactions, please see the ACR Manual on Contrast Media [46].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

1. Physicians should meet the qualifications outlined in the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [47]. Additional qualifications are available in the 2020 Guideline for Training Cardiology and Radiology Trainees as Independent Practitioners (Level II) and Advanced Practitioners (Level III) in Cardiovascular Computed Tomography: A Statement from the Society of Cardiovascular Computed Tomography (SCCT) [48].

Physicians performing and interpreting cardiac CT examinations should also meet the following qualifications:

a. For a physician with prior qualifications in general and/or thoracic CT interpretation, additional qualifications should include:
    i. Cardiac CT Category I CME or training in Cardiac CT in a training program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (RCPSC), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA),

    including

    ii. CME in cardiac anatomy, physiology, pathology, and cardiac CT imaging

    and including

    iii. Supervision, interpretation, or reporting of cardiac CT examinations. Coronary artery calcium scoring does not qualify as meeting these requirements.

b. For any physician who assumes responsibilities for cardiac CT imaging, additional qualifications should include:
    i. Completion of an ACGME-approved training program in the specialty practice plus Category I CME in the performance and interpretation of CT in the subspecialty in which CT reading occurs,

    and

    ii. Supervision, interpretation, or reporting of cases in cardiothoracic imaging. These must include a sufficient number of cardiac CT examinations in a supervised situation and thoracic CT or thoracic CTA cases. Coronary artery calcium scoring does not qualify as meeting these requirements,

    including

    iii. Completion of sufficient Category I CME in cardiac imaging, including cardiac CT, anatomy, physiology, and/or pathology, or documented equivalent supervised experience in a facility actively performing cardiac CT

2. Administration of pharmacologic agents

   The supervising physician must be knowledgeable about the administration, risks, and contraindications of the pharmacologic agents commonly used in cardiac CT imaging, such as heart rate–lowering medications and coronary vasodilators.

3. 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 ensured primarily on the basis of continuing experience, a sufficient number of examinations to maintain the physician's skills in performance and interpretation is recommended.

4. Continuing medical education (CME)

   The physician's CME should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [49] and should include CME in cardiac CT as is appropriate to the physician's practice needs.

B. Qualified Medical Physicist

See the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [50].

See the ACR Practice Parameter for Continuing Medical Education (CME). [49]

The appropriate subfield of medical physics for this practice parameter is diagnostic medical physics (previous medical physics certification categories including radiological physics, diagnostic radiological physics, and diagnostic imaging physics are also acceptable). (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022, Resolution 41f)

C. Non-Physician Radiology Provider (NPRP)

NPRPs are all Non-Physician Providers (eg, RRA, RPA, RA, PA, NP, ...) who assist with or participate in portions of the practice of a radiologist-led team (Radiologists = diagnostic, interventional, neurointerventional radiologists, radiation oncologists, and nuclear medicine physicians). The term “NPRP” does not include radiology, CT, US, NM MRI technologists, or radiation therapists who have specific training for radiology related tasks (eg, acquisition of images, operation of imaging and therapeutic equipment) that are not typically performed by radiologists.

The term 'radiologist-led team' is defined as a team supervised by a radiologist (ie, diagnostic, interventional, neurointerventional radiologist, radiation oncologist, and nuclear medicine physician) and consists of additional healthcare providers including RRAs, PAs, NPs, and other personnel critical to the provision of the highest quality of healthcare to patients. (ACR Resolution 8, adopted 2020).

1. Registered Radiologist Assistant (RRA)

An RRA is an advanced level radiographer who is certified and registered as a “Registered Radiologist Assistant” by the American Registry of Radiologic Technologists (ARRT) after successful completion of an advanced academic program encompassing an American Society of Radiologic Technologists (ASRT) RRA curriculum and a radiologist-directed clinical preceptorship.

Under radiologist supervision, the RRA may perform patient assessment, patient management, and selected examinations as delineated in the ACR Statement “Radiologist Assistant: Roles and Responsibilities” subject to state law (see the ACR Digest of Council Actions Appendix H). The RRA transmits to the supervising radiologist those observations that have a bearing on diagnosis. Performance of diagnostic interpretations (preliminary, final, or otherwise) remains outside the scope of practice of the RRA. RRAs performing invasive or non-invasive procedures should function under radiologist supervision and as part of radiologist-led teams. (Adopted 2006 Resolution 34, 2016 Resolution 1-c, Revised in 2020 Resolution 11).

The RRA’s continuing education credits should include continuing education in cardiac CT performance as is appropriate to the radiologist assistant’s practice needs. Basic life support (BLS) and automatic defibrillator (AED) training is recommended.

D. Radiologic Technologist

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [47].

In addition to the qualifications listed in the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [47], the technologist should participate in the proper positioning of the ECG leads. 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.

IV. 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 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 – revised in 2016, Resolution 12-b)

The supervising physician must have adequate understanding of the indications, risks, and benefits of the imaging examination as well as of alternative imaging procedures. The physician must be familiar with potential hazards associated with CT, including radiation exposure and potential adverse reactions to contrast media [51]. The physician should be familiar with relevant ancillary studies that the patient may have undergone, including echocardiography, cardiac catheterization, MRI, or nuclear medicine studies. 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 and ancillary supportive technology that may affect cardiac CT performance (eg, sensitivity, specificity, and positive and negative predictive values). Cardiac CT is generally used in patients with a low to intermediate pretest probability for coronary disease and patients with cardiac structural and thoracic vascular congenital and acquired disease based upon clinical, laboratory, and/or prior imaging findings. Higher-risk patients with coronary artery disease are more likely to need invasive coronary catheter studies and interventions, although the use of cardiac CT in these patient populations is continually evolving.

Patient selection for cardiac CT and coronary CTA should be in accordance with evidence-based clinical algorithms [52-55]:

1. Coronary Arteries
    a. Unexplained or atypical chest pain with low or intermediate risk for coronary artery atherosclerotic disease based on gender, age, and risk factors [55,56]. It may also be appropriate in high-probability patients.
    b. Suspected or known coronary anomaly following echocardiography or inconclusive cardiac MRI or invasive coronary angiography to determine course and origin
    c. Evaluation of a reimplanted coronary artery
    d. Diagnosis or follow-up of coronary involvement in Kawasaki disease
    e. Unexplained or atypical chest pain with low risk for coronary artery atherosclerotic disease and possible coronary artery anomaly
    f. Typical or atypical chest pain with normal or equivocal stress test and normal or equivocal ECG findings
    g. Unexplained acute chest pain in a patient with or without coronary disease risk factors who has negative cardiac enzymes and normal or equivocal ECG findings
    h. Unexplained acute chest pain in which the clinical presentation requires exclusion of coronary artery disease versus other thoracic vascular causes of chest pain, such as pulmonary embolism and acute aortic pathology (eg, dissection). The patient may or may not have coronary artery disease risk factors. Cardiac enzymes should be negative and ECG findings normal or equivocal.
    i. Evaluation of ischemic etiology for a newly diagnosed cardiomyopathy, left bundle branch block and/or heart failure
    j. Preoperative evaluation of the coronary arteries prior to noncoronary cardiac surgery with low or intermediate risk for coronary artery atherosclerotic disease based on sex, age, and risk factors
    k. Posttranscatheter or surgical evaluation of the coronary arteries and/or cardiac structure including, but not limited to, systemic and pulmonary veins, aortic root, proximal aorta, and pulmonary arteries

   l. Postendovascular or surgical evaluation of the coronary arteries, stents, bypass grafts, and/or cardiac structure including, but not limited to, cardiac chambers and valves, systemic and pulmonary veins, aortic root, proximal aorta, and pulmonary arteries
   m. Patients with post–coronary intervention that may:
      i. Have new or recurrent symptoms or chest pain or chest pain equivalent
      ii. Be scheduled for additional cardiovascular interventions

2. Cardiac Structure (subsequent to prior imaging, eg, echocardiography)
   a. Systemic and pulmonary venous anatomy and anomalies
   b. Aortic and pulmonary arterial anatomy and anomalies
   c. Right-sided chamber obstructive disorders (including valves)
   d. Left-sided chamber obstructive disorders (including valves)
   e. Complex congenital structural disorders
   f. Cardiac and pericardial masses and thrombi
   g. Pericarditis and constriction

3. Cardiac Function (subsequent to echocardiography and if cardiac MRI cannot be obtained)
   a. Ventricular volumes and ejection fraction
   b. Valves (native and prosthetic)

4. Myocardial CT Perfusion (as an alternative for cardiac MRI)
   a. To assess myocardial ischemia during stress and rest in cases in which the degree of coronary artery stenosis can impact clinical management

Patients scheduled for CT coronary arteriography must have tolerance for necessary administration of medications as needed (eg, beta-blockers or nitroglycerin/nitrates), adequate peripheral venous access, and be able to cooperate with breath holding. Patients with irregular heart rhythms may not be appropriate candidates and should be evaluated on an individual basis for the examination, depending on local expertise and scanner capabilities. All patients referred for cardiac CT should be first evaluated by an appropriate health care provider knowledgeable of congenital and acquired cardiac and thoracic vascular disease. Cardiac CTA should be used with caution in patients with borderline or compromised renal function. Cardiac CT may be suboptimal for evaluation of atherosclerosis in patients whose body mass index (BMI) is 50 kg/m² or greater, depending on scanner capabilities.

Patients should have a liquid-only diet for 3 hours and abstain from caffeine for at least 6 hours prior to the study in the nonacute setting [57]. 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–SPR Practice Parameter for the Use of Intravascular Contrast Media [51] and the ACR Manual on Contrast Media [46]. A physician should also be available to treat adverse reactions to IV contrast media.

An appropriately sized antecubital IV catheter able to deliver at least 5 cc/s in adults and 3 cc/s in children, 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 CTA should first be tested with a rapidly injected bolus of sterile saline to ensure 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 [58-60], patients may need to be medicated with rate-controlling drugs (beta-blockers, calcium channel blockers), unless contraindicated, prior to proceeding with the cardiac CT arteriogram. Nitroglycerin/nitrates are generally also administered just prior to the CTA acquisition, unless contraindicated. Physicians performing CT coronary arteriography should be knowledgeable of the administration, risks, and contraindications of these medications. Blood pressure and heart rate should be monitored prior to, during, and following the CT coronary arteriography when medications are administered.

Pediatric patients or patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation or general anesthesia may enable achievement of the examination, particularly in young children. If moderate sedation is necessary, refer to the [ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia] [61].

B. Examination Technique

A coronary artery calcium scoring study may be acquired prior to contrast injection. This is typically performed with prospective axial sequential, prospective volumetric scanning, or high-pitch helical ECG triggering and 3-mm-thick sections with 120 kVp beginning at or just below the carina and extending inferior to the left ventricle.

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 either of two techniques:

1. Test bolus technique. IV injection of a small bolus (eg, 10-20 mL) of contrast media at the flow rate and via the IV site that will be used for the examination. Sequential stationary CT images are acquired at the anatomic area of interest (for instance, thoracic aorta 2 cm from the left main coronary artery ostium) during the test bolus. The timing of the contrast delivery and ensuing enhancement of the vessel 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 tracking 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. Note: For pediatric patients, in whom reduction of both contrast media and radiation dose is preferable, the appropriate scan delay time can be determined using the bolus track and trigger technique with low-dose sequential monitoring images; alternatively, an empiric delay time after the initiation of the contrast injection may be used.

A right arm injection is preferable to avoid artifacts from undiluted contrast media in the left brachiocephalic vein as it crosses the mediastinum. A bolus of saline following the iodinated contrast media injection should be used to 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. A triphasic contrast protocol using an intermediate phase of mixed iodine and saline (or reduced flow rate) between the full contrast and saline boluses can also be used to attenuate the contrast concentration in the right heart, if desired. Contrast injection parameters should be modified on an individual patient basis whenever possible. The administration of iodinated contrast media for contrast-enhanced cardiac CT should ideally be performed with a minimum flow rate of 5 to 7 mL/s in any patient weighing 50 kg or more. Flow rates of 5 mL/s or greater are required for coronary CT. Use of low tube voltage (kVp) in patients with low BMI, and especially in children, may achieve satisfactory vascular contrast enhancement with slower flow rates and lower radiation dose. In children, contrast media dosing should be scaled by body weight, with injection rate scaled similarly. Whenever possible, the contrast should be 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 ≤1 mm, depending on the cardiac structure to be assessed. If performed for function or cardiac morphology only, 1.25- to 1.5-mm section thickness may be adequate, whereas for coronary CTA, 0.5- to 0.70-mm slice thickness is desirable. If the patient has had previous CABG surgery, 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 cardiac synchronization. Multisector reconstruction associated with lower pitch values may improve the effective temporal resolution of the reconstructed images, depending on the heart rate and the CT scanner. Prospective ECG triggering and prospectively ECG-triggered high-pitch helical scanning should be used as a radiation dose reduction method whenever possible if this technology is available [62]. Other radiation dose reduction methods, such as low-kVp, ECG-dependent, tube-current modulation, and iterative reconstruction techniques, should be used when appropriate and available [63-67].

For CT coronary arteriography, oral and/or IV rate-controlling drugs, beta-blockers, if not contraindicated, may be used to obtain a stable heart rate of approximately 50 to 70 beats per minute (bpm), depending on scan temporal resolution. A sublingual nitroglycerin tablet or spray may be used to vasodilate the coronary arteries for better visualization, provided that the patient's blood pressure is adequate and no other contraindications exist. Scan data acquired with retrospective ECG gating should be reconstructed at various phases of the cardiac cycle, and all acquisitions should be reconstructed with overlapping sections at a maximum slice increment of 50% of the effective section thickness and a FOV of approximately 18 to 20 cm, if possible. Thin-section reconstruction during the most optimal temporal window is recommended to improve conspicuity of the structures of interest. Thicker section reconstructions that span the entire cardiac cycle can be performed to assess cardiac contractility. For prospective ECG triggering, scanning is triggered at a certain interval in the cardiac cycle, typically during diastole, for image acquisition and subsequent reconstruction. With higher heart rates (90 bpm and above, frequently present in pediatric patients), triggering in end-systole typically renders best image quality. Opening the scan pulse in prospective triggering ("padding") allows the acquisition of, and reconstruction of more phases when appropriate and available.

Postprocessing of the cardiac CT data should be performed by physicians, registered radiology technologists, or other experienced personnel knowledgeable of cardiovascular anatomy and pathophysiology. Images from calcium scoring studies should be reviewed to ensure that only calcifications within the coronary arteries or aortic valve (for aortic valve calcium scoring) are included as part of the scoring. The cardiac CT data are formatted and presented using various display techniques, including multiplanar reformations (MPRs), curved planar reformations (CPRs), maximum-intensity projections (MIPs), 3-D volume renderings (VRs), 3-D shaded surface displays, and/or 4-D dynamic reconstructions.

Images are to be labeled at the minimum with the following: 1) patient identification, 2) facility identification, 3) examination date, and 4) the anatomic location. Postprocessed images should be recorded and archived in a manner similar to the source CT sections.

If available and clinically deemed appropriate, the coronary artery CT source data can be sent for fractional flow reserve (FFR)CT analysis, which can determine lesion-specific hemodynamics and improve the diagnostic performance of coronary CTA in selected cases, particularly in lesions with moderate (50%-69%) stenosis and calcified plaques [68].

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 and morphology characteristics, and degree of luminal narrowing; vascular anomalies; the presence and status of stents ≥ 3 mm and/or coronary bypass grafts; and abnormalities of the cardiac chambers, myocardium, and pericardium. Frequently, reconstructions from different phases of the cardiac cycle may be required to fully interpret the examination. For functional cardiac assessment, multiple phases from a retrospective gated study 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 tissues, mediastinum, pulmonary, and bony portions of the chest. Comparison with previous chest or cardiac CT images should be performed if available.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [69].

Reporting of coronary artery disease should be in accordance with the Coronary Artery Disease- Reporting and Data System (CAD-RADS)™ [70].

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.

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [50].

Technology in this area is changing rapidly, and with the advent of new-generation CT scanners, such as the volume and dual-source scanner, there are added benefits of providing reliable high-quality images at reduced doses as well as the ability to perform dynamic vascular imaging. The following specifications should therefore be regarded as the minimum standard for CT scanners to perform cardiac CT examinations.

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

1. ECG synchronization for all scans, with the ability to perform prospective triggering and retrospective gating
2. Setup for bolus tracking of the administered contrast material for appropriate timing of contrast-enhanced cardiac CT examinations
3. Automated tube-current modulation during image acquisition for dose reduction
4. Contrast-enhanced cardiac CTA (should meet or exceed a 64-detector scanner), including CT coronary arteriography, a scanner capable of achieving in-plane spatial resolution of $\leq 0.5 \times 0.5$ mm axial, z-axis spatial resolution of ≤ 1 mm longitudinal, and temporal resolution of ≤ 0.25 second
5. Noncontrast CT for coronary artery calcium scoring may be adequately performed on a scanner with a temporal resolution of 0.50 seconds using prospectively ECG-triggered “step and shoot” sequential acquisition
6. Minimum section thickness: should be ≤ 3 mm for coronary calcium scoring and ≤ 1 mm for CT coronary arteriography
7. Volumetric CT dose index (CTDI vol) and dose length product (DLP) must be available after each scan for transfer to individual PACS workstations

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 4 cc/s for delivery of ≥ 300 mg of iodine per milliliter is necessary (in pediatric patients, 2-2.5 cc/s if 22-gauge catheters are used). A dual-chambered power injector is preferred in order to administer a saline flush immediately after the IV 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 4-D dynamic reconstructions should be available for coronary CTA and for other applications as appropriate. The coronary postprocessing package should include vessel/lumen analysis, cardiac calcium scoring, and cardiac function analysis.

For pediatric facilities, sufficient space should be available for anesthesia equipment in the room in which the scanner is housed. Appropriate algorithm must be available for treating soft-tissue infiltration of intravenously administered iodinated contrast material. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions, an acute coronary syndrome, and cardiac arrest. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers**,** 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 who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

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

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). 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 periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, 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; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

VIII. 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 *ACR Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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Writing Committee – members represent their societies in the initial and final revision of this practice parameter

ACR	NASCI	SPR
Klaus Hagspiel, MD, Chair	Cristina Fuss, MD	David Biko, MD
Lucia Flors Blasco, MD, PhD	Prabhakar Rajiah MD	Siddharth Jadhav, MD
Larissa Braga Casaburi, MD, MPH, MHA		Karen Lyons, MB, BCh, BAO
Yoo Jin Lee, MD		Evan Zucker, MD

Beverley Newman, MB, BCh, BSc, FACR

Committee on Body Imaging – Cardiovascular
(ACR Committee responsible for sponsoring the draft through the process)

Klaus Hagspiel, MD, Chair
Lucia Flors Blasco, MD, PhD
Larissa Braga Casaburi, MD, MPH, MHA
Yoo Jin Lee, MD
Scott K. Nagle, MD, PhD
Ashley Prosper, MD
Steven S. Raman, MD
Andrew L. Rivard, MD
Phillip M. Young, MD

Committee on Practice Parameters – Pediatric Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Terry L. Levin, MD, FACR, Chair
John B. Amodio, MD, FACR
Jesse Berman, MD
Tara M. Catanzano, MB, BCh
Harris L. Cohen, MD, FACR
Kassa Darge, MD, PhD
Dorothy L. Gilbertson-Dahdal, MD
Lauren P. Golding, MD
Safwan S. Halabi, MD
Jason Higgins, DO
Jane Sun Kim, MD
Jennifer A Knight, MD
Jessica Kurian, MD
Matthew P. Lungren, MD, MPH
Helen R. Nadel, MD
Erica Poletto, MD
Richard B. Towbin, MD, FACR
Andrew T. Trout, MD
Esben S. Vogelius, MD

Andrew B. Rosenkrantz, MD, Chair, Commission on Body Imaging
Richard A. Barth, MD, FACR, Chair, Commission on Pediatric Radiology
David B. Larson, MD, MBA, Chair, Commission on Quality and Safety
Mary S. Newell, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comment Reconciliation Committee
Monica Wood, MD, Chair
Jamaal Benjamin, MD, PhD, Co-Chair
Richard A. Barth, MD, FACR
David Biko, MD
Lucia Flors Blasco, MD, PhD
Larissa Braga Casaburi, MD, MPH, MHA
Richard Duszak Jr., MD, FACR
Cristina Fuss, MD
Klaus Hagspiel, MD
Jane P. Ko, MD
Amy Kotsenas, MD, FACR
David B. Larson, MD, MBA
Paul A. Larson, MD, FACR
Terry L. Levin, MD, FACR
Yoo Jin Lee, MD
Karen Lyons, MB, BCh, BAO
Mary S. Newell, MD, FACR
Beverley Newman, MB, BCh, BSc, FACR
Prabhakar Rajiah MD
Andrew B. Rosenkrantz, MD
Quynh A. Truong, MD
Evan Zucker, MD

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