

Technical and Personnel Requirements

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Abstract

In this chapter, we summarize the requirements for setting up a coronary CT angiography practice.

2.1 Technical Requirements

Noninvasive coronary angiography is an ascending clinical application that requires very high spatial and temporal resolution. Thus, CT scanners with multiple detector rows (multislice CT [MSCT]), short gantry rotation times, and thin-slice collimation are essential for establishing a successful cardiac CT imaging center. Because 64-slice CT is superior to 16-slice CT in terms of image quality and diagnostic accuracy, we believe that (at least) 64-slice technology is necessary for performing noninvasive coronary angiography (**List 2.1**). CT with 64-slice technology not only increases the quality of the images (**Figs. 2.1–2.3**) but also improves the workflow because scanning and breath-hold times are shorter (**Table 2.1**). The shorter breath-hold time is also very relevant for patients after coronary bypass grafting, for whom 64-slice CT reduces the breath-hold time to about 15 s (**Fig. 2.4**). The faster gantry rotation speed (**List 2.1**) improves temporal resolution and dramatically reduces the likelihood of relevant motion artifacts.

Temporal resolution can be significantly improved by using two simultaneous X-ray sources (dual-source

List 2.1. Technical requirements for coronary CT angiography

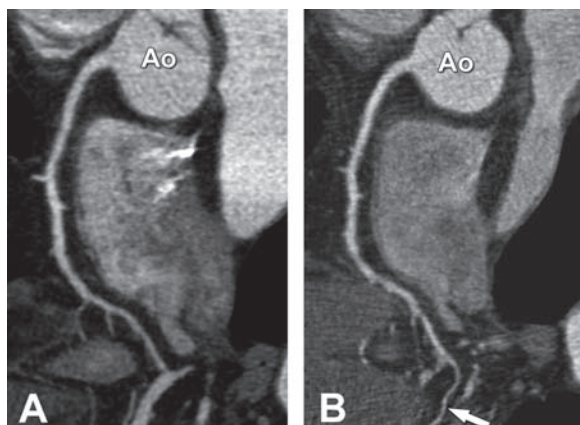
1. CT scanner with at least 64 simultaneous slices
2. CT scanner with a gantry rotation time of below 400 ms
3. Adaptive multisegment reconstruction or dual-source CT
4. ECG for gating and triggering^a of acquisitions
5. Dual-head contrast agent injector for saline flush
6. Workstation with automatic curved multiplanar reformation and 3D data segmentation and analysis capabilities

^a This refers to the acquisition method: retrospective (ECG gating) or prospective (ECG triggering)

CT, Siemens) and adaptive multisegment reconstruction (Toshiba and Philips). We believe that one of these two approaches should be implemented on cardiac CT scanners to reduce the influence of heart rate on image quality (**List 2.1**). In addition to these technical improvements, beta blocker administration should be used whenever possible to lower the heart rate to below approximately 65 beats per min, because slowing the heart rate to this level further improves both the image quality and the diagnostic accuracy (Chaps. 6 and 7). Finally, an ECG, a dual-head contrast agent injector, and an automatic 3D cardiac analysis workstation are required for cardiac CT (**List 2.1**).

2.2 Purchasing a Scanner

The purchase costs of 16 and 64-slice CT scanners still differ enormously. For applications other than cardiac imaging, 16-slice CT scanners are clearly sufficient to answer the vast majority of clinical questions.

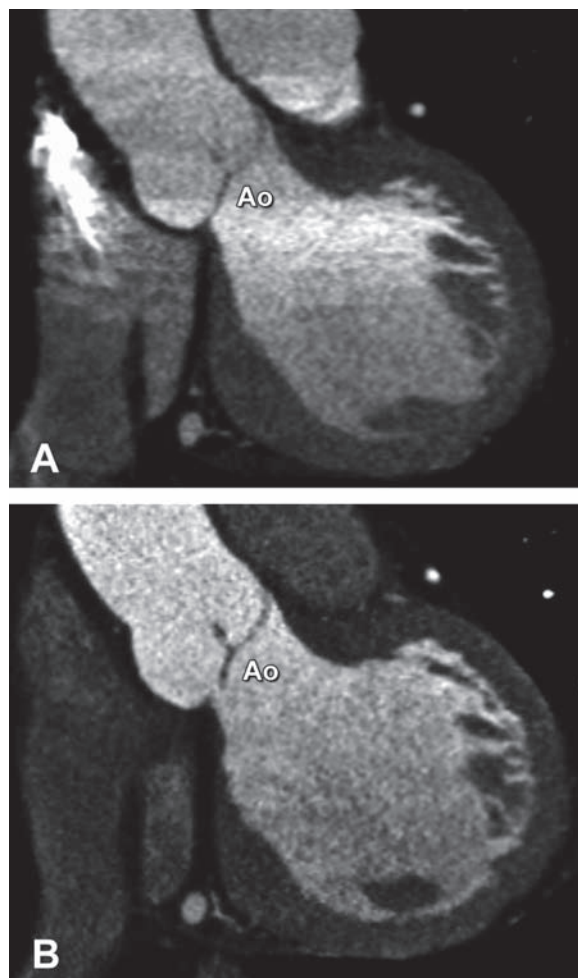


■ **Fig. 2.1** Comparison of 16-slice (**Panel A**) and 64-slice CT coronary angiography (**Panel B**) of the right coronary artery (curved multiplanar reformation) in a 61-year-old male patient. 64-slice CT shows longer vessel segments, especially in the periphery (*arrow*). This enhanced performance can be explained by fewer motion artifacts (due to breathing, extrasystoles, or variations in the length of the cardiac cycle) and the better contrast between arteries and veins resulting from the faster scan and consequently better depiction of the arterial phase. The improved depiction of the arterial phase using 64-slice CT is also demonstrated in **Fig. 2.2**. **Panel B** also illustrates the slightly higher image noise with 64-slice CT, which can be compensated for by the better depiction of the arterial phase and the higher intravascular density. Ao aorta

For cardiac applications, however, at least 64-slice technology is clearly needed. The decision to purchase a scanner from any particular manufacturer not only depends on its meeting the relevant technical criteria, such as those mentioned earlier, but will definitely also be influenced by local pricing policies and, more important, by the quality of the maintenance and service support (**List 2.2**). How to perform cardiac CT exams using scanners from different vendors is explained in Chap. 8.

List 2.2. Factors to consider in deciding to purchase a particular CT scanner

1. Local situation and mixture of different examination types
2. Quality of technical and maintenance support
3. Availability of high temporal and spatial resolution
4. Quality and durability of the application support
5. Integration into existing picture archiving and communication systems
6. Local pricing policies



■ **Fig. 2.2** The improved depiction of the arterial phase using 64-slice (**Panel B**), when compared with 16-slice, CT coronary angiography (**Panel A**) is illustrated by a double-oblique coronal slice along the left ventricular outflow tract, with the aortic valve nicely depicted (Ao). In the craniocaudal direction, the density in the aorta and left ventricle shows less variation and decline when 64 simultaneous detector rows are used (**Panel B**). Use of 64-slice CT improves image quality and facilitates the application of automatic coronary vessel and cardiac function analysis tools

Multislice CT has a variety of other applications in addition to cardiac imaging, and CT scanners used solely for cardiac applications are very unlikely to reach the break-even point. Thus, we believe that a mixture of different CT applications is a prerequisite for clinical and economic success. In the US, the Center for Medicare and Medicaid Services (CMS) recently decided after an extensive review that no Medicare national coverage of coronary CT angiography is appropriate at this time. In the decision memo, it is concluded

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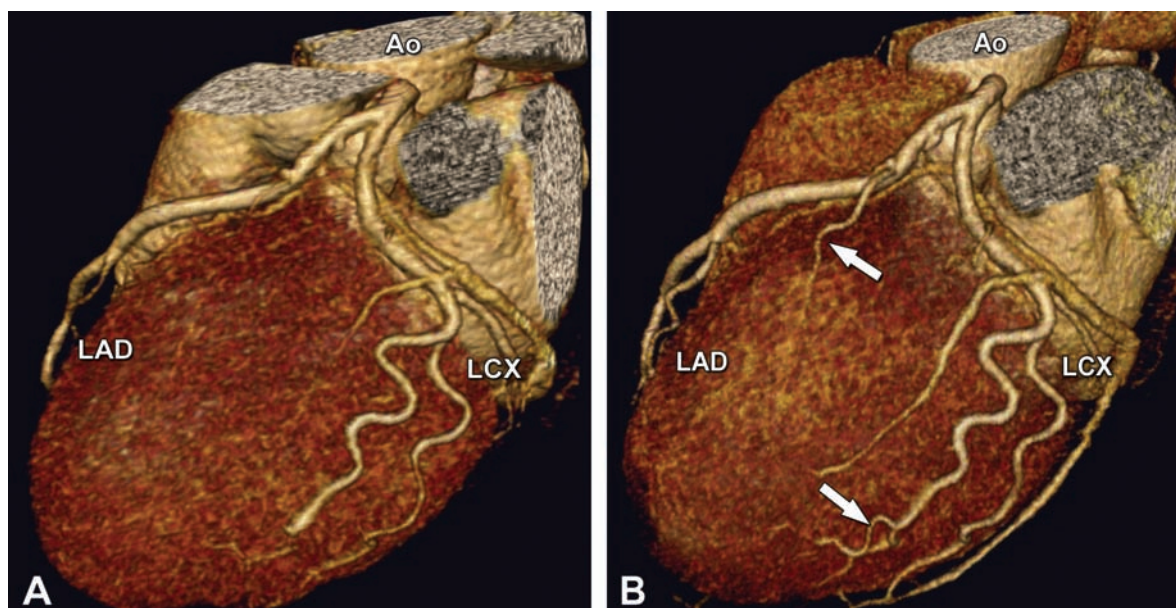


Fig. 2.3 Another example illustrating the improved depiction of distal coronary artery branches using 64-slice CT (**Panel B**) in a 58-year-old female patient. Three-dimensional volume-rendered reconstructions of the left coronary artery with the left anterior descending (LAD) and left circumflex coronary artery (LCX) examined using 16-slice (**Panel A**) and 64-slice CT coronary angiography (**Panel B**). Note the improved depiction of smaller side branches with the 64-slice technology (arrows in **Panel B**), when compared with the same segments in 16-slice CT (**Panel A**) Ao aorta

that no adequately powered study has established that improved health outcomes can be causally attributed to coronary CT angiography for any well-defined clinical indication. Thus, coverage will be determined by local contractors through the local coverage determination process or case-by-case adjudication. However, the debate is ongoing and further decisions are expected. Chapter 5 presents clinically most relevant indications for coronary CT angiography.

2.3 Personnel Requirements

Having well-trained technicians who are knowledgeable in cardiac CT applications is a prerequisite for success (**List 2.3**). It is better to have a limited number of specialized technicians who perform coronary CT angiography than to have all technicians perform this test. On the one hand, having specialized staff members can ensure a consistently high level of image quality, and these experienced technicians can assist in further educating other coworkers about the entire scanning and reconstruction procedure. On the other hand, if more technicians are involved in performing cardiac CT, coronary CT angiography can easily be offered at night; doing so would,

however, also require a physician trained in reading the images. What we consider most helpful in terms of training is to give constant feedback to the technicians about good as well as bad examinations. This approach ensures that a high level of quality is maintained, and small mistakes are prevented from creeping in. Moreover, providing positive feedback about high-quality examinations is very motivating.

List 2.3. Personnel requirements for coronary CT angiography

1. Well-trained and experienced CT technicians
2. Physician knowledgeable in CT and radiation protection
3. Physician knowledgeable in cardiac anatomy and pathophysiology
4. Team focused on quality assurance

There are two major prerequisites for physicians, in addition to good anatomical, technical (incl. radiation issues), and clinical knowledge: (1) a clear understanding of the entire examination procedure, and (2) the ability

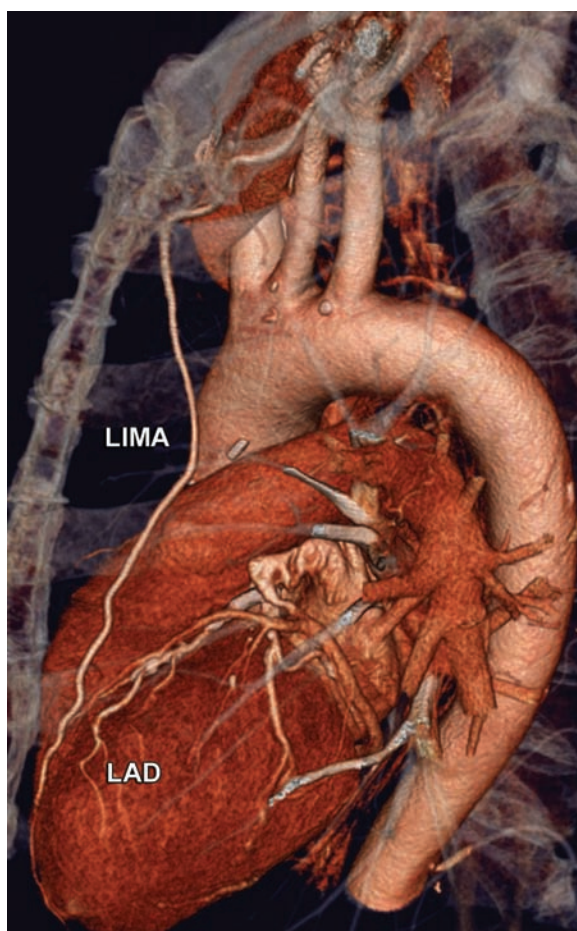


Fig. 2.4 Arterial bypass graft (left internal mammary artery, LIMA), which extends all the way down to the LAD and was scanned in less than 15 s, using a 64-slice CT scanner. With this technology, preoxygenation is no longer necessary for bypass imaging. With 16-slice technology, the scanning took an average of 40–50 s, and preoxygenation was almost always required. Note that CT nicely depicts the distance between the sternum and coronary bypass graft, which can be of relevance if repeat cardiac surgery is considered

to independently interpret three-dimensional coronary CT angiography datasets on workstations.

Chapters 6 and 7 will discuss how to prepare the patient for coronary CT angiography and how to perform the procedure. Being present during examinations is the key to understanding the work of the technicians and the special requirements of cardiac CT. It is also enlightening for physicians to perform examinations themselves, because doing so can yield important insights into the procedural steps and problems that can be encountered

Table 2.1 Typical characteristics of 16 and 64-slice CT scanners

	16-slice	64-slice
<i>Slice collimation</i>		
Coronary arteries	0.5–0.75 mm	0.5–0.75 mm
Coronary bypass grafts	0.5–1.25 mm	0.5–0.75 mm
<i>Gantry rotation time</i>		
Coronary angiography	0.4–0.6 s	0.33–0.6 s
<i>Scan length</i>		
Coronary arteries	9–13 cm	Increase by 15% ^a
Coronary bypass grafts	15–22 cm	Increased by 5 to 10%
<i>Effective radiation dose</i>		
Coronary arteries	5–15 mSv	10–20 mSv ^b
Coronary bypass grafts	10–30 mSv	20–40 mSv
<i>Contrast-to-noise ratio</i>		
Coronary angiography	15–25	Similar
<i>Vessel lengths free of motion</i>		
Coronary angiography		Improved by 10–30% ^c
<i>Breath-hold time</i>		
Coronary arteries	25–30 s	8–12 s
Coronary bypass grafts	40–50 s	12–15 s
<i>Contrast agent amount</i>		
Coronary arteries	90–130 ml	60–90 ml
Coronary bypass grafts	130–160 ml	80–110 ml

^a This increase is due to the larger over-ranging effect of 64-slice CT, which in turn also increases radiation exposure by 15%

^b The increase in effective dose with 64-slice CT can be explained by the larger over-ranging effect, the fact that scanning cannot be stopped as abruptly once the lower border of the heart has been reached because of the faster table speed, and the higher mA settings necessary (because of the increased scattered radiation and noise with 64-slice CT)

^c The increase in the visible vessel length free of motion that can be obtained for the three coronary arteries with 64-slice CT scanners is approximately 10% for the left anterior descending, 20% for the left circumflex, and 30% for the right coronary. Most notably, in more than one-third of all cases, the length of the right coronary free of motion is increased by more than 5 cm when 64-slice CT is used

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during scanning. This hands-on training also strengthens the position of the physician as an educator of other physicians or technicians. In larger centers, it is good to identify two to three doctors who will be considered the primary contacts for cardiac CT imaging for the technicians as well as the referring physicians.

Competence in image interpretation is best achieved by correlating conventional coronary angiograms with CT angiography results. How to read and interpret cardiac CT scans is explained in Chap. 9. To understand and gain skill in using the workstations, physicians should practice operating them without time pressure. The time necessary to feel comfortable with the workstations will depend on an individual's general computer skills, but 2–4 continuous weeks should be sufficient, and attending one of the true hands-on workshops is a good way to begin the learning process. Such workshops should ideally offer direct comparison of CT findings (on interactive workstations) with conventional angiography findings or the results of cardiac stress tests. This is the only way of acquiring a thorough understanding of coronary and cardiac pathology. Good cardiac CT courses also offer active participation in patient preparation and scanning. Nevertheless, the learning curve for centers with early experience has been shown to last at least 6 months.

However, learning does not stop after a few weeks of intensive familiarization with the workstations or a short course: Even in a team of experienced readers, certain coronary lesions will sometimes be misinterpreted (overcalled or even overlooked). Thus, continuous learning

efforts (with comparison of CT to the invasive coronary angiography findings, e.g., in joint interdisciplinary conferences) are necessary to maintain high quality.

There is also a formal accreditation of the physicians' skills and knowledge. The American College of Radiology (ACR) and the American College of Cardiology (ACC) have established guidelines for assessing clinical competence in performing and interpreting cardiac CTs. These guidelines play an increasing role in obtaining certification for coronary CT angiography and claiming reimbursement in the US. Those outside the US may find it useful to study these guidelines as a basis for starting discussions about certification of coronary CT angiography readers and centers in their own countries.

In Germany, for instance, the law requires that every physician performing CT (of any organ) hold the *Fachkunde* ("technical qualification") for CT, which requires having conducted 1,000 examinations over a period of at least 12 months and participating in a course on radiation protection. Such regulations offer promise for increasing radiation safety, and they emphasize the relevance of the ongoing discussion on requirements for coronary CT angiography.

2.3.1 Guidelines of the ACR

Several ACR guidelines are relevant to coronary CT angiography. Most important is the "ACR Practice Guideline for the Performance and Interpretation of

Table 2.2 ACR physician requirements for coronary CT angiography

	Not trained in general or thoracic CT	Board-certified radiologists ^a
CME (category I)	Completion of an ACGME approved training program in the specialty practiced 200 hours in cardiac CT ^b	Training in cardiac CT in an ACGME approved training program 30 h in cardiac anatomy, physiology, pathology, and cardiac CT
Interpretation, reporting, and/or supervised review ^c	500 CT examinations ^d	50 cardiac CT examinations
Maintaining competence	75 contrast-enhanced cardiac CT examinations every 3 years 150 h of CME every 3 years	

ACGME Accreditation Council for Graduate Medical Education

^a In addition, at least 100 CT examinations are required during each of the past 3 years, as also at least 100 CT examinations per year to maintain competence according to the ACR practice guideline for performing and interpreting diagnostic CT

^b Including at least 30 h in cardiac anatomy, physiology, pathology, and cardiac CT

^c Examinations (noncontrast examinations do not count) in a supervised environment during the past 3 years; supervising physician needs to meet the ACR requirements

^d At least 100 must be a combination of thoracic CT or thoracic CT angiography (exclusive of calcium scoring exams). At least 50 contrast-enhanced cardiac CT examinations must also be included

Cardiac Computed Tomography” (http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/dx/cardio/ct_cardiac.aspx). Other important guidelines are the “ACR Clinical Statement on Noninvasive Cardiac Imaging,” “ACR Practice Guideline for the Performance and Interpretation of CT Angiography,” and the “ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography.” Later we briefly outline and discuss the recommendations arising from the guidelines that directly relate to coronary CT angiography.

The ACR defines cardiac CT as a chest CT performed primarily for the evaluation of the heart (including the cardiac chambers, valves, myocardium, aorta, central pulmonary vessels, pericardium, coronary arteries, and veins). However, noncardiac structures are included and must be evaluated by a trained physician. Trained physicians are defined in the “ACR Practice Guideline for Performing and Interpreting Diagnostic Computed Tomography” as board-certified radiologists who have interpreted and reported at least 100 CT examinations over each of the past 3 years and interpret and report at least 100 CT examinations per year to maintain competence. These physicians can achieve competence in the performance and interpretation of coronary CT angiography by at least 30 h of CME in cardiac anatomy, physiology, pathology, and cardiac CT, plus the interpretation, reporting, and/or supervised review of at least 50 cardiac CT examinations during the past

3 years (**Table 2.2**). Physicians who are not defined in this guideline as trained physicians in diagnostic CT can achieve competence in the performance and interpretation of coronary CT angiography by at least 200 h of CME in the performance and interpretation of cardiac CT, plus the interpretation, reporting, and/or supervised review of at least 500 chest CT examinations (including 50 cardiac CT examinations) during the past 3 years (**Table 2.2**). The ACR stresses that all physicians performing cardiac CT need to be knowledgeable about the administration, risks, and contraindications of beta blockers and nitroglycerin.

2.3.2 Guidelines of the ACC

The “ACC Clinical Competence Statement on Cardiac Imaging with Computed Tomography and Magnetic Resonance” (<http://www.acc.org/qualityandscience/clinical/competence/imaging/index.pdf>) states that it is intended to be complementary to the recommendations of the ACR on noninvasive cardiac imaging. Cardiac CT is defined in this guideline as the imaging of anatomy, function, coronary calcium, noncalcified plaque, and congenital heart disease. The guideline defines three levels of competence in coronary CT angiography, of which two are relevant here. Level 2 allows independent performance and interpretation of cardiac CT and requires 8 weeks (each consisting of at least 35 h) of cumulative training in a clinical cardiac CT laboratory plus 150 contrast-enhanced and 50

Table 2.3 ACC physician requirements for coronary CT angiography

	Level 2 ^a	Level 3 ^b
CME (category I)	20 h in cardiac CT	40 h in cardiac CT
Training ^c	8 weeks	6 months
Interpretation, reporting, and/or supervised review	50 noncontrast cardiac CT examinations 150 contrast-enhanced cardiac CT examinations ^d	100 noncontrast cardiac CT examinations 300 contrast-enhanced cardiac CT examinations ^d
Maintaining competence	50 contrast-enhanced cardiac CT examinations every year 20 h of CME in cardiac CT every 3 years	100 contrast-enhanced cardiac CT examinations every year 40 h of CME in cardiac CT every 3 years

^a Allows independent performance and interpretation of cardiac CT

^b Allows serving as a director of an independent cardiac CT center

^c Training must be conducted under the supervision of a level 3 physician. Each week consists of at least 35 h. The time commitment does not go into effect until July 2010

^d Physically present and involved in the acquisition, performance, and interpretation of 50 (level 2) or 100 (level 3) contrast-enhanced cardiac CT examinations. The noncontrast examinations can be performed in the same patients who undergo contrast-enhanced CT

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noncontrast cardiac CT examinations. A physician willing to achieve level 2 competence needs to be physically present and involved in the acquisition and performance of 50 of the 150 contrast-enhanced cardiac CT examinations (**Table 2.3**). Level 3 allows serving as a director of an independent cardiac CT center and requires 6 months of cumulative training in a clinical cardiac CT laboratory plus 300 contrast-enhanced and 100 noncontrast cardiac CT examinations. A physician willing to achieve level 3 competence needs to be physically present and involved in the acquisition and performance of 100 of the 300 contrast-enhanced cardiac CT examinations (**Table 2.3**). An additional recommendation for “Training in Advanced Cardiovascular Imaging (Computed Tomography)” has been released by the ACC. The ACC stresses that all physicians performing cardiac CT need to be knowledgeable about radiation risks and noncardiac findings on coronary CT angiography.

Recommended Reading

- 1 Budoff MJ, Achenbach S, Berman DS, et al. Task force 13: training in advanced cardiovascular imaging (computed tomography) endorsed by the American Society of Nuclear Cardiology, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, and Society of Cardiovascular Computed Tomography. *J Am Coll Cardiol* 2008; 51:409–14
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- 3 Chin S, Ong T, Chan W, et al. 64 row multi-detector computed tomography coronary image from a centre with early experience: first illustration of learning curve. *J Geriatric Cardiology* 2006; 3:29–34
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- 6 Hamon M, Morello R, Riddell JW. Coronary arteries: diagnostic performance of 16 versus 64-section spiral CT compared with invasive coronary angiography—meta-analysis. *Radiology* 2007; 245:720–31
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- 8 Jacobs JE, Box LM, Desjardins B, Fishman EK, Larson PA, Schoepf J. ACR practice guideline for the performance and interpretation of cardiac computed tomography (CT). *J Am Coll Radiol* 2006; 3:677–85
- 9 Pannu HK, Alvarez W, Jr., Fishman EK. Beta-blockers for cardiac CT: a primer for the radiologist. *AJR Am J Roentgenol* 2006; 186: S341–5
- 10 Weinreb JC, Larson PA, Woodard PK, et al. ACR clinical statement on noninvasive cardiac imaging. *J Am Coll Radiol* 2005; 2:471–7

The ACR practice guideline for the performance and interpretation of cardiac CT (Jacobs et al.) can be accessed at:

http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/dx/cardio/ct_cardiac.aspx

The guideline of the ACC (Budoff et al.) can be accessed at:

<http://www.acc.org/qualityandscience/clinical/competence/imaging/index.pdf>

<http://www.escr.org>

<http://www.nasci.org>

<http://www.scct.org>

<http://www.springer.com/978-3-540-79843-9>

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