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

Matthew J. Budoff, Stephan Achenbach, Daniel S. Berman, Zahi A. Fayad, Michael Poon, Allen J. Taylor, Barry F. Uretsky, and Kim Allan Williams

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Matthew J. Budoff, MD, FACC, *Chair*
Stephan Achenbach, MD (*Society of Cardiovascular Computed Tomography Representative*),
Daniel S. Berman, MD, FACC, Zahi A. Fayad, PhD, FACC (*Society of Atherosclerosis Imaging and Prevention Representative*), Michael Poon, MD, FACC, Allen J. Taylor, MD, FACC,
Barry F. Uretsky, MD, FACC (*Society for Cardiovascular Angiography and Interventions Representative*),
Kim Allan Williams, MD, FACC (*American Society of Nuclear Cardiology Representative*)

Computed tomography (CT) is one of the most rapidly evolving techniques for assessing cardiovascular anatomy. The complex nature of the imaging devices and anatomy and the rapidly advancing uses of these modalities require the trainee to be introduced to this modality. Clinical application of CT encompasses noncontrast (coronary calcium evaluation), contrast (CT angiography and function), and hybrid studies (combining nuclear cardiac scanning with CT). Computed tomography, like invasive catheterization, provides information concerning cardiovascular anatomy and function (i.e., ejection fraction). Hybrid devices are rapidly evolving to incorporate state-of-the-art, high-speed multi-detector computed tomography (MDCT) technology, along with the latest positron emission tomography (PET) and single-photon emission computed tomography (SPECT) detector systems. Current hybrid systems (MDCT plus nuclear) provide attenuation correction for SPECT and PET thereby further improving the diagnostic accuracy of more traditional radionuclide techniques.

It should be noted that the guidelines for fellows-in-training outlined here and those for physicians in practice previously published have slightly different targets for time and experience (1). The fellows-in-training are expected to get exposure to CT throughout their training, incorporating the results with echocardiography, nuclear cardiology, cardiovascular magnetic resonance (CMR), and cardiac catheterization when appropriate. Physicians in practice who are first being exposed to cardiovascular computed tomography (CCT) will most likely not have this comprehensive approach. Guidelines for practicing physicians are published by the American College of Cardiology/American Heart Association Task Force on Clinical Competence in Computed Tomography and Magnetic Resonance (2). Fellowship training in CT should include instruction in the basic aspects, but only those fellows who go beyond the basic level are trained sufficiently for independent interpretation of CT studies. Every trainee should be educated in the use of CT and in cardiovascular anatomy, physiology, and pathophysiology, as well as physics of CT and radiation generation and exposure. As many CCT studies are done before and after intravenous administration of iodinated contrast, a thorough understanding of contrast injection methods, adverse events and their treatments, and contrast kinetics in patients will be required. In particular, knowledge is needed in the methods of contrast-enhanced imaging of the pericardium, right ventricle, right atrium, and superior and inferior vena cavae as well as imaging of the left heart, surrounding great vessels, and the central circulation.

By the end of the fellowship, trainees should have been exposed to CCT studies, both in interpretation and performance. It is currently recognized that many programs might not have availability of CCT, and options should be made available to obtain training at a different facility if the primary program cannot accommodate. The trainee should master the relation between the results of the CT examination and findings of other cardiovascular tests, such as catheterization, nuclear cardiology, magnetic resonance, and echocardiography. Every cardiology fellow should be exposed to and be familiar with the technical performance, interpretation, strengths, and limitations of CT and its multiple clinical applications. It is recognized that CT is an evolving technology in a rapid phase of development and improvement, with an expanding list of clinical indications.

For appropriate use of this technology, it is possible to define 3 levels of expertise (Table 1). All cardiology fellows must attain at least the first level of expertise. This entails under-

Table 1 Requirements for CCT Study Performance and Interpretation to Achieve Level 1, 2, and 3 Clinical Competence

	Cumulative Duration of Training	Minimum Number of Mentored Examinations Present During Performance	Minimum Number of Mentored Examinations Interpreted
Level 1	1 month*	—	50†
Level 2	2 months*	35	150 CCT cases†
Level 3	6 months*	100	300 CCT cases†

*This represents cumulative time spent interpreting, performing, and learning about cardiovascular computed tomography (CCT), and need not be a consecutive block of time, but at least 50% of the time should represent supervised laboratory experience. In-lab training time is defined as a minimum of 35 h/week. †The caseload recommendations may include studies from an established teaching file, previous CCT cases, journals and/or textbook, or electronic/on-line courses/continuing medical education.

standing the basic principles, indications, applications, and technical limitations of CT and the interrelation of this technique with other diagnostic methods. This level will not qualify a trainee to perform CT or to interpret CT independently.

Level 2 is defined as the minimum recommended training for a trainee to independently perform and interpret CCT. Level 3 expertise would enable the trainee to direct a CT laboratory.

General Standards

The CT laboratory in which training is undertaken should be under the direct supervision of a full-time qualified director (or directors) who has achieved Level 3 training. Training guidelines in the present document are primarily directed to trainees performing CCT examinations in adult patients with acquired and congenital heart disease. Participation of additional full- or part-time faculty is highly desirable because of the multiple applications of CT (i.e., attenuation correction of nuclear imaging, noncontrast and contrast studies, function, structure, congenital, and vascular imaging). The CCT examination is an operator-dependent procedure in which it is possible to introduce confounding artifacts or omit data of diagnostic importance. Hands-on training is important, not to develop technical expertise in acquiring images, but rather as a valuable aid to learn tomographic cardiac anatomy, integrate planar views into a 3-dimensional framework (nonplanar and oblique/multiplanar imaging), and understand the distinction between reliable and unreliable data. Understanding the source of the artifacts (breath-holding, gating, or arrhythmias) present on the images is vital.

Content of the Training Program

Although numbers of studies and time intervals of training are given as guidelines, these numbers are less important than depth of understanding and quality of the clinical experience. It is recommended that fellows keep a log documenting their involvement in CT studies, as well as their exposure to appropriate continuing medical education hours.

The recommendations for all levels of training in the following text represent a cumulative experience, and it is expected that for many fellows, the training will not be continuous. A summary of the training requirements is given in Table 1. For all Level 2 and Level 3 requirements, the minimum time in a CCT laboratory is 50% of the time listed. The remaining time required can be garnered by supervised time, CT exposure in courses, case studies, CD/DVD training, time at major medical meetings devoted to performance of CCT, or other relevant educational training activities, to name just a few examples. The caseload recommendations may include studies from an established teaching file, previous CCT cases, and electronic/on-line experience or courses.

Description of Cases

Activities that qualify for the 35 cases where the candidate is "physically present and involved in the acquisition and interpretation of the case":

The following 3 elements must be met:

1. Candidate must be present in the scanning suite (or control room) or in the presence of a video feed during CT raw data acquisition and image reconstruction from that raw data.
2. Interactive manipulation of the reconstructed data sets for evaluation of the scan must be performed by the candidate. Individual cases should include all components of cardiac structure and function as well as noncardiac structures as indicated.
3. During this data evaluation process, there must be an opportunity for interaction between the candidate and trainer.

Activities that qualify for the additional 100 cases include:

1. A maximum of 50 cases from an educational CD or presentation granting continuing medical education credit that contains CT data review, clinical information, and appropriate clinical correlative information (e.g., invasive coronary angiographic images).
2. Up to 100 but not less than 50 of the cases must involve interactive manipulation of reconstructed data sets using a workstation or equivalent.

Level 1 Training (1 Month, at Least 50 Examinations Interpreted)

Level 1 is defined as the minimal introductory training for familiarity with CCT, but it is not sufficient for independent interpretation of CCT images. The individual should have intensive exposure to the methods and the multiple applications of CCT for a period of at least 1 month. The time commitment for training is defined as 35 h per week. This should provide a basic background in CCT for the practice of adult cardiology. During this cumulative 4-week experience, individuals should have been actively involved in CCT interpretation under the direction of a qualified (preferably Level 3–trained) physician-mentor (1). There should be a mentored interpretative experience of at least 50 cases for all studies in which other cardiovascular imaging methods are also available, correlation with CCT findings, and interpretation. Mentored interpretive experience may include studies from an established teaching file or previous CCT cases and also includes the potential for CD/DVD and on-line training.

For all levels of competence, it is expected that the candidate will attend lectures on the basic concepts of CCT and include parallel self-study reading material. A basic understanding of CCT should be achieved including: the physics of CCT imaging, the basics of CCT scan performance, safety issues in CCT performance, side effects (and their treatment) of medications used currently including beta blockers and nitrates, post-processing methods, and basics of CCT interpretation as compared with other cardiovascular imaging modalities including echocardiography, nuclear cardiology, CMR, and invasive cardiac and vascular x-ray angiography. Furthermore, auxiliary cardiac diagnostics should include recognition of ventricular hypertrophy, dilation, valve pathologies such as mitral stenosis/annular and leaflet calcification, cardiac masses, aortic valve pathology (number of cusps) and calcification/aortic stenosis, pericardial and infiltrative myocardial disease, internal mammary arteries, left atrial and pulmonary and coronary venous abnormalities, thoracic aortic pathology, and saphenous vein grafts.

Level 2 Training (2 Months of Training and Interpretation of 50 Noncontrast and 150 Contrast Studies Total, 35 of Which the Fellow is Present During Performance)

Level 2 is defined as the minimum recommended training for a physician to independently perform and interpret CCT. To accomplish this, the fellow should devote an additional 1 month, or the equivalent, interpreting a minimum of 150 contrast studies total. The noncontrast and contrast studies may be evaluated in the same patients. Of these, at least 35 cases should be performed with the fellow present under appropriate supervision. Competence at this level implies that the fellow is sufficiently experienced to interpret the CT examination accurately and independently. Continued exposure to special CT procedures, such as hybrid studies with nuclear imaging and integration of images into electrophysiologic procedures, is appropriate during Level 2 training.

Didactic studies should include advanced lectures, reading materials, and formal case presentations. These didactic studies should include information on the sensitivity, specificity, accuracy, utility, costs, advantages, and disadvantages of CCT as compared with other cardiovascular imaging modalities. Each fellow should receive documented training from a CCT mentor and/or physicist on the basic physics of CT in general and on CCT in particular. Lectures will include discussions of anatomy, contrast administration and kinetics, and the principles of 3-dimensional imaging and post-processing. The fellow should also receive training in principles of radiation protection, the hazards of radiation exposure to both patients and CT personnel, and appropriate post-procedure patient monitoring.

A fellow with Level 2 and Level 3 training should demonstrate clear understanding of the various types of CT scanners available for cardiovascular imaging (electron beam tomography and MDCT) and understand, at a minimum, the common issues related to imaging, post-processing, and scan interpretation including:

- Indications and risk factors that might increase the likelihood of adverse reactions to contrast media
- Radiation exposure factors
- CT scan collimation (slice thickness)
- CT scan temporal resolution (scan time per slice)
- Table speed (pitch)
- Field of view
- Window and level view settings
- Algorithms used for reconstruction
- Contrast media
- Presence and cause of artifacts
- Post-processing techniques and image manipulation on work stations
- Total radiation dose to the patient

Incidental Noncardiac Findings

During a CCT examination, the standard use of a small field of view (e.g., limited lung fields) precludes complete evaluation of the entire thorax. However, to address the possibility that significant noncardiac imaging findings, (e.g., aortic disease, hilar adenopathy, large pulmonary nodules, and pulmonary emboli) might be present on a CCT scan, specific interpretation of the extra-cardiac fields should be performed. The patient and the referring physician should understand that the focus of the CCT examination is the detection of cardiac disease, and the scan does not encompass the entire lung field. Regarding the cardiovascular medicine specialist performing CCT, the Task Force recognizes and endorses education and training of such individuals in the recognition of incidental scan findings in support of quality imaging care of patients with cardiovascular disease. These cases require referral to a specialist or a radiologist with expertise in chest imaging. To this end, it is felt that Level 2 and Level 3 training should include the review of all CCT cases for noncardiac findings.

The review of 150 CCT cases for incidental findings should include the review of a dedicated teaching file of 25 CCT cases featuring the presence of significant noncardiac pathology. Furthermore, part of the core curricula for Level 2 and Level 3 should include specific lectures on non-CCT pathology.

Level 3 Training (Total 6 Months of Training, Inclusive of Level 1 and 2, 150 Additional Examinations)

Level 3 training represents the highest level of exposure/expertise that would enable an individual to serve as a director of an academic CCT section or director of an independent CCT facility or clinic. This individual would be directly responsible for quality control and training of technologists and be a mentor to other physicians seeking such training. For a trainee desiring to direct a CT laboratory (Level 3), a total of 6 months of training devoted to CT is required, with an additional 6 months experience which can be obtained concurrently with training in other imaging modalities. To attain Level 3, candidates should be involved with interpretation of at least 100 noncontrast and 300 contrast CCT examinations. For at least 100 of these cases, the candidate must be physically present and be involved in the acquisition and interpretation of the case. At the discretion of the director, increasing independence in interpretation and over-reading of CT studies can be implemented.

In addition to the recommendations for Level 1 and Level 2 training, Level 3 training should include active and ongoing participation in a basic research laboratory, clinical research, or graduate medical teaching. Level 3 training should also include exposure to administrative aspects of running a CT laboratory and documented experience in CT research, as well as understanding of new and evolving CT and nuclear/CT technologies. To complete Level 3, the trainee should fulfill all of the previously described requirements and develop competence in performing and interpreting special procedures, such as hybrid studies and electrophysiologic studies (integration of CT images with fluoroscopic images to provide enhanced visualization for ablation).

Training for Physicians in Practice

It should be recognized how difficult it is to recreate the breadth and intensity of a training fellowship once an individual has assumed the full-time responsibilities of a practice setting. For the practicing physician interested in obtaining equivalent training, please refer to the recent report of the ACC/AHA/American College of Physicians Task Force on Clinical Competence on Computed Tomography and Magnetic Resonance (2).

Vascular CT Imaging

Vascular CT, at this point, represents an optional portion of training. As a cardiovascular specialist, it is expected that the cardiology fellow acquire skills beyond the cardiac structures and coronary tree. It is well established that CT has a high sensitivity and specificity for vascular disease outside the heart. Carotid, renal, and peripheral imaging has been well validated, even prior to MDCT availability. The additional benefits of large volumes of coverage per rotation with the newer MDCT scanners allows for very rapid imaging of the carotid, renal, or peripheral vascular bed, with minimal contrast requirements and great spatial resolution. The lack of motion of these vascular beds makes imaging less difficult for interpretation than coronary evaluation. Furthermore, the acquisition of the images are much easier for peripheral beds, and physics, acquisition parameters, and reconstruction techniques learned during cardiac evaluations are similar for vascular imaging. However, vascular imaging requires additional knowledge of the anatomy, as well as pathophysiology of each vascular bed. For the candidate to achieve Level 2 competence in cardiac and vascular CT, it is recommended that an additional 35 mentored contrast cases be included (over the 150 case requirement for cardiac), specifically targeting peripheral vascular beds. To achieve Level 3 for cardiac and vascular CT, 100 additional mentored vascular cases should be reviewed by the trainee. There is currently no pathway for vascular CT imaging without meeting the Level 2 or Level 3 criteria for CCT outlined in Table 1.

Trainee Evaluation

Even in academic centers, where most trainees are taught, there is currently a failure to provide ideal CCT services to cardiovascular patients. The individual must have knowledge of the specific equipment to be used in each procedure, including x-ray contrast, CCT physics, and radiation exposure. Assessment of technical performance is best done by direct oversight during interpretation of procedures. The competence of all cardiology trainees in CCT should be documented by both the cardiovascular program director and the program director of the CCT laboratory. Records must be maintained of all evaluations and of the number and type of all laboratory procedures performed by each trainee. Numbers of cases that the trainee is involved in, both in the live acquisition of cases, as well as the number of cases the trainee is involved in the interpretation is critical for competence in CCT. The use of examinations (e.g., the Cardiac Computed Tomography Self-Assessment Program [CCTSAP]) at the end of CCT training is strongly encouraged. All procedures performed by the trainee must be documented electronically or in a logbook.

This is an update of the 2006 document that was written by Matthew J. Budoff, MD, FACC—Chair; Stephan Achen-

bach, MD (Society of Cardiovascular Computed Tomography Representative); Zahi A. Fayad, PhD (Society of Atherosclerosis Imaging and Prevention Representative); Daniel S. Berman, MD, FACC; Michael Poon, MD, FACC; Allen J. Taylor, MD, FACC; Barry F. Uretsky, MD, FACC (Society for Cardiovascular Angiography and Interventions Representative); and Kim Allan Williams, MD, FACC (American Society of Nuclear Cardiology Representative).

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2. Budoff MJ, Cohen MC, Garcia M, et al. ACC/AHA clinical competence statement on cardiac imaging with computed tomography and magnetic resonance: a report of the American College of Cardiology/American Heart Association/American College of Physicians Task Force on Clinical Competence (ACC/AHA Committee on Cardiac Tomography). J Am Coll Cardiol 2005;46:383–402.

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APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 13: TRAINING IN ADVANCED CARDIOVASCULAR IMAGING (COMPUTED TOMOGRAPHY)

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Stephan Achenbach	• Bristol-Myers Squibb Imaging	• Siemens	None	• Bracco • Siemens	None	None	None
Dr. Daniel S. Berman	• Tyco-Mallinckrodt	• Astellas • Bristol-Myers Squibb Imaging • GE Healthcare	• Spectrum Dynamics	None	None	• Spectrum Dynamics	• Cedars-Sinai Medical Center—Software royalties
Dr. Matthew J. Budoff	None	None	None	• GE Healthcare	None	None	None
Dr. Zahi A. Fayad	None	None	None	None	None	None	None
Dr. Michael Poon	None	None	• Chase Medical • Siemens • TeraRecon	None	None	None	None
Dr. Allen J. Taylor	None	• Kos Pharmaceuticals	• Pfizer	• Kos Pharmaceuticals	None	None	None
Dr. Barry F. Uretsky	None	None	None	None	None	None	None
Dr. Kim Allan Williams	• King Pharmaceuticals	• Bristol-Myers Squibb Imaging • CV Therapeutics • GE Healthcare	• GE Healthcare	• Astellas • GE Healthcare	None	None	None

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APPENDIX 2. PEER REVIEWER RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 13: TRAINING IN ADVANCED CARDIOVASCULAR IMAGING (COMPUTED TOMOGRAPHY)

Name*	Affiliation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. David J. Clardy	• Official–Board of Governors	None	None	None	None	None	None	None
Dr. Rick A. Nishimura	• Official–Board of Trustees	None	None	None	None	None	None	None
Dr. John J. Mahmarian	• Organizational–American Society of Echocardiography	None	None	None	None	None	None	None
Dr. Mylan C. Cohen	• Organizational–American Society of Nuclear Cardiology	None	None	None	None	None	None	None
Dr. Harvey S. Hecht	• Organizational–Society of Atherosclerosis Imaging and Prevention	None	None	None	None	None	None	None
Dr. Paolo Raggi	• Organizational–Society of Atherosclerosis Imaging and Prevention	None	None	None	None	None	None	None
Dr. Amjad Almahameed	• Organizational–Society for Vascular Medicine	• GlaxoSmithKline	None	None	• Aventis • GlaxoSmithKline • Sanofi	None	• GlaxoSmithKline	None
Dr. Joshua A. Beckman	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. Susan M. Begelman	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. Leonardo C. Clavijo	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. James B. Froehlich	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. Scott Kinlay	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. Emile R. Mohler, III	• Organizational–Society for Vascular Medicine	None	None	None	None	None	None	None
Dr. John E. Brush, Jr.	• Content–Individual Reviewer	None	None	None	None	None	None	None
Dr. Marcello DiCarli	• Content–Individual Reviewer	• Bracco • Bristol-Myers Squibb Imaging • GE Healthcare	• Astellas • Bracco • Bristol-Myers Squibb Imaging • GE Healthcare	• Bracco • Bristol-Myers Squibb Imaging • GE Healthcare	• Astellas • Bracco • GE Healthcare	None	None	None

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