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Task Force 12: Training in Advanced Cardiovascular Imaging (Computed Tomography)

Endorsed by the American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Atherosclerosis Imaging and Prevention, and Society of Cardiovascular Computed Tomography

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Computed tomography (CT) is one of the most rapidly evolving techniques for assessing cardiovascular anatomy. The complex nature of the imaging devices and anatomy as well as the rapidly advancing uses of these modalities requires the trainee to be introduced to this modality. Clinical application of CT encompasses non-contrast (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, and single-photon emission computed tomography (SPECT) detector systems. Current hybrid systems (MDCT plus nuclear) provide attenuation correction for SPECT, 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. The fellows-in-training are expected to gain 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 being exposed to cardiac CT for the first time 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 CT and MR (1). 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 cardiovascular computed tomographic (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 cardiac CT 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, MR, 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 three levels of expertise (Table 1). All cardiology fellows must attain at least the first level of expertise. This entails understanding 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. A third level of 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 preferably achieved Level 3

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†
Level 3	6 months*	100	300†

*This represents cumulative time spent interpreting, performing and learning about 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.

CCT = cardiovascular computed tomography.

training. Training guidelines in the present document are primarily directed to trainees performing cardiac CT 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, non-contrast and contrast studies, function, structure, and congenital). The cardiac CT 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 three-dimensional framework (non-planar 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 the number of studies and time intervals of training are given as guidelines, these numbers are less important than the 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 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 a few examples. The caseload recommendations may include studies from an established teaching file, previous CCT cases, electronic/online experience, or courses.

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

Level 1 is defined as the minimal introductory training for familiarity with CCT, but 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/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 as well as 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 online 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 the basics of CCT interpretation as compared with other cardiovascular imaging modalities including echocardiography, nuclear cardiology, cardiac MR, and invasive cardiac and peripheral X-ray angiography. Furthermore, auxiliary cardiac diagnostics should include recognition of ventricular hypertrophy, dilation, valve pathologies such as mitral stenosis/annular and leaflet calcification, aortic valve pathology (number of cusps), and calcification/aortic stenosis, pericardial disease, internal mammary arteries, and saphenous vein grafts.

Level 2 Training (2 Months of Training and Interpretation of 50 Non-Contrast and 150 Contrast Studies Total, of Which in 35 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 non-contrast 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-lecture 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 three-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 a clear understanding of the various types of CT scanners available for cardiovascular imaging (electron beam tomography and MDCT) and understand, at a minimum, 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 artifact
- Post-processing techniques and image manipulation on work stations
- Total radiation dose to the patient

Incidental Non-Cardiac Findings

During a cardiac CT examination, the standard use of a small field of view (e.g., limited lung fields) precludes a complete evaluation of the entire thorax. However, to address the possibility that significant non-cardiac imaging findings (e.g., aortic disease, hilar adenopathy, large pulmonary nodules, and pulmonary emboli) might be present on a cardiac CT scan, specific interpretation of the extra-cardiac fields should be performed. The patient and the referring physician should understand that the focus of the cardiac CT examination is the detection of cardiac disease, and the scan does not encompass the entire lung field. Regarding the cardiovascular medicine specialist performing a cardiac CT, the American College of Cardiology 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 cardiac CT cases for non-cardiac findings. The review of 150 cardiac CT cases for incidental findings should include the review of a dedicated teaching file of 25 cardiac CT cases featuring the presence of significant non-cardiac pathology. Furthermore, part of the core curricula for Level 2 and Level 3 should include specific lectures on non-cardiac CT pathology.

Level 3 Training (Total 12 Months of Training, Inclusive of Level 1 and Level 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 that can be obtained concurrently with training in other imaging modalities. To attain Level 3, candidates should be involved with interpretation of at least 100 non-contrast 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 overreading 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 American College of Cardiology Foundation/American Heart Association/American College of Physicians Task Force on Clinical Competence on CT and MR (1).

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REFERENCE

1. 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.

APPENDIX 1. Author Relationships With Industry for the ACCF 2006 Update for Training in Adult Cardiovascular Medicine—Task Force 12: Advanced Cardiovascular Imaging (Computed Tomography)

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
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Dr. Marcello DiCarli	None	None	None	None	None	None	None
Dr. Zahi Fayad	None	None	None	None	None	None	None
Dr. Michael Poon	None	None	Chase Medical Siemens TeraRecon, Inc.	None	None	None	None
Dr. Allen J. Taylor	None	Kos Pharm	None	Kos Pharm	None	None	None
Dr. Barry F. Uretsky	None	None	None	None	None	None	None
Dr. Kim Allan Williams	King	GE Healthcare BMS CVT	GE Healthcare	GE Healthcare Astellas	None	None	None

This table represents the relationships of committee members with industry that were reported by the authors as relevant to this topic. It does not necessarily reflect relationships with industry at the time of publication.

APPENDIX 2. External Peer Reviewer Relationships With Industry for the ACCF 2006 Update for Training in Adult Cardiovascular Medicine—Task Force 12: Advanced Cardiovascular Imaging (Computed Tomography)*

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Mazen Abu-Fadel	Content Reviewer–ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None	None	None
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Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
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Dr. Harvey Hecht	Content Reviewer–Individual Review	None	Philips Medical	None	None	None	None	None
Dr. John McB. Hodgson	Organizational Reviewer–Society for Cardiovascular Angiography and Interventions	Volcano	GE Medical	GE Medical	Volcano	None	Technology Solutions Group	None
Dr. Ami E. Iskandrian	Content Reviewer–ACCF Cardiovascular Imaging Committee	CV Therapeutics International Atomic Energy Agency	Astellas Pharma Molecular Insight Corp. GE Medical CV Therapeutics BMS	None	None	None	None	Acusphere Inc.–Blinded Reader
Dr. Spencer King, III	Content Reviewer–ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None	None	None
Dr. Edward T. Martin	Content Reviewer–Individual Review	Guidant	Guidant	Guidant	GE Medical	None	None	None
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Dr. Paolo Raggi	Content Reviewer–Cardiovascular Imaging Committee	None	Pfizer Genzyme	None	Genzyme Astra Zeneca	None	None	None
Dr. Charanjit S. Rihal	Content Reviewer–ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None	None	None
Dr. Thomas L. Rosamond	ACC Official Reviewer–Board of Governors	None	None	None	None	None	None	None

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APPENDIX 2. Continued

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
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Dr. John A. Rumberger	Content Reviewer—Individual Review	None	None	None	None	None	None	None
Dr. Robert Schwartz	Organizational Reviewer—Society for Cardiovascular Angiography and Interventions	None	None	None	None	None	None	None

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