

ACCF 2006 Update for Training in Adult Cardiovascular Medicine (Focused Update of the 2002 COCATS 2 Training Statement)

A Report of the American College of Cardiology Foundation/
American Heart Association/American College of Physicians
Task Force on Clinical Competence and Training

AUTHORS (AND SOCIETY REPRESENTATIONS)

Introduction/Steering Committee Co-Chairs

George A. Beller, MD, MACC
Robert O. Bonow, MD, FACC
Valentin Fuster, MD, PhD, FACC

Task Force 5: Training in Nuclear Cardiology

Manuel D. Cerqueira, MD, FACC, *Chair*
Daniel S. Berman, MD, FACC
Marcelo F. Di Carli, MD, FACC
Heinrich R. Schelbert, MD, PhD, FACC
Frans J. Th. Wackers, MD, PhD, FACC
Kim Allan Williams, MD, FACC (*American Society
of Nuclear Cardiology Representative*)

Task Force 6: Training in Specialized Electrophysiology, Cardiac Pacing, and Arrhythmia Management

Gerald V. Naccarelli, MD, FACC, *Chair*
Jamie B. Conti, MD, FACC
John P. DiMarco, MD, PhD, FACC
Cynthia M. Tracy, MD, FACC (*Heart Rhythm
Society Representative*)

Task Force 12: Training in Advanced Cardiovascular Imaging (Cardiovascular Magnetic Resonance [CMR])

Gerald M. Pohost, MD, FACC, *Chair*
Raymond J. Kim, MD, FACC
Christopher M. Kramer, MD, FACC
Warren J. Manning, MD, FACC (*Society for
Cardiovascular Magnetic Resonance Representative*)

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

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

TASK FORCE MEMBERS

Mark A. Creager, MD, FACC, FAHA, *Chair*

Geno Merli, MD, FACP
George P. Rodgers, MD, FACC, FAHA
John D. Rutherford, MD, FACC, FAHA

Cynthia M. Tracy, MD, FACC
Howard H. Weitz, MD, FACC, FACP

This document was approved by the American College of Cardiology Foundation Board of Trustees in January 2006.

When citing this document, the American College of Cardiology would appreciate the following citation format: Beller GA, Bonow RO, Fuster V. ACCF 2006 Update for Training in Adult Cardiovascular Medicine (Focused Update of the 2002 COCATS 2 Training Statement): a report of the American College of Cardiology/American Heart Association/American College of Physicians Task Force on Clinical Competence and Training. *J Am Coll Cardiol* 2006;47:893-920.

Copies: This document is available on the American College of Cardiology website at www.acc.org. Single copies of this document may be purchased for \$10.00 each by calling 1-800-253-4636 or by writing to the American College of Cardiology, Resource Center, 9111 Old Georgetown Road, Bethesda, Maryland 20814-1699.

Permissions: Multiple copies, modification, alteration, enhancement, and/or distribution of this document are not permitted without the express permission of the American College of Cardiology Foundation. Please direct requests to copyright_permissions@acc.org.

Introduction

George A. Beller, MD, MACC, *Co-Chair*
Robert O. Bonow, MD, FACC, *Co-Chair*
Valentin Fuster, MD, PhD, FACC, *Co-Chair*

In 1995, guidelines for training in adult cardiovascular medicine were published as an outgrowth of a consensus statement emanating from the Core Cardiology Training Symposium (COCATS) held at Heart House, Bethesda, Maryland, June 27 to 28, 1994 (1). Since publication of the proceedings of that consensus conference, the term "COCATS" has been used when referring to the American College of Cardiology (ACC) training guidelines for fellowship programs. The first COCATS document was published in 1995, followed by a revised document published in 2002 (2).

The 2002 revision (2) was accomplished by the formation of task forces that included representatives from the subspecialty societies where appropriate. These task forces reviewed the 1995 COCATS task force reports and made revisions, additions, and deletions based on data from the literature and their expert opinion. Major changes were most often related to maturing of either new subspecialty areas in cardiology or the emergence of new technology into accepted practice. Numbers of procedures to be performed, interpreted, or both were made consistent with volume recommendations found in the ACC/American Heart Association (AHA) practice guidelines, ACC/AHA/American College of Physicians (ACP) clinical competence statements, or other relevant consensus documents.

In 2005, with further emerging technologies and the need for training, it was deemed necessary to provide additional revisions to three of the task force reports and introduce a new report on training in cardiac computed tomography. The three task force reports in this document were peer reviewed by the following ACCF committees: Clinical Electrophysiology Committee (Task Force 6); Cardiovascular Imaging Committee (Task Force 12); and the Cardiac Catheterization and Intervention Committee (Task Force 12 [CT]), as well as five members of the ACC Board of Governors. Several organizations also reviewed the document including the American Society of Nuclear Cardiology (Task Forces 5 and 12 [computed tomography (CT)]), Heart Rhythm Society (Task Force 6), Society for Cardiovascular Magnetic Resonance (Task Force 12 [magnetic resonance]), and the Society for Cardiovascular Angiography and Interventions, Society of Atherosclerosis Imaging and Prevention (SAIP), and Society of Cardiovascular Computed Tomography (Task Force 12 [CT]). Organizational endorsements are noted on each Task Force report.

Task Force 5 revised the nuclear cardiology training report, which now identifies the need for both didactic learning and clinical application of hybrid systems including single-photon emission CT/CT and positron emission tomography/CT. The

CT component can be utilized for attenuation correction of radionuclide uptake as well as for specific stand-alone imaging of coronary calcification for atherosclerosis detection and CT angiography. The latter application presently employs a separate 16- or 64-slice CT scanner (see Task Force 12). The minimal number of months of training for Level 1, Level 2, and Level 3 categories remains at 2, 4, and 12 months, respectively. Education in radiation safety requires a minimum of 80 h and must be clearly documented. For Level 2 training, a total of 300 cases should be interpreted under preceptor supervision from direct patient studies. In this revised task force report, guidelines for the radiation safety curriculum that meets Nuclear Regulatory Commission requirements or the equivalent agreement state requirements are outlined in detail. General and specialized training in positron emission tomography imaging are clearly described in this section, as is training with hybrid CT imaging technology, including the physics of hybrid systems, CT attenuation correction, principles and application of CT coronary calcium assessment, and principles and application of CT coronary angiography.

Task Force 6 revisions on training in specialized electrophysiology, cardiac pacing, and arrhythmia management are included in this interim COCATS report. The field of clinical cardiac electrophysiology has experienced major advances in recent years, and such progress is now reflected in these updated training recommendations. The guidelines for use of implantable pacemakers and implantable cardioverter-defibrillators (ICDs) have significantly expanded since 2002, as have interventional ablation techniques as for atrial fibrillation.

The expanded indications for these devices or technology have necessitated concomitant revisions for training of physicians in the subspecialty of electrophysiology, which are reflected in this revised task force report. The minimum number of months for Level 1, Level 2, and Level 3 training in cardiac electrophysiology are 2, 6, and 12 months of training, with the latter requiring a full fourth year of fellowship. Level 2 training now also emphasizes acquisition of skills and experience for managing patients with biventricular pacing and ICD systems. In addition to completing Level 1 and Level 2 training, Level 3 training requires that trainees perform at least 150 electrophysiologic procedures and be a primary operator and analyze 100 to 150 diagnostic studies, of which 50 to 75 involve patients with supraventricular arrhythmias. Training guidelines for gaining additional expertise in atrial fibrillation ablation are expanded to include exposure to imaging technologies used to define intracardiac anatomy. A detailed description of how Level 2 and Level 3 trainees can acquire training in the surgical

aspects of device implantation are provided, as are guidelines for becoming proficient in implantation and follow-up of ICD and biventricular pacing systems. Numbers of procedures as a primary operator for these technologies are given.

The revised report “Task Force 12: Training in Advanced Cardiovascular Imaging” has been expanded to now include a new section on training in CT. This accompanies revised training guidelines in cardiovascular magnetic resonance (CMR). Both of these imaging technologies have been characterized by significant progress in the past 4 years since the last COCATS training guidelines were published. Level 2 training for gaining familiarity with cardiac CT is designated for 4 weeks, and Level 2 training is divided into 4 weeks for non-contrast CT procedures and 8 weeks for procedures using contrast. For Level 3 training, 6 months are recommended. This represents cumulative time spent interpreting, performing, and learning about cardiac CT, and need not be a consecutive block of time. The minimum numbers of mentored examinations where the trainee is present during performance of the procedures, and when interpretation only is required, are provided for all three levels of clinical training for competency. A curriculum for didactic teaching in CT is also outlined.

The other section of Task Force 12 includes expanded guidelines for training in CMR. For such training, Level 1, Level 2, and Level 3 require minimal times of 1, 3, and 12 months, respectively. As with cardiac CT, the number of mentored CMR examinations for all levels of training is provided. For Level 2 training, 150 or more mentored interpretations with 50 as a primary interpreter (and operator, if possible) are recommended, whereas for Level 1 training, at least 50 mentored interpretations are required. As with other task force reports, a list of didactic activities in the CMR task force report is clearly defined. As with the original document (1), in these revised training guidelines, fellow and trainee are used interchangeably, as are cardiovascular medicine and cardiology. Although numbers of procedures that should be completed to achieve levels of training are provided, the mere accomplishment of such numbers of procedures is not synonymous with excellence in their performance and interpretation. It is vital to the excellence of a training program that dedicated faculty members be available to supervise and critique performance and interpretation of procedures.

Throughout these task force reports, training is suggested at three levels:

Level 1—Basic training required of all trainees to be competent consultant cardiologists.

Level 2—Additional training in one or more specialized areas that enables the cardiologist to perform or interpret (or both) specific procedures at an intermediate skill level or engage in rendering cardiovascular care in specialized areas.

Level 3—Advanced training in a specialized area that enables a cardiologist to perform, interpret, and train others to perform and interpret specific procedures at a high skill level.

The ever-expanding knowledge base in basic cardiovascular science and cardiovascular medicine requires that all training programs have a rich assortment of didactic offerings for fellows. Case-based conferences, such as the traditional catheterization laboratory conference, are vital to train fellows and to develop their skills in evidence-based decision-making. Self-learning needs to be emphasized, and internet-based, on-line educational programs, many of which are interactive, will play a greater role in a fellow's overall learning experience during fellowship and after training. Such didactic activities are outlined throughout the task force reports.

The ACCF/AHA/ACP Task Force makes every effort to avoid any actual or potential conflicts of interest that might arise as a result of an outside relationship or a personal interest of a member of its writing committees. Specifically, all members of a writing committee are asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest relevant to the document topic. These changes are reviewed by the Writing Committee and updated as changes occur. The relationships with industry information for authors and peer reviewers are published in the appendices of each Task Force report.

Please view the 2002 COCATS report at <http://www.acc.org/clinical/training/cocats2.pdf> to review the ACCF's current policy for training requirements on content areas not contained in this 2006 focused update.

REFERENCES

1. COCATS Guidelines. Guidelines for Training in Adult Cardiovascular Medicine, Core Cardiology Training Symposium. June 27–28, 1994. American College of Cardiology. *J Am Coll Cardiol* 1995;25:1–34.
2. Beller GA, Bonow RO, Fuster V, et al. ACC Revised Recommendations for Training in Adult Cardiovascular Medicine Core Cardiology Training II (COCATS 2) (Revision of the 1995 COCATS Training Statement). 2002. American College of Cardiology Website. Available at: <http://www.acc.org/clinical/training/cocats2.pdf>. Accessed January 9, 2006.

APPENDIX 1

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (Months)	Minimal Cumulative Number of Cases	
1	Clinical cardiology	1		36		
2	Electrocardiography	1	500 to 3500*†		3500	
		2			greater than 3500	
	Ambulatory monitoring	1	150*	150		
		2	75	225		
		2	100	300		
3	Diagnostic catheterization	1	100	4	100	
		2	200	8	300	
4	Interventional catheterization	3	250	20	550	
		Echocardiography	1	150	3	150
			2	150	6	300
3		3	450	12	750	
5	Nuclear cardiology	1	80 h	2	80 h	
		2	300 cases	4 to 6	300+ cases	
		3	600 cases	12	600+ cases	
6	Electrophysiology, pacing, and arrhythmias	1	20	2	10 temporary pacemakers	
		2	100	6	10 DC cardioversions	
		3	300	24	100 pacemaker interrogation/reprogramming 150+ EP cases 75 ablations 75+ pacemaker/ICDs	
7	Research	1		6 to 12‡		
		2		24		
		3		24 to 36		
8	Heart failure and transplantation	1		1‡		
		2		6		
		3		12		
9	Congenital heart disease	1		Core lectures‡	40 catheterizations	
		2		12	300 TTE cases	
		3		24	50 TEE cases	
	Preventive cardiology	1		1‡		
		2		6 to 12		
		3		12		
11	Vascular medicine and peripheral catheter-based intervention	1		2*		
		2		14¶	400+ noninvasive cases#	
		3		20**	160+ cases‡‡	
		3		34††		
12	Advanced cardiovascular imaging—cardiovascular magnetic resonance	1		1§	50 cases	
		2		3 to 6	150 cases	
		3		12	300 cases	
12	Advanced cardiovascular imaging—computed tomography	1		1§	50 cases	
		2		2	150 cases	
		3		6	300 cases	

*Can be taken throughout the training program. †The committee strongly recommends that cardiologists achieve Level 2 training in electrocardiographic interpretation. ‡Can be taken as part of 9 months of required nonlaboratory clinical practice rotation. §Can be taken as part of 6 months of noninvasive imaging rotation. ||It is assumed that trainees will obtain additional training in heart failure and preventive cardiology beyond the 1-month core training as part of the experience during other clinical months, such as consult services and cardiac care unit. ¶2 months of vascular medicine as defined by Level 1, plus 12 months of Level 2 training. Level 2 training is not a prerequisite for Level 3 training but is intended for individuals who want to become a vascular medicine specialist. #In addition, observing 25 peripheral angiograms and 25 peripheral interventions. **Including 2 months of vascular medicine training as defined by Level 1, 8 months of diagnostic catheterization training, and 12 months of interventional lab training. Interventional training for Level 3 requires a 4th year. The 12 months of Level 2 training are not required for this interventional training year. ††Including 2 months of Level 1 and 12 months of Level 2 vascular medicine training, 8 months of diagnostic catheterization training, and 12 months of interventional lab training. ‡‡Including 100 diagnostic peripheral angiograms, 50 peripheral interventions, and 10 thrombolysis/thrombectomies.

DC = direct current; EP = electrophysiologic; ICD = implantable cardioverter-defibrillator; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

APPENDIX 2. Cochair Relationships With Industry for the ACCF 2006 Update for Training in Adult Cardiovascular Medicine—Introduction

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. George A. Beller	None	BMS Medical Imaging GE Healthcare	BMS Medical Imaging GE Healthcare Vasomedical Corp.	None	None	None	None
Dr. Robert O. Bonow	None	None	None	None	None	None	None
Dr. Valentin Fuster	Glaxo SmithKline	None	Vasogen Kereos	None	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.

TASK FORCES

Task Force 5: Training in Nuclear Cardiology

Endorsed by the American Society of Nuclear Cardiology

Manuel D. Cerqueira, MD, FACC, *Chair*

Daniel S. Berman, MD, FACC, Marcelo F. Di Carli, MD, FACC,

Heinrich R. Schelbert, MD, PhD, FACC, Frans J. Th. Wackers, MD, PhD, FACC,

Kim Allan Williams, MD, FACC (*American Society of Nuclear Cardiology Representative*)

The recommendations of this Joint Task Force, made up of representatives of the American College of Cardiology Foundation (ACCF) and the American Society of Nuclear Cardiology (ASNC), have been approved by the governing bodies of the ACCF and the ASNC in January 2006.

TRAINING IN NUCLEAR CARDIOLOGY

Nuclear cardiology (Table 1) provides important diagnostic and prognostic information that is an essential part of the knowledge base required of the well-trained cardiologist for optimal management of the cardiovascular patient. Training of fellows in nuclear cardiology is divided into three levels:¹

- General (Level 1, 2 months): makes trainee conversant with the field of nuclear cardiology for application in general clinical management of cardiovascular patients.
- Specialized (Level 2, 4 to 6 months): provides trainee with special expertise to practice clinical nuclear cardiology.
- Advanced (Level 3, 1 year): provides advanced training sufficient to pursue an academic career or direct a nuclear cardiology laboratory.

General Cardiology Training Background

To have an adequate understanding of the clinical applications of nuclear cardiology and to perform tests safely, the cardiology trainee must acquire knowledge and proficiency in the following areas of general cardiology:

1. Coronary angiography and physiology
2. Cardiac physiology and pathophysiology
3. Rest and exercise electrocardiography
4. Exercise physiology
5. Pharmacology of standard cardiovascular drugs
6. Cardiopulmonary resuscitation and treatment of other cardiac emergencies
7. Pharmacology and physiology of commonly used stress agents, such as dipyridamole, adenosine, and dobutamine
8. Clinical outcomes assessment

¹The issues of ongoing clinical competence and training or retraining of practicing cardiologists are beyond the scope of this document. The Certification Board of Nuclear Cardiology (CBNC) was established jointly by the ACC and ASNC and assesses knowledge and mastery in the areas of radiation safety and the technical and clinical performance of nuclear cardiology procedures. For additional information, contact CBNC at 19562 Club House Road, Montgomery Village, Maryland 20886. <http://www.cbnc.org>.

Overview of Nuclear Cardiology Training

Training in nuclear cardiology at all levels should provide an understanding of the indications for specific nuclear cardiology tests, the safe use of radionuclides, basics of instrumentation and image processing, methods of quality control, image interpretation, integration of risk factors, clinical symptoms, and stress testing, and the appropriate application of the resultant diagnostic information for clinical management. The depth of understanding will vary with each of the three levels of training. Training in nuclear cardiology is best acquired in Accreditation Council for Graduate Medical Education (ACGME) approved training programs in cardiology, nuclear medicine, or radiology. An exception to this ACGME requirement is the didactic and laboratory training in radiation safety and radioisotope handling that may be provided by qualified physicians/scientists in a non-ACGME program when such a program is not available as part of the clinical ACGME training program.

Nuclear cardiology training consists of the components shown in Table 2. Didactic, clinical case experience, and hands-on training hours require documentation in a log-book, having the trainee's name appear on the clinical report, or having some other specific record. The hours need to be monitored and verified by the nuclear cardiology training preceptor. For the advanced trainee, specialized training and research can be derived as part of an established program in either cardiology or a division of nuclear medicine. The person(s) responsible for the didactic, clinical, and hands-on training and experience are responsible for evaluating the competence of the trainee in nuclear cardiology upon completion of the program. This can be accomplished by observing the daily performance of the fellow, a formal testing procedure, or both. The preceptor for specialized or advanced training should have Level 3 (or the equivalent) training in nuclear cardiology.

Didactic Program

Lectures and self-study. This component is composed of lectures on the basic aspects of nuclear cardiology and parallel self-study material consisting of reading and viewing cases on video or CD. The lectures and reading should provide the fellow with an understanding of the clinical

Table 1. Classification of Nuclear Cardiology Procedures

1. Standard nuclear cardiology procedures
 - a. Myocardial perfusion imaging
 - i. SPECT with technetium-99m agents and thallium-201
 - ii. PET with rubidium-82 and nitrogen-13 ammonia
 - iii. Planar with technetium-99m agents and thallium-201
 - iv. ECG gating of perfusion images for assessment of global and regional ventricular function
 - v. Imaging protocols
 - vi. Stress protocols
 1. Exercise stress
 2. Pharmacologic stress
 - vii. Viability assessment including reinjection and delayed imaging of thallium-201 and metabolic imaging where available
 - b. Equilibrium gated blood pool or “first pass” radionuclide angiography at rest and during exercise or pharmacologic stress
 - c. Qualitative and quantitative methods of image display and analysis
2. Less commonly used nuclear cardiology procedures
 - a. Combined myocardial perfusion imaging with cardiac CT
 - b. Metabolic imaging using single-photon and/or positron-emitting radionuclides
 - c. Myocardial infarct imaging
 - d. Cardiac shunt studies

CT = computed tomography; ECG = electrocardiographic; PET = positron emission tomography; SPECT = single-photon emission computed tomography.

applications of nuclear cardiology, including imaging with positron-emitting radionuclides and computed tomography (CT) hybrid systems including single-photon emission computed tomography (SPECT)/CT and positron emission tomography (PET)/CT. The material covered should include radiopharmaceuticals, radiation physics instrumentation, nuclear cardiology diagnostic tests, and procedures/protocols, general cardiology as it relates to image interpretation, risk stratification, myocardial perfusion imaging, ventricular function imaging, and assessment of myocardial viability. Specificity, sensitivity, diagnostic accuracy, utility in assessing prognoses and interventions, costs, indications, and pitfalls in interpretation and clinical application must be emphasized for each patient subset.

This program may be scheduled over a 12- to 24-month period, concurrent with other fellowship assignments. Some of the information can be effectively transmitted as part of a weekly non-invasive or invasive cardiology conference with presentation and discussion of nuclear cardiology image data.

Radiation safety. The second component of the didactic program should provide the fellow with an understanding of radiation safety as it relates to patient selection and administration of radiopharmaceuticals and utilization of CT systems. Fellows seeking Level 2 or Level 3 training will require greater in-depth knowledge as well as hands-on practical experience. These are detailed for each level.

Interpretation of Clinical Cases

During training, fellows should actively participate in daily nuclear cardiology study interpretation under the direction of a qualified preceptor in nuclear cardiology. For all studies

in which angiographic or hemodynamic data are available, such information should be correlated with the nuclear cardiology studies. Although experience in all aspects of nuclear cardiology is recommended, some procedures may not be available—or may be performed in low volume—in some training programs. Under such circumstances, an adequate background for general fellowship training can be satisfied with appropriate reading or review of case files. Training in nuclear cardiology needs to include extensive experience with the standard nuclear cardiology procedures and as much exposure as possible to the less commonly performed procedures. The training program needs to provide a teaching file consisting of perfusion and ventricular function studies with angiographic documentation of disease.

Hands-On Experience

Clinical cases. Fellows should have hands-on supervised experience in an appropriate number of the standard procedures (e.g., myocardial perfusion imaging and radionuclide angiography) and as many of the less commonly performed procedures as possible. Such experience should include pretest patient evaluation; radiopharmaceutical preparation—measuring the dose, administration, and experience with relevant radionuclide generators; operation and quality control of planar and SPECT gamma camera and CT systems; setup of the imaging computer; utilization of electrocardiogram (ECG) gating; performing treadmill, bicycle, and pharmacologic stress testing techniques; processing the data for display; interpreting the study; and generating a clinical report. Complete nuclear cardiology studies should be performed under the supervision of qualified personnel.

Radiation safety. Fellows need to be familiar with radiation biology and the regulations governing the use of radioactive materials and ionizing radiation for performing diagnostic nuclear cardiology and hybrid CT studies. This knowledge includes details for protecting patients, the public, and the user from the effects of radiation.

GENERAL TRAINING— LEVEL 1 (MINIMUM OF 2 MONTHS)

The trainee is exposed to the fundamentals of nuclear cardiology for a minimum period of 2 months during training. This 2-month experience provides familiarity with nuclear cardiology technology and its clinical applications in the general clinical practice of adult cardiology, but it is not sufficient for the specific practice of nuclear cardiology. The

Table 2. Nuclear Cardiology Training Components

1. Didactic program
 - a. Lectures and self-study
 - b. Radiation safety
2. Interpretation of clinical cases
3. Hands-on experience
 - a. Clinical cases
 - b. Radiation safety

three components of training include a didactic program that includes lectures, self-study, radiation safety and regulations, interpretation of nuclear cardiology studies, and hands-on experience.

Didactic Program

Lectures and self-study. This component consists of lectures on the basic aspects of nuclear cardiology and parallel self-study material consisting of reading and viewing case files. The material presented should integrate the role of nuclear cardiology into total patient management. Such information can be included within a weekly non-invasive or invasive cardiology conference, with presentation and discussion of nuclear cardiology image data as part of diagnostic and therapeutic management.

Knowledge and appreciation of radiation safety. The didactic program should include reading and practical experience with the effects of radiation and provide the fellow with an understanding of radiation safety as it relates to patient selection and administration of radiopharmaceuticals and utilization of CT systems.

Interpretation of Nuclear Cardiology Studies

During the 2-month rotation, fellows should actively participate in daily nuclear cardiology study interpretation (minimum of 80 h). Experience in all the areas listed in Table 1 is recommended. If some procedures are not available or are performed in low volume, an adequate background for general fellowship training can be satisfied by appropriate reading or review of case files. The teaching file should consist of perfusion and ventricular function studies with angiographic/cardiac catheterization documentation of disease.

Hands-On Experience

Fellows should perform complete nuclear cardiology studies alongside a qualified technologist or other qualified laboratory personnel. They should, under supervision, observe and participate in a large number of the standard procedures and as many of the less commonly performed procedures as possible. Fellows should have experience in the practical aspects of radiation safety associated with performing clinical patient studies.

SPECIALIZED TRAINING— LEVEL 2 (MINIMUM OF 4 MONTHS)

Fellows who wish to practice the specialty of nuclear cardiology are required to have at least 4 months of training. This includes a minimum of 700 h of didactic, clinical study interpretation and hands-on clinical case and radiation safety training in nuclear cardiology. In training programs with a high volume of procedures, clinical experience may be acquired in as short a period as 4 months. In programs with a lower volume of procedures, a total of six months of clinical experience will be necessary to achieve Level 2 competency. The additional

training required of Level 2 trainees is to enhance their clinical skills and qualify them to become authorized users of radioactive materials in accordance with the regulations of the Nuclear Regulatory Commission (NRC) and/or the agreement states.²

Didactic Program

Lectures and self-study. The didactic training should include in-depth details of all aspects of the procedures listed in Table 1. This program may be scheduled over a 12- to 24-month period concurrent and integrated with other fellowship assignments.

Radiation safety. Classroom and laboratory training need to include extensive review of radiation physics and instrumentation, radiation protection, mathematics pertaining to the use and measurement of radioactivity, chemistry of byproduct material for medical use, radiation biology, the effects of ionizing radiation and radiopharmaceuticals. There should be a thorough review of regulations dealing with radiation safety for the use of radiopharmaceuticals and ionizing radiation. This experience should total a minimum of 80 h and be clearly documented.

Interpretation of Clinical Cases

Fellows should participate in the interpretation of all nuclear cardiology imaging data for the 4- to 6-month training period. It is imperative that the fellows have experience in correlating catheterization or CT angiographic data with radionuclide-derived data for a minimum of 30 patients. A teaching conference in which the fellow presents the clinical material and nuclear cardiology results is an appropriate forum for such an experience. A total of 300 cases should be interpreted under preceptor supervision from direct patient studies (Table 3).

Hands-On Experience

Clinical cases. Fellows acquiring Level 2 training should have hands-on supervised experience with a minimum of 35 patients: 25 patients with myocardial perfusion imaging and 10 patients with radionuclide angiography. Such experience

²Level 2 and Level 3 training meet eligibility criteria for taking the Certification Board of Nuclear Cardiology examination and NRC training and experience requirements to become an authorized user. The NRC establishes federal policy with regard to the medical use of nuclear reactor byproduct materials. Currently, there are 33 states that have applied and been approved by the NRC to self-regulate the use of radioactive materials, so-called "agreement states." The other 19 states are regulated by the federal policy. There is variation within the agreement states in the training and experience requirements for physicians applying to become authorized users of radioactive materials for diagnostic testing. The NRC requires only that the agreement state requirements be as stringent as the federal NRC policy, but states have the authority to make the requirements more stringent. Some states require a greater number of total hours for the didactic, classroom, and laboratory experience in radiation safety. Other states have restricted the acceptable programs or institutions where such training hours may be acquired. Given this variability in training and experience requirements within the U.S., trainees are advised to contact the NRC and the agreement states where they may seek to become authorized users of radioactive materials for the current rules and requirements. For details contact the agreement states' homepage at <http://www.hsrdr.org/nrc/home.html>. Click on directory and then click on directory of agreement states and non-agreement state directors and state liaison officers. This will provide information on contacting the individual states and getting the specific licensure requirements.

should include pre-test patient evaluation, radiopharmaceutical preparation (including experience with relevant radionuclide generators and CT systems), performance of the study, administration of the dosage, calibration, and setup of the gamma camera and CT system, setup of the imaging computer, processing the data for display, interpretation of the studies, and generating clinical reports.

Radiation safety work experience. This experience should be acquired continuously during training in the clinical environment where radioactive materials are being used and under the supervision of an authorized user who meets the NRC requirements of Part 35.290 or Part 35.290(c)(ii)(G) and Part 35.390 or the equivalent agreement state requirements, and must include:

- a. Ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;
- b. Performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;
- c. Calculating, measuring, and safely preparing patient or human research subject dosages;
- d. Using administrative controls to prevent a medical event involving the use of unsealed byproduct material;
- e. Using procedures to safely contain spilled radioactive material and using proper decontamination procedures;
- f. Administering dosages of radioactive material to patients or human research subjects; and
- g. Eluting generator systems appropriate for preparation of radioactive drugs for imaging and localization studies, measuring and testing the eluate for radionuclide purity, and processing the eluate with reagent kits to prepare labeled radioactive drugs.

Additional Experience

The training program for Level 2 must also provide experience in computer methods for analysis. This should include perfusion and functional data derived from thallium or technetium agents and ejection fraction and regional wall motion measurements from radionuclide angiographic studies.

(ADVANCED TRAINING— LEVEL 3 MINIMUM OF 1 YEAR)

For fellows planning an academic career in nuclear cardiology or a career directing a clinical nuclear cardiology laboratory, an extended program is required. This may be part of the standard three-year cardiology fellowship. In addition to the recommended program for Level 2, the Level 3 program should include advanced quality control of nuclear cardiology studies and active participation and responsibility in ongoing laboratory or clinical research. In parallel with participation in a research program, the trainee should participate in clinical imaging activities for the total training period of 12 months, to include supervised interpretative experience in a minimum of 600 cases. Hands-on experience should be similar to, or greater than, that

required for Level 2 training. The fellow should be trained in most of the following areas:

Qualitative interpretation of standard nuclear cardiology studies, including myocardial perfusion imaging, ECG-gated perfusion studies, gated equilibrium studies, “first-pass,” and any of the less commonly performed procedures available at the institution

- Quantitative analysis of perfusion and/or metabolic studies
- Quantitative radionuclide angiographic and gated perfusion analyses, including measurement of global and regional ventricular function
- SPECT perfusion acquisition, reconstruction, and display
- ECG-gated SPECT perfusion acquisition, analysis, and display of functional data
- Imaging of positron-emitting tracers using either dedicated PET systems or SPECT-like systems equipped with either high-energy photon collimators or coincidence detection

The requirements for Level 1 to 3 training in nuclear cardiology are summarized in [Table 3](#).

Specific Training in Cardiac Imaging of Positron-Emitting Radionuclides

Cardiac PET and PET/CT imaging of positron-emitting radionuclides are part of nuclear cardiology. For institutions that have positron imaging devices, training guidelines are appropriate. Training in this particular imaging technology should go hand-in-hand and may be concurrent with training in conventional nuclear cardiology. Such training should include those aspects that are unique or specific to the imaging of positron-emitting radionuclides. Depending on the desired level of expertise, training in cardiac PET and imaging with positron-emitting radionuclides should include knowledge of substrate metabolism in the normal and diseased heart; knowledge of positron-emitting tracers for blood flow, metabolism and neuronal activity, medical cyclotrons, radioisotope production, and radiotracer synthesis; and principles of tracer kinetics and their in vivo application for the non-invasive measurements of regional metabolic and functional processes. The training should also include the physics of positron decay, aspects of imaging instrumentation specific to imaging of positron emitters and the use of CT, production of radiopharmaceutical agents, quality control, handling of ultrashort life radioisotopes, appropriate radiation protection, and safety and regulatory aspects.

Table 3. Summary of Training Requirements for Nuclear Cardiology

Level	Minimum Duration of Training	Total No. of Examinations
1	2 months	80 h interpretative experience
2	4–6 months	300*
3	12 months	600*

*A minimum of 35 cases with hands-on experience must be performed and interpreted under supervision.

Consistent with the training guidelines for general nuclear cardiology, training should be divided into three classes.

GENERAL TRAINING (2 MONTHS)

This level is for cardiology fellows who are associated with an institution where PET and/or PET/CT devices are available and who wish to become conversant with cardiac positron imaging. Training should therefore be the same as for Level 1 training in nuclear cardiology but should include aspects specific to cardiac positron imaging. The additional proficiency to be acquired by physician trainees includes background in substrate metabolism, patient standardization, and problems related to diabetes mellitus and lipid disorders, positron-emitting tracers of flow, and metabolism and technical aspects of positron and CT imaging. A didactic program should include the interpretation of cardiac PET studies of myocardial blood flow and substrate metabolism, the interpretation of studies combining SPECT for evaluation of blood flow with PET for evaluation of metabolism, the evaluation of diagnostic accuracy and cost-effectiveness of viability assessment of coronary artery disease detection, and the understanding of radiation safety as specifically related to positron emitters. Hands-on experience should include supervised observation and interpretation of cardiac studies performed with positron-emitting radionuclides and PET and PET/CT imaging devices.

SPECIALIZED TRAINING (MINIMUM OF 4 MONTHS)

This level of training is for fellows who wish to perform and interpret cardiac PET or positron-imaging studies in addition to nuclear cardiology. This training should include all Level 1 and Level 2 training in nuclear cardiology (4 to 6 months) as well as general training for cardiac PET and PET/CT. Specific aspects of training for PET and for using positron-emitting radionuclides should include radiation dosimetry, radiation protection and safety, dose calibration, physical decay rates of radioisotopes, handling of large doses of high energy radioactive materials of short physical half-lives, quality assurance procedures, and NRC safety and record-keeping requirements. This level of training requires direct patient experience with a minimum of 40 patient studies of myocardial perfusion or metabolism, or both.

ADVANCED TRAINING (MINIMUM 1 YEAR)

This level of training is intended for fellows planning an academic career in cardiac PET or who wish to direct a clinical cardiac PET laboratory. Similar to Level 3 training in nuclear cardiology, this training should include active participation in laboratory and clinical research in parallel with clinical activities.

In addition to the requirements for general and specialized cardiac PET training (including standard nuclear cardiology training, as previously described), advanced training should include the following:

1. Basic principles of cyclotrons, isotope production, radiosynthesis, tracer kinetic principles and tracer kinetic models, cardiac innervation and receptors, and methods for quantifying regional myocardial blood flow and substrate metabolism.
2. Imaging instrumentation including dedicated PET systems, hybrid PET/CT systems, and SPECT-like positron imaging devices with high-energy photon collimators or coincidence detection. Image acquisition and processing to include review of sinograms, errors in image reconstruction, correction routines for photon attenuation, and patient misalignment.
3. Tissue kinetics of positron-emitting tracers; in vivo application of tracer kinetic principles; tracer kinetic models, generation of tissue time activity curves, and computer-assisted calculation of region of functional processes of the myocardium.
4. Computer-assisted data manipulation, quantitative image analysis, and image display.

Hybrid CT Imaging

Hybrid imaging devices combining PET or SPECT with CT are playing an increasing role in the field of cardiac imaging. Currently, nearly all PET scanners are sold as PET/CT devices, and SPECT/CT machines are now available from most manufacturers. As these devices become more widely disseminated, it will be important that training guidelines for their use be developed both for fellows in training and cardiologists already in practice. The applications of hybrid imaging in cardiology include the use of CT scanning to provide robust attenuation correction of SPECT or PET and to assess coronary calcium as a marker of coronary atherosclerosis. Even these non-contrast applications of hybrid imaging will require additional training beyond that required for CT alone. With CT coronary calcium and SPECT or PET perfusion assessments, additional training will be needed regarding discordant results. With contrast injection, high-resolution CT coronary angiography can be combined with rest/stress assessments of myocardial perfusion provided by PET and SPECT, allowing functional assessment of the anatomic findings. The specifics of the training required in hybrid imaging are beyond the scope of this document; nonetheless, those nuclear cardiology training programs that are equipped to perform hybrid imaging should incorporate training in this field in their programs. Training should include the physics of hybrid systems, CT attenuation correction, principles and application of CT coronary calcium assessment, and principles and application of CT coronary angiography.

This is an update of the 2002 document that was written by Manuel D. Cerqueira, MD, FACC, Heinrich R. Schelbert, MD, PhD, FACC, Frans J. Th. Wackers, MD, PhD, FACC, and Mario Verani, MD, FACC.

APPENDIX 1. Author Relationships With Industry for the ACCF 2006 Update for Training in Adult Cardiovascular Medicine—Task Force 5: Training in Nuclear Cardiology

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Daniel S. Berman	Tyco-Mallinckrodt	BMS Astellas GE Healthcare	Spectrum Dynamics	None	None	Spectrum Dynamics	Cedars-Sinai Medical Center— Software Royalties
Dr. Manuel D. Cerqueira	GE Healthcare CVT Astellas	None	CVT	GE Healthcare CVT Astellas	None	None	BMS- DSMB
Dr. Marcelo F. DiCarli	None	None	None	None	None	None	None
Dr. Heinrich R. Schelbert	None	None	None	None	None	None	None
Dr. Frans J. Th. Wackers	None	BMS GE Healthcare Astellas Acusphere Bracco	King Pharm	GE Healthcare	None	None	MedX (WLCQ software)— Royalties
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 5: Training in Nuclear Cardiology*

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. James Arrighi	ACC Official Reviewer—Board of Governors	None	None	None	None	None	None	None
Dr. Kenneth A. Brown	Content Reviewer—Individual Review	None	BMS King Pharmaceuticals	None	None	None	None	None
Dr. Maleah Grover-McKay	Content Reviewer—ACCF Cardiovascular Imaging Committee	Tarctegen	None	None	None	None	None	None
Dr. Gary V. Heller	Organizational Reviewer—American Society of Nuclear Cardiology	None	Bracco Diagnostic GE Medical BMS Medical Imaging Philips Medical	None	None	None	None	None
Dr. Ami E. Iskandrian	Content Reviewer—ACCF Cardiovascular Imaging Committee	CV Therapeutics International Atomic Energy Agency	Astellas Pharm Molecular Insight Corp. GE Medical CV Therapeutics BMS	None	None	None	None	Acusphere Inc.—Blinded Reader

Continued on next page

This table represents the relevant relationships of peer reviewers with industry to this topic that were disclosed at the time of peer review of this guideline. It does not necessarily reflect relationships with industry at the time of publication. *Participation in the peer review process does not imply endorsement of the document. †Names are listed in alphabetical order.

APPENDIX 2. Continued

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Vincent Robinson	Organizational Reviewer—American Society of Nuclear Cardiology	None	None	None	None	None	None	None
Dr. James Udelson	ACC Official Reviewer—Board of Trustees	Molecular Insight Pharm King Pharm	GE Healthcare	Molecular Insight Pharm King Pharm	None	Molecular Insight Pharm King Pharm	None	None

Task Force 6: Training in Specialized Electrophysiology, Cardiac Pacing, and Arrhythmia Management

Endorsed by the Heart Rhythm Society

Gerald V. Naccarelli, MD, FACC, *Chair*
 Jamie B. Conti, MD, FACC, John P. DiMarco, MD, PhD, FACC,
 Cynthia M. Tracy, MD, FACC (*Heart Rhythm Society Representative*)

Clinical cardiac electrophysiology and cardiac pacing have merged into a common cardiac subspecialty discipline. Today, complex cardiac arrhythmias are managed by physicians with special expertise in cardiac electrophysiology, the use of implantable pacemakers and implantable cardioverter-defibrillators (ICDs), and the application of other interventional techniques and treatments. Non-pharmacologic therapy also includes electrophysiologic mapping and subsequent catheter or surgical ablation as standard treatment for certain tachyarrhythmias. In addition, antiarrhythmic agents with diverse mechanisms of action are often used therapeutically alone or in conjunction with cardiac implantable electrical devices.

In 1986, a Task Force 6 report on training in cardiac pacing (1) was published as a result of Bethesda Conference 17 on adult cardiology training. In 1991, a training statement recommending guidelines for training in adult clinical cardiac electrophysiology was published (2). In 1995, a task force (3) combined these two closely related disciplines to reflect the current merging of science, art, and the practice of clinical cardiac electrophysiology. In 2002, updated recommendations were published (4). The current task force is charged with updating these training guidelines based on changes in the pacing and cardiac electrophysiology field since that time.

GENERAL STANDARDS AND ENVIRONMENT

Facilities and Faculty

Three organizations—the American College of Cardiology (ACC), the American Heart Association (AHA), and the Heart Rhythm Society (HRS)—have addressed training requirements and guidelines for permanent pacemaker selection, implantation, and follow-up (5,6); guidelines for the implantation and follow-up of ICDs in cardiovascular practice (7,8); guidelines for training in catheter ablation procedures (9,10); and teaching objectives for fellowship programs in clinical electrophysiology (11,12). The training recommendations for these three organizations are congruent and address new technologies, faculty, and facility requirements, as well as practice. It is strongly recommended that trainees who desire admission to the American Board of Internal Medicine (ABIM) examination for certification in cardiovascular diseases and those who seek admission to the Clinical Cardiac Electrophysiology (CCEP) examination for certification of added qualifications in clinical cardiac electrophysiology be certain to obtain specific requirements from the ABIM (13,14).

The cardiac arrhythmia aspects of a cardiology training program should meet the published recommendations and requirements regarding facilities and faculty (9,10). In order for trainees to be eligible for admission to the CCEP examination of the ABIM, training must take place in an Accreditation Council for Graduate Medical Education

(ACGME)-approved training program (13). The intensity of training and the required teaching resources may vary according to the level of training provided. Facilities should be adequate to ensure a safe, sterile, and effective environment for invasive electrophysiologic studies and implantation of arrhythmia control devices. Faculty should include specialists who are skilled in the medical and surgical aspects of pacing and electrophysiology. In addition, faculty should be knowledgeable about the risks to the patient and to medical personnel from radiation exposure. Faculty responsible for training must be board certified in clinical cardiac electrophysiology or possess equivalent qualifications. In addition, there must be a minimum of two key clinical cardiac electrophysiology faculty members, including the program director. In programs with a total of more than two residents enrolled, a ratio of such faculty to residents of at least 1:1 must be maintained (13).

LEVELS OF TRAINING

Level 1

Within the cardiology core training program, Level 1 should comprise at least 2 months of clinical cardiac electrophysiology rotation designed for cardiology trainees to acquire knowledge and experience in the diagnosis and management of bradyarrhythmias and tachyarrhythmias. Every cardiology trainee should learn the indications for and limitations of electrophysiologic studies, the appropriate use of pharmacologic and non-pharmacologic therapeutic options, and the proper and appropriate use of antiarrhythmic agents, including drug interactions and proarrhythmic potential. The Level 1 trainee should be exposed to non-invasive and invasive techniques related to the diagnosis and management of patients with cardiac arrhythmias that include ambulatory electrocardiographic (ECG) monitoring, event recorders, exercise testing for arrhythmia assessment tilt-table testing invasive electrophysiologic studies, and implantation of cardiac arrhythmia control devices. Electrocardiographic manifestations of arrhythmias should be taught on a regular basis during formal ECG conferences. Additional experience in heart rhythm disorders and clinical correlations can be obtained from didactic sessions and conferences; however, they must be supplemented by rotation on an arrhythmia consultation service, during which time the trainee should gain first-hand experience as a consultant in arrhythmia management. Arrhythmias associated with congenital heart disease, cardiac and non-cardiac surgical patients, are important components of the arrhythmia core training.

The Level 1 cardiology trainee's experience should also include learning the fundamentals of cardiac pacing, recognizing normal and abnormal pacemaker function, knowing indications for temporary and permanent pacing and the implantation of ICDs (5), knowing pacing modes, and understanding basic techniques for interrogation, programming, and surveillance of pacemakers and ICDs. Trainees

should learn about the indications for the use of biventricular pacing in patients with congestive heart failure.

The cardiology trainee should be formally instructed in and gain experience with the insertion, management, and follow-up of temporary pacemakers (4); measurement of pacing and sensing thresholds and recording of electrograms for management of patients with temporary pacemakers; and indications and techniques for elective and emergency cardioversions (15). Insertion of a minimum of 10 temporary pacemakers and performance of at least 10 elective cardioversions are required. The cardiology trainee should be formally instructed in and gain experience with the application of and use of transcutaneous pacing systems. These experiences can be obtained throughout the 24-month clinical training period.

Level 2

Some trainees in cardiology may wish to acquire advanced training in management of arrhythmias but not undertake training in all aspects of cardiac electrophysiology. Such Level 2 training would be appropriate for individuals who wish to have careers with a substantial proportion of their time spent as a heart station or ECG laboratory director or in a pacemaker or ICD follow-up or syncope evaluation service or actively involved in the interrogation and programming of cardiac implantable electrical devices on a heart failure service.

Level 2 trainees should meet all Level 1 training requirements and should obtain advanced training in normal and abnormal cardiac electrophysiology and mechanisms of arrhythmias. Level 2 training consists of a minimum of 6 months of training in non-invasive arrhythmia management techniques designed to develop advanced competence and proficiency in the diagnosis, treatment, and longitudinal care of patients with complex arrhythmias. Exposure and proficiency in the performance and interpretation of other non-invasive tests related to the evaluation of patients who have arrhythmias should be part of the training. Level 2 trainees should have a thorough knowledge of the basic and clinical pharmacology of antiarrhythmic agents and demonstrate proficiency in their use.

Of special importance for the Level 2 trainee is the acquisition of skills and experience for managing inpatients and outpatients with complex cardiac arrhythmias, including programming and follow-up management of all types of bradycardia pacing, biventricular pacing, and ICD systems. The trainee is expected to function as the primary programming operator who interrogates, interprets, prescribes, and reprograms devices in at least 100 patients. The trainee at this level must also acquire advanced expertise in temporary pacing, cardioversion, interpretation of invasive electrophysiologic study data, and complex arrhythmia ECG interpretation.

Although the Level 2 trainee must have significant exposure to invasive electrophysiology, ICDs, and the surgical aspects of arrhythmia control device implantation, Level 2 training by itself does not qualify the trainee to perform these invasive procedures. The Level 2 trainee has the option of obtaining additional training in the surgical aspects of pacemaker implantation or may choose the

Table 1. Cardiac Arrhythmia and Electrophysiology Curriculum Training Summary

Level	Curriculum/Skills	Time Requirement	Optional Training in Device Implantation
1	Cardiac arrhythmia and electrophysiology core	2 months (in addition to Task Force 2 training requirements)	No
2	Advanced noninvasive arrhythmia management	6 months	Yes: In addition to 6 months of noninvasive emphasis, another 6 months for a total of 12 months is required for pacemaker implantation training
3	Clinical invasive cardiac electrophysiology (meets the ABIM CCEP examination requirements)	1 yr	Yes: A total of 1 yr beyond the 3-yr cardiology training program is required. If surgical aspects of device implantation are desired, a total of 12 months will need to be devoted to this discipline.

ABIM = American Board of Internal Medicine; CCEP = Clinical Cardiac Electrophysiology.

additional training required for invasive cardiac electrophysiology, or both, as described under Level 3.

Level 3

This level of training is designed for the individual who wishes to specialize in invasive diagnostic and therapeutic cardiac electrophysiology (clinical cardiac electrophysiology) (16). Requirements of Level 1 and Level 2 must be fully met.

Clinical cardiac electrophysiology training will include a minimum of 4 years of training in clinical cardiology and electrophysiology. Current ACGME requirements specify a 3-year training program in general cardiology, which consists of a core 24-month clinical program and an additional 12 months, which may involve research and elective time in electrophysiology. A dedicated fourth year of training in clinical cardiac electrophysiology after 3 years is required. Given the complexity of the field and the growing amount of information and new procedures, it is common for trainees to extend training for an additional year or more to gain advanced expertise in specific procedures. The appropriate use, safe performance, and judicious interpretation of these complex procedures requires highly specialized training and competence and cannot be accomplished in a 3-year training program. Furthermore, an advanced knowledge base in basic clinical cardiac electrophysiology and pharmacology must provide a sound foundation for the acquisition of technical abilities and cognitive skills in the management of patients with complex arrhythmias.

To complete Level 3, in addition to Level 1 and Level 2 requirements, trainees should perform at least 150 electrophysiologic procedures and “be a primary operator and analyze 100 to 150 initial diagnostic studies. At least 50 to 75 of these procedures should involve patients with supraventricular arrhythmias. Because therapy with antiarrhythmic devices forms a major part of current electrophysiology practice, the trainee should also have been a primary operator during ≥ 25 electrophysiological evaluations of implantable antiarrhythmic devices” (17).

Electrophysiologic procedures should cover the total spectrum of arrhythmias, both supraventricular and ventricular tachyarrhythmias as well as bradyarrhythmias. Trainees who wish to become skilled in some of the more complex electrophysiology procedures (e.g., ablation for atrial fibrillation or evaluation of patients with congenital heart dis-

ease) would benefit from a longer period of training or post-training mentored practice.

Expertise in catheter placement, programmed electrical stimulation, endocardial mapping, catheter ablation, and interpretation of data must be ensured by the electrophysiology program director. The endocardial mapping experience should include cases of left heart mapping by the retrograde aortic approach. Training in transseptal catheterization should be provided by an individual at the training institution with expertise in the technique. Experience with at least 10 transseptal catheterization procedures is suggested as minimal required training. Participation in a minimum of 75 catheter ablations, including ablation and modification of the atrioventricular (AV) node, AV accessory pathways, atrial flutter, and atrial and ventricular tachycardia, is required (17). To gain expertise in atrial fibrillation ablation requires additional expertise in catheter manipulation and integration of knowledge related to three-dimensional mapping systems. Given the rapid evolution of new mapping technologies, it is unlikely that the trainee will be exposed to all mapping technologies as part of their training. Trainees should be exposed to tools for definition of intracardiac anatomy, such as intravascular ultrasound, cardiac magnetic resonance imaging, and computed tomographic scans. No numeric guidelines have been established for training in atrial fibrillation ablation, but it is anticipated that the Level 3 trainee should participate in 30 to 50 mentored atrial fibrillation ablations.

The trainee in electrophysiology requires ICD experience that includes assisting with the primary device implantation, with electrophysiologic testing at the time of implantation, and with follow-up assessment. This experience will include at least 50 device evaluations (combined implantation and follow-up). The trainee in electrophysiology also requires experience in left ventricular lead implantation procedures. Implantable cardioverter defibrillator implant exposure includes assisting with the device implantation, threshold and defibrillation threshold (DFT) testing at the time of implant and follow-up. This experience should include at least 15 device evaluations (implantation and follow-up). Although the Level 3 trainee must have significant exposure to the management and follow-up of ICD pacemaker implantation, he or she will not necessarily be trained in the surgical aspects of these procedures (Table 1)

unless they meet Level 3 training listed below in optional training for device implantation.

OPTIONAL TRAINING IN DEVICE IMPLANTATION (APPLICABLE TO LEVEL 2 OR LEVEL 3)

Level 2 and Level 3 trainees may choose to obtain additional training in the surgical aspects of device implantation. This device implantation training may be obtained concurrently or sequentially with Level 2 or Level 3 training, respectively. For those cardiology trainees who elect to obtain proficiency in the surgical aspects of transvenous bradycardia device implantation (pacemakers), previous or concurrent Level 2 training is required. The pacemaker implantation training must include development of expertise in permanent atrial right and left ventricular lead and ICD lead placement, threshold testing and programming of devices, principles of surgical asepsis, surgical techniques of implantation, and management of implant-related complications. Individuals receiving qualifying training in pacemaker implantation must participate as the primary operator (under direct supervision) in at least 50 primary implantations of transvenous pacemakers and 20 pacemaker system revisions or replacements. At least one-half of the implantations should involve dual-chamber pacemakers. The trainee must also participate in the follow-up of at least 100 pacemaker patient visits and acquire proficiency in advanced pacemaker electrocardiography, interrogation, and programming of complex pacemakers. Level 2 training (6 months) with the option of training in pacemaker implantation (6 months) requires a total of 1 year of advanced training beyond the cardiology core Level 1. This may be obtained within a 3-year cardiology program if 1 of the 3 years is dedicated to acquiring pacemaker implantation skills plus related management and follow-up skills. This training does not meet the ABIM requirements for admission to the CCEP examination. As part of the training regarding implantable pacemakers, exposure to the indications, implantation techniques, and follow-up of loop recorders is desirable.

The trainee pursuing a career in cardiac electrophysiology as addressed under Level 3 also has the option of obtaining expertise in the surgical aspects of pacemaker or transvenous ICD implantation, or both. The same amount of surgical experience with bradycardia pacemaker implantation is required and may be supplemented with surgical training for ICD implantation (16). If the Level 3 trainee chooses this option, he or she must participate as the primary implanter (under direct supervision) in at least 25 ICD system implantations, as well as possess the management and follow-up skills addressed under Level 3. The Level 3 trainee wishing to become proficient in implantation of biventricular pacing or defibrillating systems requires the above training and involvement in implantation and follow-up of 15 biventricular systems (6). He or she should be proficient at interpreting data gained from non-invasive tools such as echocardiography used in the evaluation of resynchronization therapies.

Pacemaker lead extraction is a specialized procedure that requires special training but is not an obligate part of training for CCEP examination eligibility. Physicians being trained in lead extraction should perform a minimum of 20 lead extractions as the primary operator under the direct supervision of a qualified training physician (18).

Level 3 trainees for ICD implantation must have an extensive knowledge of ICD indications, contradictions, and management of complications; an ability to determine defibrillation thresholds and manage high defibrillation thresholds; an understanding of drug-ICD and pacemaker-ICD interactions; and a thorough knowledge of ICD programming and management of ICD malfunction and post-operative complications. The trainee must also participate in the surgical replacement or revision of at least 10 ICD systems and follow-up of at least 50 ICD patient visits. Level 3 training with the option of pacemaker or ICD implantation or both requires a minimum of one year of dedicated clinical cardiac electrophysiology and device implantation training beyond the three-year cardiology program. In addition, Level 3 trainees must have an extensive knowledge of left ventricular lead indications, contraindications, and management of biventricular malfunctions and interactions, as well as postoperative complications. It has been advocated that physicians training in congestive heart failure/transplantation could pursue an additional year of training to achieve Level 2 and Level 3 competency in implantable devices by meeting all of the above COCATS training requirements (19,20). An alternate pathway for training in ICD implantation has been established for a small, finite group of physicians who have completed fellowship training and have been high-volume pacemaker implanters for three or more years (20). It is recommended that Level 3 fellowship training for ICD implantation follows the above COCATS requirements.

EVALUATION, COMPETENCE, AND PRIVILEGES

The program director should maintain adequate records of each individual's training experiences and performance of various procedures for appropriate documentation for Level 1, Level 2, and Level 3. The trainees should also maintain records of participation in the form of a logbook containing clinical information, procedure performed, and outcome of procedures, including any complications encountered.

The ACC, AHA, and HRS have formulated a clinical competence statement on invasive electrophysiology studies, catheter ablation, and cardioversion (17). Self-assessment programs and competence examinations in electrocardiography are available through the ACC and other organizations. Training directors and trainees are encouraged to utilize these resources.

The ACGME has published the essential components of a specialized program for training in clinical cardiac electrophysiology. The ABIM provides a special examination for additional certification in clinical cardiac electrophysiol-

ogy. Information concerning the training requirements for admission to the examination can be obtained from the ABIM; such requirements include an additional year of training in an ACGME-accredited electrophysiology program. The HRS also has a written examination of special competence in device therapy, but it does not provide certification (21). Subsequent privileges to perform invasive procedures should be granted primarily on the basis of the technical expertise acquired in the training program, the documented training, and the recommendations of the directors of electrophysiology/pacing programs.

This is a revision of the 2002 document that was written by Gerald V. Naccarelli, MD, FACC, Jamie B. Conti, MD, FACC, John P. DiMarco, MD, FACC, and Philip T. Sager, MD, FACC.

doi:10.1016/j.jacc.2005.12.028

REFERENCES

- Josephson ME, Maloney JD, Barold SS, et al. Guidelines for training in adult cardiovascular medicine: Core Cardiology Training Symposium (COCATS): Task Force 6: training in specialized electrophysiology, cardiac pacing and arrhythmia management. *J Am Coll Cardiol* 1995;25:23–6.
- Flowers NC, Abildskov JA, Armstrong WF, et al. ACC policy statement: recommended guidelines for training in adult clinical cardiac electrophysiology: Electrophysiology/Electrocardiography Subcommittee, American College of Cardiology. *J Am Coll Cardiol* 1991;18:637–40.
- Zipes DP, DiMarco JP, Gillette PC, et al. Guidelines for clinical intracardiac electrophysiological and catheter ablation procedures: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Clinical Intracardiac Electrophysiological and Catheter Ablation Procedures), developed in collaboration with the North American Society of Pacing and Electrophysiology. *J Am Coll Cardiol* 1995;26:555–73.
- Naccarelli GV, Conti JB, DiMarco JP, Sager PT. Task force 6: training in specialized electrophysiology, cardiac pacing and arrhythmia management. Available at: <http://www.acc.org/clinical/training/cocats2.pdf>. Accessed January 1, 2006.
- Gregoratos G, Abrams J, Epstein AE, et al. ACC/AHA/NASPE 2002 guideline update for implantation of cardiac pacemakers and antiarrhythmia devices: a report of the American College of Cardiology/American Heart Association/Task Force on Practice Guidelines (ACC/AHA/NASPE Committee to Update the 1998 Pacemaker Guidelines). *Circulation* 2002;106:2145–61.
- Hayes DL, Naccarelli GV, Furman S, et al. NASPE policy statement: NASPE training requirements for cardiac implantable electronic devices (CIED). Selection, implantation and follow-up. *Pacing Clin Electrophysiol* 2003;26:1556–62.
- Curtis AB, Langberg JJ, Tracy CM. Clinical competency statement: implantation and follow up of cardioverter defibrillators. *J Cardiovasc Electrophysiol* 2001;12:280–4.
- Winters SL, Packer DL, Marchlinski FE, et al. Consensus statement on indications, guidelines for use, and recommendations for follow-up of implantable cardioverter defibrillators. *Pacing Clin Electrophysiol* 2001;24:262–9.
- Scheinman MM. Catheter ablation for cardiac arrhythmias, personnel, and facilities: North American Society of Pacing and Electrophysiology Ad Hoc Committee on Catheter Ablation. *Pacing Clin Electrophysiol* 1992;15:715–21.
- American College of Cardiology Cardiovascular Technology Assessment Committee. Catheter ablation for cardiac arrhythmias: clinical applications, personnel and facilities. *J Am Coll Cardiol* 1994;24:828–33.
- Scheinman M, Akhtar M, Brugada P, et al. Teaching objectives for fellowship programs in clinical electrophysiology. *Pacing Clin Electrophysiol* 1988;11:989–96.
- Mitchell LB, Dorian P, Gillis A, Kerr C, Klein G, Talajic M. Standards for training in adult clinical cardiac electrophysiology: Canadian Cardiovascular Society Committee. *Can J Cardiol* 1996;12:476–80.
- Accreditation Council for Graduate Medical Education. Program Requirements for Residency Programs in Clinical Cardiac Electrophysiology. Available at: <http://www.acgme.org>.
- Zipes DP, Downing SM, Kangilaski R, Norcini JJ, Jr. The first cardiac electrophysiology examination for added qualifications: American Board of Internal Medicine. *Pacing Clin Electrophysiol* 1994;17:1327–31.
- Clinical competence in elective direct current (DC) cardioversion: a statement for physicians from the ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology. *J Am Coll Cardiol* 1993;22:336–9.
- Clinical competence in invasive cardiac electrophysiological studies: ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology. *J Am Coll Cardiol* 1994;23:1258–61.
- Tracy CM, Akhtar M, DiMarco JP, Packer DL, Weitz HH. American College of Cardiology/American Heart Association clinical competence statement on invasive electrophysiology studies, catheter ablation, and cardioversion: a report of the American College of Cardiology/American Heart Association/American College of Physicians—American Society of Internal Medicine Task Force on Clinical Competence. *J Am Coll Cardiol* 2000;36:1725–36.
- Wilkoff BL, Byrd CL, Love C. NASPE guidelines for lead extraction. *Pacing Clin Electrophysiol* 2000;23:544–51.
- Naccarelli GV. Does it make sense to train plumbers as electricians? *J Am Coll Cardiol* 2004;44:1358–60.
- Curtis AB, Ellenbogen KA, Hammill SC, et al. Clinical competency statement: training pathways for implantation of cardioverter defibrillators and cardiac resynchronization devices. *Heart Rhythm* 2004;3:371–5.
- Furman S, Bilitch M. NASPExAM. *Pacing Clin Electrophysiol* 1987;10:278–80.

APPENDIX 1. Author Relationships With Industry for the ACCF 2006 Update for Training in Adult Cardiovascular Medicine—Task Force 6: Training in Specialized Electrophysiology, Cardiac Pacing, and Arrhythmia Management

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Jamie B. Conti	None	Medtronic, Inc. Guidant Corp. St. Jude	Medtronic, Inc. St. Jude	None	None	None	None
Dr. John P. DiMarco	Novartis Guidant Medtronic St. Jude Medical	Guidant Sanofi-Aventis	None	Medtronic St. Jude Medical	None	None	None

Task Force 6: Training in Specialized EP, Cardiac Pacing, and Arrhythmia Management

APPENDIX 1. Continued

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Gerald V. Naccarelli	Guidant Medtronic Sanofi-Aventis Wyeth-Ayerst Boehringer-Ingelheim Pfizer Astra-Zeneca Glaxo-Smith-Kline	Guidant Medtronic Sanofi-Aventis Wyeth-Ayerst Boehringer-Ingelheim	None	None	None	None	None
Dr. Cynthia M. Tracy	None	Medtronic, Inc. Guidant Corp.	None	None	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 6: Training in Specialized Electrophysiology, Cardiac Pacing, and Arrhythmia Management*

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Loren D. Berenbom	Board of Governors Reviewer	Medtronic	None	None	None	None	None	Medtronic Guidant St. Jude Medical— Underwrite EP fellowship
Dr. Peng-Sheng Chen	Organizational Reviewer—Heart Rhythm Society	None	None	None	None	None	None	Medtronic Guidant St. Jude— Donation of ICD and pacemaker for research in animal laboratories
Dr. Leonard S. Dreifus	Content Reviewer—ACCF Electrophysiology Committee	None	None	None	None	None	None	None
Dr. Bengt Herweg	Organizational Reviewer—Heart Rhythm Society	None	None	None	None	None	None	None
Dr. Alan Kadish	Content Reviewer—Individual Review	St. Jude Medical Lifewatch	St. Jude Medical Medtronic Guidant	None	None	None	None	None
Dr. Bradley P. Knight	Content Reviewer—ACCF Electrophysiology Committee	Guidant Medtronic CardioOptics	Guidant Medtronic CardioOptics	CardioOptics	Guidant Medtronic	None	None	None
Dr. Peter Kowey	Content Reviewer—ACCF Electrophysiology Committee	None	None	None	None	None	None	None

Continued on next page

APPENDIX 2. Continued

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Bruce D. Lindsay	Content Reviewer—Individual Review	None	None	None	None	None	None	None
Dr. Michael Mirro	ACC Official Reviewer—Board of Trustees	Cambridge Heart Life Cor Medical Informatics Engineering	Astra-Zeneca Medtronic	None	Astra-Zeneca Novartis Pfizer	None	Cambridge Heart Life Cor Medtronic Medical Informatics Engineering Pfizer	None
Dr. Andrea Russo	Content Reviewer—ACCF Electrophysiology Committee	None	Guidant Medtronic St. Jude Medical	None	Guidant Medtronic St. Jude Medical	None	None	None

This table represents the relevant relationships of peer reviewers with industry to this topic that were disclosed at the time of peer review of this guideline. It does not necessarily reflect relationships with industry at the time of publication. *Participation in the peer review process does not imply endorsement of the document. †Names are listed in alphabetical order.

Task Force 12: Training in Advanced Cardiovascular Imaging (Cardiovascular Magnetic Resonance [CMR])

Endorsed by the Society for Cardiovascular Magnetic Resonance

Gerald M. Pohost, MD, FACC, *Chair*

Raymond J. Kim, MD, FACC, Christopher M. Kramer, MD, FACC,

Warren J. Manning, MD, FACC (*Society for Cardiovascular Magnetic Resonance Representative*)

Cardiovascular magnetic resonance (CMR) (Table 1), one of the newest cardiovascular imaging modalities, provides useful, often unique information with which all cardiologists should be conversant. Training in CMR for cardiology fellows should be divided into three levels.

TRAINING LEVELS

Level 1—General training (1 month) to provide the cardiovascular trainee with a working knowledge of CMR methods and diagnostic utility.

Level 2—Specialized training (at least 3 months) designed to provide fellows with the skills necessary to independently interpret CMR imaging studies.

Level 3—Advanced training for those who ultimately wish to be responsible for the operation of a CMR laboratory. Level 3 criteria must include appropriate levels of patient care, teaching, and research.

OVERVIEW OF CMR TRAINING

All cardiovascular medicine trainees should be taught the basic types of CMR studies and their indications. Mentored

interpretation of CMR studies should be coupled with comparison and integration of test results with other relevant clinical and laboratory data. A mentor is an individual with the equivalent of Level 3 CMR training. This training generally should be acquired through the Accreditation Council for Graduate Medical Education—an approved cardiology or radiology program with expertise in CMR and under the aegis of a Level 3-qualified mentor in a laboratory accredited by an organization such as the Intersocietal Commission on the Accreditation of MR Laboratories (ICAMRL). Occasionally, a Level 3 qualified mentor will not be available in the institution housing the general fellowship program, but is available at a nearby non-academic but medical center accredited for CMR by an organization such as the ICAMRL. Under these circumstances it is acceptable to place the trainee(s) at such a medical center for Level 1 to Level 3 training. The CMR training center and the trainee should maintain a logbook or other specific records to document the trainee's case review and the didactic hours in which the trainee has participated.

The depth of knowledge should increase with increasing levels of training. In the case of the Level 3 trainee,

Table 1. Classification of CMR Procedures

1. Standard CMR procedures, including:
 - a. Tomographic still-frame CMR for morphology using “bright” and/or “dark blood” methods with and/or without a paramagnetic contrast agent
 - b. Cine and other approaches to CMR for assessment of ventricular function
 - c. Magnetic resonance angiography and cine CMR of the great vessels, anomalous coronary arteries, and coronary artery bypass grafts
 - d. Delayed contrast-enhanced CMR imaging for myocardial infarction, scar, intraventricular thrombus and microvascular obstruction (associated with MI) and viability assessment and visualization of other causes of abnormal myocardial interstitium
 - e. First-pass CMR imaging (with vasodilator infusion) or cine CMR imaging with stress (with inotropic agent) for myocardial perfusion evaluation and ischemia detection
 - f. Phase-contrast velocity mapping for blood flow quantification for shunt sizing and determination of regurgitation and stenosis
 - g. Peripheral MR angiography
2. Less common procedures, including:
 - a. Myocardial tagging (approach unique to CMR that allows more detailed evaluation of intramural and transmural myocardial function than ventriculography alone and for evaluation of pericardial disease)
 - b. MR angiography of the native coronary arteries
 - c. MR spectroscopy using ³¹P (to assess “high-energy phosphate metabolism”) or other nuclei

CMR = cardiovascular magnetic resonance; MI = myocardial infarction; MR = magnetic resonance.

specialized training and, for academic trainees, research should be offered as a part of an established training program (Table 2).

LEVEL 1: GENERAL TRAINING (1-MONTH MINIMUM)

The trainee should have exposure to the methods and the multiple applications of CMR for a period of not less than 1 month or its equivalent when interwoven with other training activities. This experience should provide basic background knowledge in CMR sufficient for the practice of adult cardiology and referral for CMR, but not for the practice/independent clinical interpretation of CMR. As a practical matter, many fellowship programs in cardiovascular medicine may not be able to fulfill CMR training. In these instances, fellows should be encouraged to obtain experience in an alternate program with appropriate training and accreditation in the performance of CMR studies.

Didactic Activities

Interpretation of CMR studies. During their 1-month of training, trainees should actively participate in daily CMR study interpretation under the direction of a Level 2- or Level 3-trained CMR physician-mentor. For all studies in which angiographic, echocardiographic, radionuclide, computed tomography, or hemodynamic data are available, such information should be correlated with CMR studies. Studies should include the range of procedures listed in Table 1.

Experience in interpretation (a minimum of 50 cases) may include studies from an established CMR teaching file.

Lectures and self-study in CMR. This component should consist of lectures on the basic aspects of CMR and parallel reading material of selected articles, digital training programs, or CMR text. The lectures and reading should provide the fellow with an understanding of CMR applications. Specificity, sensitivity, diagnostic accuracy, utility in assessing prognosis and use of interventions, costs, artifacts, indications, contraindications, and pitfalls must be included for each cardiovascular diagnostic subset. Such information could be effectively transmitted within a weekly non-invasive or clinical teaching conference during which CMR data are presented.

A basic understanding of magnetic resonance physics should be provided, including the following: 1) the physics of magnetic resonance as it relates to image intensity and contrast, including flow, T₁ (spin-lattice relaxation time), T₂ (spin-spin relaxation time) and contrast agents; 2) sources of artifacts, including motion, arrhythmias, and metal objects; contrast agent side effects; 3) safety of devices in the CMR environment; and 4) general post-processing tools and analyses.

Hands-On Experience

Hands-on experience is not necessary for Level 1.

LEVEL 2: SPECIALIZED TRAINING (AT LEAST 3 MONTHS)

Training for Level 2 should begin with the CMR experience outlined in Level 1. Level 2 is for those trainees who wish to practice the specialty of CMR, including independent interpretation of CMR studies. Level 2 trainees must have at least 3 months of dedicated CMR training (where 1 month is defined as 4 weeks and a week is defined as 35 h), including the basic elements listed in the following text. The trainee would be expected to become familiar with the CMR techniques listed in Table 1.

Background

In addition to Level 1 training, understanding of CMR physics should be more advanced (see the following text).

Table 2. Components of CMR Training

1. Didactic activities
 - a. Lectures (it will be necessary in learning the physical principles and in case interpretation to derive such information from relevant lectures—no more than 5% of the cases)
 - b. Self-study (it is possible to use cases from teaching files, journals, textbooks, or electronic/on-line courses. Such self-study cases need to be well documented in the trainee’s records and should not comprise any more than 50% of the cases studied)
2. Independent interpretation of CMR cases (performed in the mentoring CMR laboratory)
3. Participation in CMR case study interpretation
4. “Hands-on” CMR experience

CMR = cardiovascular magnetic resonance.

Didactic Activities

Interpretation of CMR studies. During their 3 or more months of experience, trainees should actively participate in daily CMR study interpretation under the direction of a Level 2 or Level 3 (preferred) CMR-qualified physician. For all studies in which other cardiac imaging data are available, such information should be correlated with CMR data. The trainee should interpret at least 150 CMR examinations during this training period, including 50 for which the trainee is present during the scan, ideally as the primary operator and is the primary interpreter. Up to 50 of the 100 examinations for which the trainee is not the primary interpreter can be derived from established teaching files, journals, and/or textbooks or electronic/on-line courses. Careful documentation of all case material and the details of the way in which the case was derived is essential.

Lectures and self-study in CMR. Course work would include the components for Level 1 training but also should include more advanced lectures and reading materials. This work, with parallel reading, should continue for the duration of the traineeship. Course work should include the following:

1. Physics: trainees should receive didactic lectures from a CMR-trained physician and/or physicist on the basic physics of magnetic resonance in general and CMR in particular. The content should include the same materials as in Level 1 (basic) plus lectures with supportive reading on the following topics:
 - a. Image formation, including k-space, gradient echo, spin echo, fast spin echo, echo planar, spiral, steady-state free precession (SSFP), and parallel imaging.
 - b. Specialized imaging sequences, including flow and motion, phase imaging, time of flight, contrast agents, and radiofrequency tagging.
 - c. Hardware components, including the elements of gradient coil design, receiver coils, and digital sampling.
2. Applications, interpretation, indications, and contraindications: Level 2 didactic activities should include an understanding of the sensitivity, specificity, accuracy, utility, costs, acquisition approaches, and disadvantages of all of the contemporary techniques in CMR. The following techniques should be covered in the didactic program:
 - a. Imaging of structure and tissue characterization (T1, T2, spin echo, gradient echo, SSFP, and fat suppression).
 - b. Imaging of function (cine and tagged cine magnetic resonance including SSFP imaging).
 - c. Volumetric imaging of mass, biventricular volumes, and ejection fraction (using cine magnetic resonance imaging).
 - d. Flow imaging (e.g., velocity-encoded techniques).
 - e. Imaging of myocardial infarction, scarring, and viability assessment (delayed contrast-enhancement imaging).
 - f. Pharmacologic stress-testing with evaluation of ventricular function and/or first-pass perfusion using a contrast agent.
 - g. Magnetic resonance angiography (vascular).
 - h. Electrocardiogram and peripheral pulse gating and triggering including timing of image acquisition within the R-R interval, motion artifacts and their effects on CMR images; respiratory motion suppression methods (e.g., breath-holding and navigators).
 - i. Magnetic resonance spectroscopy methods (e.g., depth resolved surface coil spectroscopy or DRESS).
 - j. Cardiovascular magnetic resonance image analysis and post-processing tools.
 - k. Contraindications for CMR study.
 - l. Incidental findings suggesting pathology outside of the cardiovascular system.

Evaluation

The person responsible for the CMR training program must be responsible for assessing the competence of the CMR trainee at the completion of the program. This is accomplished by examining the ability of the trainee in the understanding of the acquisition methods and the interactive role of the operator during the performance of studies and in the interpretation of the data acquired during daily reading sessions. This may be supplemented by formal testing.

**LEVEL 3: ADVANCED TRAINING
 (12 MONTHS OR MORE FOR THOSE
 INTERESTED IN RUNNING AN ACADEMIC PROGRAM)**

Level 3 CMR training represents the highest level of training and would enable the trainee to pursue a clinical or

Table 3. Summary of Requirements for Each Level of CMR Training

Level	Duration of Training (Months)	Number of Cases
1	1	50+ Mentored interpretations (by a Level 2- or 3-trained physician)
2	3 to 6*	150+ Mentored interpretations (by a certified Level 2- or Level 3- [preferred] qualified CMR physician) including at least 50 as primary interpreter (and operator, if possible)†
3	12 or more months of training*	300+ Mentored interpretations (by a Level 3-qualified CMR physician) including 100+ as primary interpreter (and operator, if possible)†

*This time represents the number of months spent reviewing cases, and interpreting, performing, and learning about CMR, and need not be a consecutive block of time, but at least 50% of the time should represent mentored laboratory experience. †The case recommendations may include studies from an established teaching file, previous CMR cases, journals, and/or textbook or electronic/on-line courses/continuing medical education. No less than 50% of the cases should be from those performed at the mentoring CMR laboratory.

CMR = cardiovascular magnetic resonance.

Task Force 12: Training in Advanced Cardiovascular Imaging (CMR)

academic career in CMR and to direct a CMR laboratory. Level 3 training in CMR could be obtained as part of a 3- or 4-year cardiology fellowship. In addition to the recommendation for Level 2, the Level 3/academic program should include active participation in ongoing basic or clinical CMR research or both, with individual responsibility for a specific portion of that research. Focused research work with publication of one or more manuscripts is an important part of Level 3 training. Level 3 training must be performed under the guidance of at least one Level 3-trained CMR physician.

In parallel with research activities, the Level 3 trainee must participate in clinical imaging that should include supervised interpretation of at least 300 CMR cases. The trainee must be physically present and involved in the acquisition and the primary interpretation of at least 100 CMR cases. In the remaining 200 cases, the trainee should review at least 100 of these with the Level 3 mentor at the training facility. The remaining cases can be derived from established teaching files, journals, and/or textbooks or electronic/on-line courses. Careful documentation of all case material and the details of the way in which the case was derived are essential.

Knowledge of magnetic resonance physics must be more advanced than Level 2 and include the following:

1. Analysis of why certain specialized imaging sequences are applicable for specific clinical protocols, including imaging of heart function, coronary arteries, perfusion, delayed enhancement, and peripheral arteries.
2. Basic understanding of the clinically applicable spectroscopic methods.
3. The essentials of data collection, including capturing of digital data, the maintenance of accurate databases and records, signal processing, and the approach for obtaining quantitative data.

Evaluation

Evaluation should be similar to that of Level 2.

Summary of Recommendations

The overall requirements for training in CMR are summarized in Table 3.

This is an update of the 2002 document that was written by Gerald M. Pohost, MD, FACC, Raymond J. Kim, MD, FACC, Christopher M. Kramer, MD, FACC, and Nathaniel Reichek, MD, FACC.

doi:10.1016/j.jacc.2005.12.029

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

Name	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Raymond J. Kim	Mallinckrodt	None	None	None	None	None	Siemens-Educational Grant
Dr. Christopher M. Kramer	None	Fujisawa Novartis	None	GE Healthcare	None	None	Siemens, Merck-Research materials support
Dr. Warren J. Manning	None	None	None	None	None	None	None
Dr. Gerald M. Pohost	None	None	None	Takeda Pharmaceuticals	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: Training in Advanced Cardiovascular Imaging (Cardiac Magnetic Resonance)*

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Stock Holder
Dr. Maleah Grover-McKay	Content Reviewer-ACCF Cardiovascular Imaging Committee	Tarctegen	None	None	None	None
Dr. John McB. Hodgson	Organizational Reviewer-Society for Cardiovascular Angiography and Interventions	Volcano	GE Medical	GE Medical	Volcano	Technology Solutions Group
Dr. Spencer King, III	Content Reviewer-ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None
Dr. Edward T. Martin	Content Reviewer-Individual Review	Guidant	Guidant	Guidant	GE Medical	None
Dr. Patrick O'Gara	ACC Official Reviewer-Board of Trustees	Boston Scientific Corp.	None	None	None	None
Dr. Dudley Pennell	Content Reviewer-Individual Review	Siemens BMS Novartis	None	Preventicum	None	Cardiovascular Imaging Solutions
Dr. Nathaniel Reichek	Content Reviewer-Individual Review	None	None	None	None	None
Dr. Charanjit S. Rihal	Content Reviewer-ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None
Dr. Thomas L. Rosamond	ACC Official Reviewer-Board of Governors	None	None	None	None	None
Dr. Carlos Ruiz	Content Reviewer-ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None
Dr. Robert Schwartz	Organizational Reviewer-Society of Cardiovascular Angiography & Intervention	None	None	None	None	None

This table represents the relevant relationships of peer reviewers with industry to this topic that were disclosed at the time of peer review of this guideline. It does not necessarily reflect relationships with industry at the time of publication. *Participation in the peer review process does not imply endorsement of the document. †Names are listed in alphabetical order.

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

Matthew J. Budoff, MD, FACC, FAHA, *Chair*

Stephan Achenbach, MD (*Society of Cardiovascular Computed Tomography Representative*),

Zahi Fayad, PhD (*Society of Atherosclerosis Imaging and Prevention Representative*),

Daniel S. Berman, MD, FACC, Michael Poon, MD, FACC, Allen J. Taylor, MD, FACC, FAHA,

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 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.

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.

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 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).

doi:10.1016/j.jacc.2005.12.030

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
Dr. Stephan Achenbach	None	Siemens	None	None	None	None	None
Dr. Daniel S. Berman	Tyco-Mallinckrodt	BMS Astellas GE Healthcare	Spectrum Dynamics	None	None	Spectrum Dynamics	Cedars-Sinai Medical Center—Software Royalties
Dr. Matthew J. Budoff	None	None	None	Pfizer GE Healthcare	None	None	None
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
Dr. Bruce Brundage	Content Reviewer—Individual Review	None	None	None	None	None	None	None

Continued on next page

APPENDIX 2. Continued

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Maleah Grover-McKay	Content Reviewer—ACCF Cardiovascular Imaging Committee	Tarctegen	None	None	None	None	None	None
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
Dr. Patrick O'Gara	ACC Official Reviewer—Board of Trustees	Boston Scientific Corp.	None	None	None	None	None	None
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

Continued on next page

APPENDIX 2. Continued

Peer Reviewer Name†	Representation	Consultant	Research Grant	Scientific Advisory Board	Speakers' Bureau	Steering Committee	Stock Holder	Other
Dr. Carlos Ruiz	Content Reviewer—ACCF Cardiac Catheterization and Intervention Committee	None	None	None	None	None	None	None
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

This table represents the relevant relationships of peer reviewers with industry to this topic that were disclosed at the time of peer review of this guideline. It does not necessarily reflect relationships with industry at the time of publication. *Participation in the peer review process does not imply endorsement of the document. †Names are listed in alphabetical order.