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APPENDIX 2. PEER REVIEWER RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 11: TRAINING IN VASCULAR MEDICINE AND PERIPHERAL VASCULAR CATHETER-BASED INTERVENTIONS

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This table represents the relationships of peer reviewers 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. *Names are listed in alphabetical order with each category of review.

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

Endorsed by the Society for Cardiovascular Magnetic Resonance

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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. Accordingly, cardiovascular trainees should receive training that would provide at least a basic understanding of the methods and utility of CMR in the practice of cardiology. To accomplish such an understanding for fellows with different levels of interest in CMR, training in CMR should be provided at 3 levels—general, specialized, and advanced.

Training Levels

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

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

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 for myocardial infarction, scar, intraventricular thrombus, and microvascular obstruction (associated with myocardial infarction) and viability assessment and visualization of other causes of abnormal myocardial interstitium
   e. First-pass CMR (with vasodilator infusion) or cine CMR with stress (with inotropic agent) for myocardial perfusion evaluation, ischemia detection, and assessment of patients with coronary microvascular disease
   f. Phase-contrast velocity mapping for blood flow quantification for shunt sizing and determination of valvular regurgitation and stenosis
   g. Peripheral magnetic resonance 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. Coronary magnetic resonance imaging of the native coronary arteries
   c. Magnetic resonance spectroscopy using ^{31}P (to assess "high energy phosphate metabolism") or other nuclei

CMR = cardiovascular magnetic resonance.

Level 3—Advanced training is provided for those who ultimately wish to be responsible for the operation of a CMR laboratory. Level 3 criteria must include adequate 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 results with other relevant clinical and laboratory testing. 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 (ACGME)—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 nonacademic medical center accredited for CMR by an organization such as the ICAMRL. Under these circumstances it is acceptable to provide the training in CMR at such a medical center for all levels of training. The CMR training center and the trainee should maintain a logbook or other specific records to document the cases reviewed 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, specialized training and, for academic trainees, research training related to CMR 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 integrated with other training activities. This experience should provide basic background knowledge in CMR sufficient for the practice of adult cardiology and referral for CMR evaluation, but not for the practice or 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.

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 his or her 1 month of training, the trainee 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 tomographic, or hemodynamic data are available, this other imaging information should be correlated with CMR studies. Studies should include the range of procedures listed in Table 1. Experience in interpretation (a minimum of 25 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 consisting 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, costs, artifacts, indications, contraindications, and pitfalls must be included for each cardiovascular diagnostic subset. Such information could be effectively transmitted within a weekly noninvasive 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, T2, density of nuclear species (e.g., proton), and contrast agents; 2) sources of artifacts, including motion, arrhythmias, and metal objects; 3) safety of implanted devices (e.g., pacemakers, automatic implantable cardioverter-defibrillators), external ferromagnetic devices, and gadolinium-based contrast agents (for a summary of safety issues in CMR, see www.mrisafety.com); and 4) basic post-processing approaches 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 include the CMR experience described for Level 1. Level 2 is for those trainees who wish to practice the clinical subspecialty 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 1 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

An understanding of CMR physics should be substantially more advanced than in Level 1 training (see the following text).

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-mentor. 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 scanning procedure, 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 are essential.

Lectures and self-study in CMR. Course work would include the components for Level 1 training but should also 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 (who has achieved Level 2 or 3 in CMR) and/or physicist on the basic physics of magnetic resonance in general and as it relates to 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, image contrast mechanisms, and fat suppression)
   b. Imaging of function (cine and tagged cine magnetic resonance including SSFP imaging approaches)

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 imaging using a contrast agent
g. Magnetic resonance angiography (vascular)
h. Mechanisms, types, and pharmacologic aspects of CMR contrast agents
i. 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)
j. Magnetic resonance spectroscopy methods (e.g., depth resolved surface coil spectroscopy, or DRESS, and 3-dimensional Fourier transform approaches)
k. CMR image analysis and post-processing tools
l. Contraindications for CMR study
m. 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, the interactive role of the operator during the performance of CMR studies, and the interpretation of the data acquired during daily reading sessions. This may be supplemented by formal didactic training.

Level 3: Advanced Training (at Least 12 Months for Those Interested in Pursuing a Clinical or Academic Career in CMR or Directing a CMR Laboratory)

Level 3 CMR training represents the highest level of training and would enable the cardiovascular trainee to pursue a clinical or 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 an ongoing basic and/or clinical CMR research, with independent responsibility for a specific portion of that research. Focused research work with publication of 1 or more manuscripts is an essential component 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, which 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 cases with the Level 3 mentor. 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 details of the way in which the case was derived are essential.

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

1. An understanding 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 approaches for quantitating 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.

Table 3 Summary of Requirements for Each Level of CMR Training

Level	Duration of Training (Months)	Number of Cases
1	1	25+ mentored interpretations (by a Level 2– or Level 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	At least 12 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 cardiovascular magnetic resonance (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.

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APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 12: TRAINING IN ADVANCED CARDIOVASCULAR IMAGING (CARDIOVASCULAR MAGNETIC RESONANCE [CMR])

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