

Task Force 3: Training in Diagnostic and Interventional Cardiac Catheterization

Endorsed by the Society for Cardiovascular Angiography and Interventions

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Background

Since the second edition of Task Force 3 of the American College of Cardiology (ACC) Core Cardiology Training Symposium (COCATS) guidelines was published (1), both the cognitive knowledge and technical skill required of the invasive and interventional cardiologist have continued to grow. Concomitantly, the role of the cardiac catheterization laboratory in trainee education and as a clinical care facility continues to evolve. The cardiac catheterization laboratory serves as both a diagnostic and therapeutic facility. It has an important diagnostic role in the evaluation and management of all types of heart disease: coronary, valvular, congenital, and primary myocardial. This role includes invasive hemodynamic measurements and angiographic delineation of cardiovascular anatomy and pathology. The information derived from these studies has a complementary overlap with that derived from other diagnostic modalities such as echocardiography, computed tomography (CT), and magnetic resonance imaging (MRI). This relationship has value both in enhancing diagnostic accuracy and in fostering the understanding of cardiovascular physiology, pathology, and pathophysiology. The widespread use of echocardiography in addition to the growing use of cardiovascular magnetic resonance (CMR) and CT angiography has also changed the practice of invasive and interventional cardiology. Patients with diagnostic echocardiographic hemodynamic assessment of valvular or myocardial/pericardial disease may be referred for diagnostic coronary angiography only. However, patients in whom the echocardiographic findings are conflicting are still referred to the catheterization laboratory for hemodynamic assessment; these patients are often exceedingly complex. Thus, somewhat paradoxically in this era of enhanced noninvasive imaging, the understanding and proper performance of detailed hemodynamic evaluation in such patients is of even greater importance.

The therapeutic role of the cardiac catheterization laboratory continues to increase as interventional cardiology procedures are applied to increasingly complex and critically ill patients.

Urgent catheterization and percutaneous revascularization are now considered to be the standard of care for patients with unstable coronary ischemic syndromes, ST-elevation myocardial infarction, and cardiogenic shock. Furthermore, new adjunctive pharmacologic regimens and interventional devices have emerged. In addition, many noncoronary therapeutic procedures including percutaneous closure of atrial septal defects and patent foramen ovale, valve repair or replacement, and septal artery ablation are currently in various stages of investigation and are likely to significantly expand the scope of the field of interventional cardiology. This evolution has increased the cognitive and technical knowledge base required of invasive and interventional cardiologists. Consequently, this document revises and updates the standards for training in invasive cardiology.

The American Board of Internal Medicine (ABIM) provides an added qualification certifying examination in interventional cardiology, and the Residency Review Committee of the American Council for Graduate Medical Education (ACGME) has a formal accreditation mechanism for interventional cardiology training programs. The recommendations in this document are consistent with the requirements of the ABIM and the ACGME. In 1999, the ACC published a training statement on recommendations for the structure of an optimal adult interventional cardiology training program (2), and the recommendations are summarized in this document.

Program Accreditation

Training in diagnostic cardiac catheterization (Levels 1 and 2) must occur within a cardiology training program that is fully accredited by the ACGME. If the program does not include an accredited training program in interventional cardiology, exposure to an active interventional cardiology program should be provided. Training in interventional cardiology (Level 3) must occur within an ACGME-accredited program. All interventional cardiology training programs in the United States must satisfy the basic standards developed by the ACGME

and must be accredited by the ACGME for candidates to be eligible for the clinical interventional cardiology certificate of added qualification of the ABIM. The ACGME standards represent the qualifying requirements. This document endorses the ACGME standards for program accreditation and makes additional recommendations over and above those standards.

Program Goals

The ultimate goal of a cardiac catheterization training program is to teach the requisite cognitive and technical knowledge of invasive cardiology. This includes indications and contraindications for the procedures, pre- and post-procedure care, management of complications, and analysis and interpretation of the hemodynamic and angiographic data. The cardiac catheterization laboratory provides a platform for the teaching of the core knowledge bases of cardiac anatomy, pathology, physiology, and pathophysiology that should be possessed by all cardiologists whether or not they perform invasive cardiovascular procedures. In addition, it is the facility that provides training in the basic intravascular catheter insertion and manipulation skills needed to care for cardiac patients in critical care environments. The trainee's overall professional goals determine the requisite knowledge and skill set to be acquired. In general, trainees may be divided into 3 broad groups with differing training requirements:

Level 1—Trainees who will practice noninvasive cardiology and whose invasive activities will be confined to critical care unit procedures. However, this level will provide training in the indications for the procedure and in the accurate interpretation of data obtained in the catheterization laboratory.

Level 2—Trainees who will practice diagnostic but not interventional cardiac catheterization.

Level 3—Trainees who will practice diagnostic and interventional cardiac catheterization.

Each level has specific goals for training that build on each other and which are detailed in the following text. All cardiologists should have Level 1 knowledge and skills.

Program Structure

Faculty

Faculty should be full-time, experienced, and committed to the teaching program. Exposure to multiple faculty mentors substantially enhances the quality of a training experience. The faculty should consist of a program director, key faculty, and other associated faculty. An optimal program should have a minimum of 3 key faculty members, one of whom is the program director and each of whom maintains a minimum procedural volume of 150 diagnostic catheter-

ization procedures per year and devotes at least 20 h per week to the program. Associated faculty may have varying levels of commitment and involvement in the program.

Program Director

The program director for the invasive cardiology curriculum should be certified in cardiovascular medicine by the ABIM and should be recognized as an expert in cardiac catheterization. Preferably, the program director will have completed his or her training at least 5 years previously and will be a full-time faculty member of the overall cardiovascular training program and committed to medical education and teaching. If the program also provides training in interventional cardiology, the program director must be board-certified in interventional cardiology and should have a career experience of at least 5 years after completion of training, including an aggregate experience of 1000 coronary interventional procedures. The program director should be responsible for the invasive teaching curriculum and overall teaching program in addition to trainee evaluation. If the program director is the director of the catheterization laboratory, this individual should also be responsible for the administration of the laboratory, quality assurance, and radiation safety.

Other Key Faculty

Key faculty members should be certified in cardiovascular medicine by the ABIM and have expertise in all aspects of diagnostic procedures, including the evaluation of coronary, valvular, congenital, and cardiomyopathic disease, and should be familiar with complex hemodynamics in patients with all types of heart disease. The program faculty should include individuals with expertise in the performance of myocardial biopsies, trans-septal catheterization, and the interpretation and performance of intracoronary ultrasound and intracoronary physiologic assessment (Doppler coronary flow and intracoronary pressure measurement), although each member need not have expertise in every area. If the program also provides training in interventional cardiology, its faculty must satisfy the requirements for accreditation in interventional cardiology by the ACGME (http://www.acgme.org/acWebsite/RRC_140/140_prIndex.asp) and the requirements outlined in the previously published ACC training statement (2). Ideally, in institutions where patient volume is adequate, the program should include faculty who possess skills in advanced interventional cardiovascular techniques such as patent foramen ovale and atrial septal defect closure, septal ablation for hypertrophic obstructive cardiomyopathy, and balloon valvuloplasty. In addition, ideally the program should include faculty with expertise in peripheral vascular disease.

Facilities and Environment

All training facilities must be equipped and staffed to function in accordance with the ACC/Society for Cardiovascular Angiography and Interventions clinical expert con-

sensus document on cardiac catheterization laboratory standards (3).

X-Ray Imaging Equipment

The cardiac catheterization laboratory must generate high quality X-ray digital images during diagnostic and interventional catheterization procedures. The laboratory must have access to the support personnel needed to ensure that image quality is optimal and that radiation exposure to patients and staff is minimized.

Hemodynamic Monitoring and Recording Equipment

The facility must have high-quality physiologic monitoring and recording equipment to permit the accurate assessment of complex hemodynamic conditions. The presence of equipment for assessment of coronary physiology such as fractional flow reserve, Doppler coronary velocity, and coronary anatomy such as intravascular ultrasound and intracardiac echocardiography (the latter for programs performing percutaneous treatment of structural heart disease), is strongly recommended.

Ancillary Support Capabilities

The program must have on-site access to all core cardiology services, including a cardiac critical care facility, echocardiography, stress testing with nuclear imaging, and electrophysiologic testing. Required on-site support services for interventional cardiology training include cardiac surgery, anesthesia, vascular and interventional radiology, vascular surgery, nephrology, and hematology.

Program Activity Level and Patient Mix

Level 1 and Level 2 training require comprehensive exposure to the full variety of cardiovascular disorders and clinical procedures. This is important not only to provide direct hands-on training experience but also to provide the requisite material for clinical conferences. In addition to experience with the many manifestations of coronary artery disease, all trainees should also acquire experience in the hemodynamic assessment, evaluation, and management of patients with valvular, myocardial, and congenital heart disease. Level 3 training requires exposure to the full spectrum of cardiac ischemic syndromes and noncoronary heart disease (2) to provide comprehensive experience in the scope of interventional cardiology procedures and to maintain faculty expertise.

Duration of Training

Level 1 (Minimum of 4 Months)

Level 1 training requires a minimum of 4 months of experience in the cardiac catheterization laboratory. During this period, a trainee should participate in a minimum of 100 diagnostic cardiac catheterization procedures over a period of 2 to 3 years (Table 1). Only one Level 1 trainee may claim credit for participation in a given procedure. An essential part of this training is the instruction in evaluating hemodynamic data and reading cardiac and coronary angiographic studies, and the trainee should acquire Level 1 cognitive knowledge (see Training Program Curriculum).

Level 2 (Minimum of 8 Months Over a 3-Year Period)

Level 2 training requires a minimum of 8 months (over the course of 3 years) in the cardiac catheterization laboratory and participation in the performance (under direct supervision) of a minimum of 300 diagnostic cardiac catheterization procedures (Table 1). Only one Level 2 trainee may claim credit for participation in a given procedure. During this period, the trainee should acquire Level 2 cognitive knowledge (see Training Program Curriculum).

Level 3

Level 3 training must be performed during a fourth year of fellowship dedicated primarily to cardiovascular interventional training (2). During this period, the trainee should participate in a minimum of 250 coronary procedures (Table 1) (with each patient counting as 1 procedure regardless of the number of interventions) in addition to other noncoronary interventional procedures and acquire Level 3 cognitive knowledge (2).

Conduct of Training

The nature of a trainee's participation in a given procedure will vary depending on the procedure's complexity and the trainee's experience level. Requisite participation in a procedure includes the following elements:

1. *Pre-procedural evaluation to assess appropriateness and to plan procedure strategy.* Before the procedure, it is expected that the trainee will review the patient's medical record and obtain a confirmatory history and physical examination, with specific attention given to factors known to increase the risk of the procedure, such as vascular disease, renal failure, history of contrast reaction, congestive heart failure, anemia, active infection,

Table 1 Summary of Training Requirements in Diagnostic and Interventional Cardiac Catheterization

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (Months)	Minimal Cumulative Number of Cases
3	Diagnostic catheterization	1	100	4	100
		2	200	8	300
	Interventional catheterization	3	250	20	550

and conditions known to increase the risk of bleeding. The trainee should also obtain informed consent and document a pre-procedural note that includes indications for the procedure, risks of the procedure, and alternatives to the procedure.

2. *Performance of the procedure by the trainee at a level appropriate to experience, always (at all levels) under the direct supervision of a program faculty member.* Level 1 trainees will begin in a mostly observational role and assume greater participation as experience is gained. Level 2 trainees will assume progressive responsibility for the conduct of diagnostic procedures as they acquire skills. Highly experienced Level 2 (or Level 3) trainees may collaborate in a procedure with Level 1 trainees under the direct supervision of a program faculty member. In this circumstance, both Level 1 and Level 2 (or Level 3) trainees may claim credit for participation in the procedure. Level 3 trainees will assume progressive responsibility for the performance of interventional procedures as they acquire skills.
3. *Participation in the analysis of the hemodynamic and angiographic data obtained during the procedure and preparation of the procedure report.*
4. *Active involvement in post-procedural management both in and out of the catheterization laboratory.* After the procedure, a preliminary catheterization report or note should be placed in the patient's file. The trainee should monitor the patient's status and be available to respond to any adverse reactions or complications that may arise, such as hypotension, vascular complications, heart failure, renal failure, bleeding, or myocardial ischemia. A post-procedural note should be completed before hospital discharge. If a complication occurs, the trainee should participate in the follow-up and management of the complication.

Training Program Curriculum

The trainee should possess the cognitive knowledge and technical skills detailed in the following text.

Knowledge Base

Level 1 Cognitive Knowledge

1. Understand coronary anatomy, its variations, and congenital abnormalities
2. Understand coronary physiology
3. Understand cardiac hemodynamics, including the measurement and interpretation of pressure, flow, resistance, and cardiac output. Understand ventricular and myocardial mechanics and the determinants of cardiovascular performance
4. Interpret hemodynamic findings in a variety of cardiac conditions, including various forms of myocardial disease, pericardial disease, valvular stenosis and regurgi-

tation, congenital heart disease, and pulmonary vascular disease. Understand how to differentiate the hemodynamics of constrictive pericarditis from restrictive cardiomyopathy

5. Understand the relationship between hemodynamic assessment as determined by invasive measurements and echocardiography in addition to other noninvasive modalities
6. Understand the indications and contraindications for cardiac catheterization and coronary intervention
7. Understand the complications of the procedure and their management, such as hypotension, acute myocardial ischemia, congestive heart failure, renal failure, contrast reactions, retroperitoneal bleeding, cardiac tamponade, vascular problems, arrhythmias, and stroke
8. Select the optimal treatment modality, including medical therapy, percutaneous coronary and noncoronary intervention, or surgical therapy, with understanding of the indications for and risks of each revascularization strategy
9. Understand the indications for and complications of temporary transvenous pacing
10. Understand the indications for and complications of pericardiocentesis and recognize tamponade physiology
11. Understand the indications for and complications of other laboratory procedures, such as endomyocardial biopsy, intra-aortic balloon counterpulsation, and retrieval of foreign bodies
12. Understand basic principles of X-ray imaging, radiation protection, and radiation safety
13. Understand the anatomy of and methods to access cardiac chambers and coronary arteries via the femoral, brachial, and radial access sites
14. Interpret diagnostic coronary angiograms and appreciate the interface with noninvasive techniques of coronary imaging
15. Interpret ventricular, atrial, and aortic angiography and determine left ventricular ejection fraction
16. Understand the indications for and complications of contrast agents, the risk of contrast nephropathy, and the risks and benefits of various renal protective regimens
17. Understand the indications for and complications of drugs commonly used for invasive procedures, such as unfractionated heparin, low-molecular-weight heparin, glycoprotein IIb/IIIa receptor antagonists and other antiplatelet drugs, direct thrombin inhibitors, vasopressors, vasodilators, and fibrinolytic and antiarrhythmic agents
18. Understand the indications for and the mechanisms of action of mechanical circulatory support devices
19. Understand the indications for and complications of vascular closure devices

Level 1 Technical Skills

1. Perform percutaneous vascular access from the femoral artery and vein and subclavian or internal jugular vein

2. Perform right heart catheterization using a balloon flotation catheter
3. Perform temporary right ventricular pacemaker insertion
4. Perform left heart catheterization and coronary angiography of native arteries (using standard views) and left ventriculography under supervision

Level 2 Cognitive Knowledge

1. All Level 1 items
2. Understand radiologic imaging, including design and operation of X-ray cineradiographic units, digital imaging and storage, radiation physics, factors influencing image quality, radiation quality assurance, and physiology of X-ray contrast media
3. Understand the basic operation of physiologic recorders, pressure transducers, oximeters, and oxygen consumption measurement equipment
4. Understand coronary physiology using techniques such as Doppler flow and fractional flow reserve
5. Understand the indications for and methods of performing trans-septal catheterization
6. Acquire knowledge of peripheral vascular anatomy and understand the indications and complications of peripheral vascular angiography

Level 2 Technical Skills

1. All Level 1 items
2. Perform vascular access from the femoral, radial, or brachial route
3. Perform left heart catheterization and coronary angiography, as well as visualization of venous bypass and internal mammary and radial artery grafts
4. Perform angiography of the cardiac chambers (in addition to the left ventricle) and aorta
5. Perform intra-aortic balloon insertion and operate a balloon pump
6. Perform cardiac catheterization in common types of valvular, adult congenital, and cardiomyopathic heart disease
7. Perform pericardiocentesis, preferably under echocardiographic guidance
8. Perform right ventricular endomyocardial biopsy
9. Perform vascular closure device insertion
10. Perform aortography and femoral artery angiography

Level 3 Cognitive Knowledge and Technical Skills

The trainee should possess the cognitive knowledge and technical skills outlined in the previously published ACC training statement (2). In addition, the trainee should acquire knowledge about trans-septal catheterization, percutaneous management of access site complications, and management of other complications of including but not limited to coronary perforation, no reflow (and its prevention), and stent thrombosis. The trainee should obtain a core experience in balloon angioplasty, intracoronary stents, atherectomy techniques, distal (and proximal) protection

devices, intravascular ultrasound, and measurement of fractional flow reserve. Familiarity with noncoronary (peripheral) angiography and intervention should be encouraged.

Conferences

Levels 1 and 2

All trainees must attend a regular cardiac catheterization conference. This may be a combined medical/surgical conference. The conference must present hemodynamic and angiographic data that are discussed in context with history, physical examination, and noninvasive findings. Indications, complications, and management strategies should also be discussed. It is particularly important that the Level 1 and 2 curriculum focus on teaching hemodynamics, cardiovascular physiology, and the pathophysiology of the major cardiovascular disorders. In this role, it is important that the cardiac catheterization program establish a close liaison with other noninvasive diagnostic laboratories, particularly the echocardiography laboratory. The educational program should emphasize the relationships between the findings provided by the different diagnostic modalities in order to create a clear picture of the physiology and pathophysiology of the various cardiovascular disorders. A regular morbidity and mortality conference, either as part of the cardiac catheterization conference or as a separate conference, is also required.

Level 3

The interventional cardiology training program should conduct a regularly scheduled clinical interventional cardiology conference at least weekly (2) and journal club at least monthly.

Research

All trainees should be exposed to the principles of research and to research conducted in the cardiac catheterization laboratory. For those who plan to perform independent catheterization and angiography, it is desirable that they actively participate in the research and attend research conferences that discuss such studies. Those planning a career in interventional cardiology must participate in research, either during their 3-year fellowship training or during their subsequent interventional training.

Trainee Evaluation

Trainee evaluation involves 3 components: cognitive, technical, and documentary. Case selection and pre-, intra-, and post-procedural care and judgment must be evaluated in every trainee. Facilities that foster the trainee's involvement in the continuum of care (outpatient or inpatient) from pre-procedural assessment to post-procedural follow-up are required. In every trainee, interpretive skills that relate to assessment of complex hemodynamics, coronary angiographic images, and physiologic studies must also be eval-

uated. Quality of clinical follow-up, reliability, interaction with other physicians, patients, and laboratory support staff, and the initiative and ability to make independent, appropriate decisions are to be considered. The individual must have knowledge of the specific equipment to be used in each procedure, including X-ray contrast, diagnostic catheters, and potential closure devices. Assessment of technical performance is also a requirement. This is best done by direct oversight during procedures of actual handling of equipment and devices, by assessment of the interaction of the trainee with the device and specific anatomy being treated, and by procedural complication rate. The competence of all cardiology trainees in cardiac catheterization should be documented by both the cardiovascular program director and the program director of the cardiac catheterization laboratory. All procedures performed by the trainee must be documented electronically or in a logbook.

Responsibility for trainee evaluation resides with the catheterization laboratory program director, who performs the assessment of the success of the trainee's progress in collaboration with the other program faculty. The overall evaluation includes rigorous compilation of trainee experience and assessment of the trainee's cognitive knowledge, technical skill, and clinical and procedural judgment. Evaluative feedback, verbal and written, to the trainee on a

bi-annual basis during the training period is vital to direct the trainee's progress.

This is a revision of the April 2002 document that was written by Alice K. Jacobs, MD, FACC—Chair; David P. Faxon, MD, FACC; John W. Hirshfeld, Jr., MD, FACC; and David R. Holmes, Jr., MD, FACC.

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Key Words: ACCF Training Statement ■ COCATS 3 ■ diagnostic cardiac catheterization ■ interventional cardiac catheterization.

APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 3: TRAINING IN DIAGNOSTIC AND INTERVENTIONAL CARDIAC CATHETERIZATION

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Dr. David R. Holmes, Jr.	None	None	None	None	None	None	None
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APPENDIX 2. PEER REVIEWER RELATIONSHIPS WITH INDUSTRY—ACCF 2008 RECOMMENDATIONS FOR TRAINING IN ADULT CARDIOVASCULAR MEDICINE CORE CARDIOLOGY TRAINING (COCATS 3)—TASK FORCE 3: TRAINING IN DIAGNOSTIC AND INTERVENTIONAL CARDIAC CATHETERIZATION

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Task Force 4: Training in Echocardiography

Endorsed by the American Society of Echocardiography

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Echocardiography is currently the most widely used imaging technique for assessing cardiovascular anatomy and function. Clinical application of ultrasound encompasses M-mode, two-dimensional (2D), pulsed, and continuous-wave Doppler and color-flow imaging. Echocardiography, like invasive catheterization, provides information concerning cardiovascular anatomy, function (i.e., ejection fraction), hemodynamic variables (i.e., gradient or pressure), and flow

disturbances by means of pulsed, continuous-wave, and color-flow Doppler imaging. Today, an echocardiography laboratory can appropriately be called an ultrasound imaging and hemodynamic laboratory.

Fellowship training in echocardiography should include instruction in the basic aspects of ultrasound, but only those fellows who go beyond the basic level are trained sufficiently for independent interpretation of echocardiographic studies.