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ACC/ACP/SCAI/SVMB/SVS CLINICAL COMPETENCE STATEMENT

ACC/ACP/SCAI/SVMB/SVS Clinical Competence Statement on Vascular Medicine and Catheter-Based Peripheral Vascular Interventions

A Report of the American College of Cardiology/ American Heart Association/American College of Physicians Task Force on Clinical Competence (ACC/ACP/SCAI/SVMB/SVS Writing Committee to Develop a Clinical Competence Statement on Peripheral Vascular Disease)

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PREAMBLE

The granting of clinical staff privileges to physicians is a primary mechanism used by institutions to uphold the quality of care. The Joint Commission on Accreditation of Health Care Organizations requires that the granting of continuing medical staff privileges be based on assessments of applicants against professional criteria specified in the medical staff bylaws. Physicians themselves are thus charged with identifying the criteria that constitute professional competence and with evaluating their peers accordingly. Yet the process of evaluating physicians' knowledge and competence is often constrained by the evaluator's own knowledge and ability to elicit the appropriate information, problems compounded by the growing number of highly specialized procedures for which privileges are requested.

The American College of Cardiology/American Heart Association/American College of Physicians (ACC/AHA/ACP) Task Force on Clinical Competence was formed in 1998 to develop recommendations for attaining and maintaining the cognitive and technical skills necessary for the competent performance of a specific cardiovascular service, procedure, or technology. These documents are evidence-based, and where evidence is not available, expert opinion is utilized to formulate recommendations. Indications and contraindications for specific services or procedures are not included in the scope of these documents. Recommendations are intended to assist those who must judge the competence of cardiovascular health care providers entering practice for the first time and/or those who are in practice and undergo periodic review of their practice expertise. The assessment of competence is complex and multidimensional, therefore isolated recommendations contained herein may not necessarily be sufficient or appropriate for judging overall competence.

The ACC/AHA/ACP Task Force on Clinical Competence makes every effort to avoid any actual or potential conflicts of interest that might arise as a result of an outside relationship or personal interest of a member of the writing panel. Specifically, all members of the writing panel were asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest. These statements were reviewed by the ACC/AHA/ACP Task Force on Clinical Competence, were reported orally to all members of the Writing Committee at the first meeting, and were updated at each meeting or as changes occurred.

Mark A. Creager, MD, FACC, FAHA
Chair, ACC/AHA/ACP Task Force on Clinical Competence

INTRODUCTION

The discipline of vascular medicine and the performance of catheter-based peripheral vascular interventions are unique areas of competence. This statement on clinical competence in vascular medicine and catheter-based peripheral vascular interventions is designed to assist in the assessment of physicians' expertise in the care of patients with vascular diseases and in the performance of catheter-based vascular procedures. The minimum education, training, experience, and cognitive skills necessary for the evaluation and management of all vascular diseases, including arterial, venous, and lymphatic diseases, are specified. Also specified are the minimum education, training, experience, and cognitive and technical skills necessary for the performance of catheter-based peripheral procedures, including angiography, percutaneous transluminal angioplasty, insertion of stents and stent grafts, thrombolysis and thrombectomy. It is important to note that these are minimum training and experience requirements for the assessment of expertise in this discipline and these procedures in the broadest sense. Whenever possible, the specifications are based on published data that link these factors with competence or, in the absence of such data, on the consensus of expert opinion. The specifications are applicable to most practice settings and can accommodate a number of ways in which physicians can substantiate expertise and competence in the evaluation of patients with vascular disease and in the performance of specific catheter-based vascular procedures. The Writing Committee included representatives from the American College of Cardiology (ACC), the American College of Physicians (ACP), the Society for Cardiovascular Angiography and Interventions (SCAI), the Society for Vascular Medicine and Biol-

ogy (SVMB), and the Society for Vascular Surgery (SVS). In addition to content peer reviewers, "official" reviewers were provided by the ACC, ACP, SCAI, SVMB, and SVS. This document was approved for publication by the governing bodies of the ACC, ACP, SCAI, SVMB, and the SVS.

Rationale for Developing a Competence Statement

In this document, the term peripheral vascular diseases refers to diseases of arteries, veins, and lymphatic vessels, including atherosclerotic disease of the aorta and its principal branches, the brachiocephalic, extracranial carotid, mesenteric, renal, and limb arteries, aneurysms of the aorta and peripheral arteries, acute thrombo-embolic arterial occlusion, large and small vessel vasculitis, vasospasm (such as Raynaud's phenomenon), acute venous thrombosis, pulmonary embolism, venous insufficiency, lymphangitis, and lymphedema. Diseases of the coronary arteries and intracranial cerebral vessels are outside the realm of this document.

Vascular diseases constitute some of the most common causes of morbidity and mortality in western society. A coterie of physicians with necessary expertise to manage and coordinate the care of patients with vascular disease is required, particularly as the scientific community is making such rapid advancement in vascular biology, pharmacology, and technology.

Indeed, these scientific advances have substantially increased the diagnostic and therapeutic capabilities applicable to vascular disease. Thus, a substantial body of knowledge exists that permits medical practitioners to recognize and treat many forms of vascular disease. Vascular disease is often clinically occult yet may present with catastrophic events. Early recognition and appropriate preemptive treatment of the underlying disease and its pathogenetic factors can potentially avoid such occurrences. Hence, it is important that physicians be aware of vascular disease and be familiar with both the diagnostic and therapeutic techniques available.

Though internists, family physicians, general surgeons, and radiologists should possess core knowledge of vascular medicine, it is unreasonable to expect the majority of such physicians to hold the entire vascular medicine knowledge base. Thus, there is a role for specialists who have more in-depth understanding of the diagnosis and management of vascular disease. Medical specialists trained in the distinct disciplines of cardiovascular medicine, interventional radiology, and vascular surgery are all involved in the diagnosis and management of peripheral vascular diseases, albeit from differing perspectives. These perspectives, however, also share many common features, emphasizing the importance of a broadly based, multidisciplinary approach for management. These specialist physicians also can be subdivided into those who practice the cognitive aspects of vascular medicine, including evaluation and medical management, and those who, in addition, perform vascular procedures—either catheter-based or surgical. Each of these subsets of physicians concerned with the care of the patient with vascular disease must hold a specialized knowledge base that is applicable to their particular discipline. This document addresses the minimal knowledge base required for expertise, the education and training pathways available to acquire that expertise, and the requirements to maintain expertise for each of two related disciplines that involve the care of patients with vascular diseases. The first of these, vascular medicine, is defined hereafter as a medical area of competence that involves the comprehensive evaluation and management of patients with vascular disease. The second is vascular intervention, defined herein as an area of competence that involves the performance of catheter-based, peripheral (noncoronary) vascular interventions. Vascular surgery is a distinct subspecialty dedicated to the care of patients with vascular disease. However, a detailed discussion of the specialized qualifications for the performance of vascular surgical procedures falls outside the realm of this document and the reader is referred to published guidelines (1,2). Accordingly, this document is presented in two major sections: 1) vascular medicine, and 2) catheter-based peripheral vascular interventions. In each section, the document describes the cognitive, clinical, and/or procedural skills required for expertise, the training necessary for achieving competence, and the means for maintaining expertise and competence.

Distinguishing Expertise in Vascular Medicine From Expertise in Catheter-Based Peripheral Interventions

Expertise in caring for patients with vascular disease requires a comprehensive and sophisticated knowledge base of vascular diseases, skills in patient evaluation, and a thorough understanding of the therapeutic options available to treat these patients. Physicians with expertise in vascular medicine would be expected to diagnose and coordinate treatment of all vascular disorders, including aortic diseases, peripheral arterial disease, cerebrovascular disease, renal artery stenosis, vasculitis, atherothrombotic embolism, vasospastic disease, autonomic dysfunction, venous thromboembolic disease, chronic venous disorders, lymphatic disease, as well as other less common vascular diseases. They should also be able to identify and treat disorders that contribute to vascular disease, such as dyslipidemia, hypertension, diabetes, and hypercoagulable states. These physicians should understand the epidemiology, pathology, pathophysiology, clinical presentation, natural history, and therapeutic options relevant to each vascular disease. Expertise in the noninvasive vascular laboratory, including the ability to perform and interpret duplex ultrasound examinations of the veins and arteries of the limbs, the aorta and its branches, carotid arteries, and vascular bypass grafts, and also physiologic tests of peripheral arteries and veins, is desirable. In addition, specialists in vascular medicine should be skilled in the interpretation of other imaging

modalities, including magnetic resonance and contrast angiography. Physicians who specialize in vascular medicine also should have a thorough understanding of the indications for, and potential outcomes of, invasive diagnostic procedures, catheter-based treatments, and vascular surgery.

Physicians with expertise in catheter-based peripheral vascular interventions must possess many of the cognitive skills required of the vascular medicine specialist. In addition, the catheter-based vascular interventionalist must have a particular fund of knowledge, technical skills, and clinical judgment requisite for performing noncardiac, catheter-based interventional procedures. Expertise in catheter-based peripheral vascular intervention includes a knowledge of cardiovascular angiographic laboratory equipment, such as physiologic recorders, pressure transducers, image intensifiers and other X-ray equipment, cine processing, digital imaging, and image archiving. Expertise in catheter-based vascular interventional procedures also requires knowledge of the indications, limitations, and complications of these procedures and an understanding of alternative treatment methods. Also, the vascular interventionalist should be knowledgeable about adjunctive medical and surgical therapies requisite to optimizing both short- and long-term outcomes.

Advances in our understanding of vascular diseases, new treatment modalities, and the evolution of catheter-based therapy have created models whereby physicians generally emphasize either noninvasive or invasive skills in managing patients with vascular disease. Thus, although some physicians will have comprehensive expertise in both vascular medicine and catheter-based vascular interventions, most will choose to develop skills within one of these two areas. Fundamental knowledge is required for all physicians caring for patients with vascular diseases, but it is expected that those with expertise in vascular medicine will be able to evaluate, medically manage, and refer appropriately for catheter-based and surgical interventions, whereas those with expertise in catheter-based interventions will possess the requisite technical skills and have a thorough understanding of the diseases that they are treating.

VASCULAR MEDICINE

Justification for Recommendation

The concept of vascular medicine has evolved slowly in the U.S. Over the past two decades, dramatic advances have occurred in diagnostic capabilities, pharmacotherapy, surgical techniques, and endovascular interventions. Important new developments in vascular biology and pathophysiology have paralleled these technical advances and greatly increased our understanding of atherogenesis, atherosclerosis, thrombosis, and vasculitis. These have led to important discoveries in drug therapies, including statins, renin-angiotensin system inhibitors, and antiplatelet, antithrombotic, and thrombolytic agents that have substantially reduced the morbidity and mortality of vascular disease. Great opportunities exist for early diagnosis and effective treatment of many vascular diseases, and it is time that the medical profession recognizes vascular medicine as a specialty area comprised of individuals with "specialized" training and with skills that have met defined measures of expertise and competence.

Today, several medical disciplines are dedicated to the care of patients with vascular diseases, including vascular medicine (per se), cardiovascular medicine, vascular surgery, and interventional radiology. In this document, vascular medicine is defined as an area of competence in which the practitioners thoroughly understand the nature of vascular disease and possess skills for the comprehensive evaluation and management of patients with vascular diseases. It is important to emphasize that vascular surgery training provides in-depth exposure, not only to surgical and endovascular techniques, but also to the pathophysiology, diagnosis, and medical management of vascular disease. Indeed, for the past 50 years, vascular surgeons, in addition to performing operations, have functioned as principal care providers for patients with peripheral vascular disease. Vascular surgeons will continue to provide a significant proportion of the nonoperative vascular care to these patients.

The justification for recognizing vascular medicine as a distinct area of medical competency, with clearly defined guidelines for competence, stems from the recognition that vascular disease is the major cause of death and disability in Western society. The number of people with vascular disease exceeds 25 million in the U.S. and the numbers will increase further as the population ages. Novel technologies are permitting opportunities for more accurate diagnosis, and new discoveries in vascular biology are being translated to therapeutics at a phenomenal pace. Thus, substantial benefits for the comprehensive care of patients with vascular disease can accrue when vascular medicine physicians are working together with vascular surgeons and interventional radiologists to coordinate the principal responsibilities of diagnosis, acute interventional treatment, and longitudinal management. For these reasons, this portion of the document focuses on the qualifications required for specialization in vascular medicine in order to establish a framework for the growth and development of this medical area of competence. In this document, the term vascular medicine specialist is used to define a physician who has acquired competence in vascular medicine.

The indications and recommendations for the minimum education, training, experience, and skills necessary to establish expertise in vascular medicine are derived from the ACC's Core Cardiology Training in Adult Cardiovascular Medicine (COCATS) document, the Society for Vascular Medicine and Biology's Vascular Medicine Training Guidelines, and the ACC's Recommendations for Training in Vascular Medicine (3–5). In the absence of a formal certification process by the American Board of Medical Specialties, acknowledgment of expertise in vascular medicine must be determined on an individual basis and may

Table 1. Cognitive Skills Required for Competence in Vascular Medicine

The vascular medicine physician should be knowledgeable about each of the following:
• Vascular biology precepts that govern normal blood vessel function
• Pathologic mechanisms that lead to vascular disease, including the molecular and cellular processes that result in atherosclerosis and thrombosis
• Systemic manifestations of atherosclerosis and the risk factors that contribute to its development
• Guidelines established to modify risk factors
• Pathophysiology, clinical manifestations, natural history, evaluation, and management of peripheral arterial disease, renal artery stenosis, extracranial cerebrovascular disease, aortic and peripheral artery aneurysms, and other arterial diseases
• Pathophysiology, clinical manifestations, evaluation, and management of venous thromboembolism
• Prothrombotic disorders including inherited and acquired hypercoagulable states
• Pathophysiology, clinical manifestations, evaluation, and treatment of chronic venous insufficiency and lymphedema
• Preoperative evaluation and perioperative care of the vascular surgery patient
• Noninvasive vascular tests including duplex ultrasonography of peripheral arteries and veins, carotid arteries, renal arteries, and physiologic tests of the peripheral circulation
• Magnetic resonance and computed tomographic angiography
• Conventional contrast angiography

include successful completion of a vascular medicine training program and confirmation of the individual's experience and competence by the training program director.

Many physicians will acquire expertise in vascular medicine by supplementing their training during a cardiovascular medicine fellowship. Board certification in cardiovascular diseases acknowledges some expertise in vascular medicine, but this is not adequate to validate competence as a vascular medicine specialist. Physicians who have been certified in internal medicine may receive specialized training in vascular medicine at centers where this training is available, or make special arrangements to acquire the breadth and depth of training required for competence. Similarly, vascular surgeons and interventional radiologists may seek to acquire additional training in vascular medicine. Several comprehensive vascular medicine training programs exist, but the numbers are not adequate to accommodate the needs of the many individuals seeking expertise in this area. Therefore, other disciplines may be involved in the training, including cardiology, hematology, neurology, vascular surgery, and radiology.

Minimal Knowledge and Skills Required for Expertise

Fundamentals of vascular biology. The vascular medicine physician should have a fundamental understanding of the vascular biology precepts that govern normal blood vessel function and those that mediate vascular injury and diseases, such as atherosclerosis, thrombosis, and vasculitis. Expertise in vascular medicine requires: knowledge of normal blood vessel characteristics including the gross, histologic, and cellular components that comprise vascular structure and regulate vascular function; knowledge of vascular anatomy; knowledge of hemorheology, including viscosity and shear; and knowledge of vascular hemodynamic characteristics, such as flow, resistance, pressure, and compliance. There should also be an understanding of the normal neural and humoral mechanisms that regulate blood vessel function as well as knowledge of the autocrine and paracrine substances that modulate vascular function. It is also important that the vascular medicine specialist have knowledge of the mechanisms that normally regulate hemostasis, which include an understanding of the humoral and cellular processes involved in coagulation, platelet function, and fibrinolysis. Knowledge of the pathophysiologic mechanisms that lead to the clinical manifestations of vascular diseases is essential. This includes an understanding of atherogenesis and the molecular and cellular processes that result in atherosclerosis. Likewise, there should be appreciation of the substances and mechanisms that regulate platelet adhesion, activation, and aggregation and familiarity with the interaction between platelets and components of the coagulation cascade and the local fibrinolytic system, as there is important interdependence between plaque and the thrombotic consequences of plaque rupture. The vascular specialist should be cognizant of the vascular and hematologic mechanisms that cause venous thrombosis. This too requires an understanding of the molecular, cellular, and humoral components of thrombus formation and propagation, including the role of vascular injury and inherited and acquired procoagulant factors. The vascular medicine expert also must possess knowledge of the immunologic mechanisms and inflammatory processes that cause the vascular pathologic changes responsible for the various clinical manifestations of vasculitis.

Evaluation and Medical Management of Patients With Vascular Diseases

Specialists in vascular medicine must possess a broad range of cognitive skills to evaluate and manage patients with vascular disease (Table 1). Expertise in vascular medicine requires knowledge about the systemic manifestations of atherosclerosis and the risk factors that contribute to its development. Vascular medicine physicians must be cognizant about the adverse effects of smoking, obesity, and inactivity, and be skilled in counseling lifestyle changes to promote cardiovascular health. There should be familiarity

with guidelines established to modify risk factors such as those provided by the Joint National Committee on the Detection, Evaluation and Treatment of High Blood Pressure; the American College of Chest Physicians; the National Cholesterol Education Program; and the American Diabetes Association (6–9). The vascular specialist should be knowledgeable about pharmacotherapy employed to prevent the progression of atherosclerosis and adverse cardiovascular events.

The vascular medicine specialist must have expertise in the evaluation and medical management of peripheral arterial disease and be especially aware of the potential limb complications related to critical ischemia and the risk for adverse and potentially fatal cardiovascular events such as myocardial infarction and stroke. There should be a comprehensive understanding of the utility of noninvasive diagnostic tests used to evaluate peripheral arterial disease (including the ankle brachial index, segmental blood pressures, pulse volume recordings, duplex ultrasound, magnetic resonance angiography, and computed tomographic angiography). The specialist should be familiar with exercise rehabilitation and be knowledgeable about the medical therapies used to reduce symptoms of peripheral arterial disease and improve quality of life. Both indications for, as well as limitations and potential complications of catheter-based and open surgical interventions for peripheral arterial disease should be clearly understood.

In addition, the vascular specialist must understand the pathophysiology and manifestation of renal artery stenosis and its clinical consequences, hypertension, renal insufficiency, and congestive heart failure. Expertise requires knowledge about the noninvasive tests to be used to diagnose renal artery stenosis and familiarity with the indications and contraindications for catheter-based and surgical interventions. Similarly, there should be a comprehensive understanding of the pathophysiology and clinical manifestations of mesenteric vascular diseases, as well as knowledge of the diagnostic evaluation and indications for intervention.

The vascular medicine specialist must know the natural history of extracranial carotid atherosclerosis, and the signs and symptoms of cerebrovascular ischemia and stroke and methods of prevention. The vascular medicine physician must be able to utilize noninvasive modalities available to diagnose and follow patients with carotid artery disease, specifically duplex ultrasound, magnetic resonance angiography, and computed tomographic angiography. There should be familiarity with the medical management of cerebrovascular disease, especially blood pressure control and antithrombotic and lipid-lowering therapy. The specialist should have a basic understanding of the techniques of carotid endarterectomy and carotid stenting, know the indications for, and potential complications of, surgical and catheter-based interventions, and be able to manage these patients medically subsequent to the intervention.

Expertise in vascular medicine requires a basic understanding of the causes and clinical manifestations of aortic and peripheral aneurysms, including less common aneurysms caused by inherited connective tissue diseases and vasculitides. The specialist in vascular diseases must be knowledgeable about the natural history, the diagnostic evaluation, and the indications for surgical and endovascular treatment of aneurysms. Also, the vascular medicine specialist must be capable of recognizing, diagnosing, and instituting treatment for aortic dissection as well as spontaneous dissection of peripheral arteries, especially the carotid and vertebral arteries.

Venous diseases constitute an important component of vascular medicine. Competence requires cognitive and clinical expertise in the evaluation of deep venous thrombosis of the upper and lower extremities. This includes skills in the utilization of duplex ultrasonography, magnetic resonance angiography, and venography. Similarly, the vascular specialist should know the signs and symptoms of acute and chronic pulmonary embolism and the various diagnostic modalities that are useful in making the diagnosis such as ventilation and perfusion lung scanning, spiral computed tomography, magnetic resonance angiography, echocardiography, and pulmonary angiography. The vascular specialist must be able to interpret relevant diagnostic tests and institute appropriate therapy for these conditions. The vascular medicine physician should know when and how to evaluate patients for inherited and acquired hypercoagulable states such as resistance to activated protein C, prothrombin gene mutation, antiphospholipid antibody syndrome, and hyperhomocysteinemia. Effective methods for prophylaxis and treatment of thrombotic disorders, such as those recommended by the American College of Chest Physicians Consensus Conference on Antithrombotic Therapy, should be fully understood (7). Expertise requires knowledge about the use of antithrombotic and thrombolytic agents as well as inferior vena cava filter placement and pulmonary thromboembolectomy.

Chronic venous insufficiency is a common problem encountered by the vascular specialist. Hence, the vascular physician should be able to diagnose and advise management strategies for treatment of chronic venous disease. Vascular medicine physicians must be able to recognize the primary and secondary forms of lymphedema and be familiar with the diagnostic tests and be knowledgeable about the various treatment modalities for patients afflicted with lymphedema.

Competence in vascular medicine requires skill in the diagnosis and management of vasospastic diseases such as Raynaud's phenomenon and other temperature-related vascular disorders, including acrocyanosis, livedo reticularis, pernio, and erythromelalgia. The vascular medicine specialist also should be knowledgeable about uncommon but important vascular disorders such as: Takayasu's arteritis, giant cell arteritis, and thromboangiitis obliterans; connective tissue diseases such as systemic lupus erythematosis, rheumatoid arthritis, scleroderma, and mixed connective tissue diseases; leg ulcers; occupational vascular diseases

Table 2. Cognitive Skills and Training Requirements for Interpretation of Noninvasive Vascular Tests

Cognitive Skills
The vascular medicine physician should be knowledgeable about each of the following: • Physiologic principles governing tests such as limb segmental blood pressure measurements, pulse volume recordings, and treadmill exercise tests • Ultrasound physics, transducer technology, and ultrasound instrument characteristics • Ultrasound instrument settings and transducer manipulation required to obtain an optimal image • Appropriate indications for noninvasive vascular imaging, including duplex ultrasonography of peripheral veins, carotid arteries, peripheral arteries, bypass grafts, and renal arteries • Diagnostic criteria and technical limitations for each test
Training Requirements
The vascular medicine physician should interpret at least 100 cases from each of the following categories: • Physiologic tests (limb segmental blood pressure measurement, pulse volume recordings, treadmill tests) • Peripheral venous duplex ultrasonography • Arterial duplex ultrasonography • Carotid artery duplex ultrasonography • Visceral (renal and mesenteric) artery and venous duplex ultrasonography

such as those related to vibration tools, and hypothenar hammer syndrome; vasospasm caused by illicit drug use (cocaine, amphetamines, ergotamines); fibromuscular dysplasias; vascular malformations; neurovascular compression syndromes, such as thoracic outlet syndrome and popliteal artery entrapment; and cystic adventitial disease.

VASCULAR DIAGNOSTIC LABORATORY

The vascular medicine specialist must have a thorough understanding of all aspects of the noninvasive vascular laboratory. This requires familiarity with ultrasound physics, transducer technology, and ultrasound machine characteristics. The vascular medicine physician should be competent in interpreting noninvasive vascular tests, including duplex ultrasound studies of veins, and of peripheral, carotid, and renal arteries, and should have a detailed knowledge of each of the tests that are performed, their technical limitations, and the criteria for diagnosis of each of the tests (Table 2). Moreover, the vascular specialist should understand physiologic tests such as segmental blood pressures, pulse volume recordings, and treadmill exercise testing.

Guidelines for the minimum number of noninvasive vascular laboratory studies required to achieve competence have been established by the Intersocietal Commission for the Accreditation of Vascular Laboratories (ICAVL) (10). The minimum number of studies to be interpreted is 100 venous duplex examinations, 100 carotid artery duplex examinations, 100 arterial duplex examinations, 100 visceral artery or venous duplex examinations, and 100 physiologic arterial examinations (Table 2).

Magnetic Resonance and Computed Tomographic Angiography

The vascular medicine specialist should be knowledgeable about the application of magnetic resonance and computed tomographic imaging of blood vessels for the evaluation of common arterial and venous disorders including atherosclerosis, thrombosis, vasculitis, aneurysm, and dissection. Vascular medicine expertise includes understanding the basic physical principles underlying magnetic resonance imaging, including intrinsic contrast mechanisms and the use of contrast agents. There should be familiarity with spin-echo, time-of-flight, contrast-enhanced and phase-contrast vascular imaging techniques, and image display formats such as maximum intensity projection and multiplanar reformatting. The vascular specialist should know the technical limitations of magnetic resonance angiography that can affect its application in certain forms of vascular disease.

The vascular medicine physician should know the basic mechanisms of computed tomographic image formation as well as the uses of iodinated contrast agents for vascular imaging. This includes familiarity with image display tools such as projections, reformatting, and three-dimensional rendering. At a minimum, the vascular medicine specialist should be able to understand magnetic resonance and computed tomographic images and apply these to management of diseases of the aorta, carotid, renal, mesenteric, peripheral, and pulmonary circulations. It is not anticipated that vascular medicine physicians would have independent skills in imaging protocol development or primary scan interpretation. Standards for monitoring and interpretation of cardiovascular magnetic resonance images have been developed by the Intersocietal Commission for the Accreditation of Magnetic Resonance Laboratories (ICAMRL) (11) and are under development by the American College of Radiology.

Conventional Contrast Angiography

Vascular medicine physicians should be capable of interpreting conventional contrast arteriograms and venograms. This requires familiarity with arterial and venous anatomy. They should understand the indications and contraindications and potential complications of invasive angiography. It is not anticipated that vascular medicine physicians be skilled

in the performance of angiography, unless they wish to acquire advanced training in catheter-based interventions.

Preoperative Evaluation and Perioperative Care of Vascular Surgery Patients

The vascular medicine physician should possess the cognitive and clinical skills to participate closely with the vascular surgeon and anesthesiologist in the care of patients undergoing vascular surgery. This includes the ability to evaluate coexisting cardiovascular disease, assess risk, and manage adverse cardiovascular events in patients undergoing vascular surgery. A minimal knowledge base includes understanding the indications for operative intervention, salient features of the operation, anticipated outcome, and potential cardiovascular complications. The vascular medicine physician must be able to evaluate the patient's current cardiovascular status, assess cardiovascular risk, and make recommendations regarding the perioperative medical management. Guidelines for the preoperative evaluation for patients undergoing noncardiac surgery, including vascular surgery, have been published (12). Thus, the vascular medicine specialist should possess the skills to evaluate clinical predictors of adverse outcomes, including coronary artery disease, and particularly unstable coronary syndromes, congestive heart failure, arrhythmias, diabetes mellitus, and uncontrolled hypertension. The vascular medicine physician should know the indications for provocative cardiac testing in the preoperative period including treadmill exercise tests, pharmacologic stress tests, nuclear imaging, echocardiography, and cardiac catheterization as required. The vascular medicine physician should be able to evaluate and manage perioperative cardiovascular complications, including acute coronary syndromes, congestive heart failure, and atrial and ventricular arrhythmias. This requires an understanding of the use of pharmacological agents such as beta blockers, vasodilators, and antiarrhythmic and antithrombotic drugs in order to prevent and manage cardiovascular events.

Formal Training to Achieve Competence

There are multiple ways to achieve expertise in vascular medicine. Fellowships are available in vascular medicine for the individual who has completed a three-year internal medicine residency. One year of additional clinical training in vascular medicine would provide a solid knowledge base and satisfy the minimum requirements for competence (4) (Table 3). This includes two to three months devoted to inpatient vascular medicine, three to four months to the noninvasive vascular diagnostic laboratory, one to two months to vascular surgery, one to two months to peripheral angiography and interventions, and one to two months of elective rotations in vascular pathology, thrombosis, rheumatology, or magnetic resonance and computed tomographic imaging. Also, there should be a longitudinal outpatient clinic at least one-half to a full day per week. For the individual training in a cardiovascular fellowship program, the ACC Core Cardiology Training Symposium document offers guidelines for such training (3). It is currently recommended that core training for all cardiovascular fellows include at least two months of vascular medicine, either as dedicated rotations, or in the aggregate as an integral component of other rotations. This fundamental knowledge base will permit the physician to recognize a wide variety of vascular diseases and medical disorders associated with vascular disease, to initiate appropriate medical management, and to appropriately refer patients to a vascular specialist, when necessary, for further evaluation and intervention. This level of training, however, is not sufficient to qualify the trainee as a vascular specialist capable of managing complex vascular patients. For the individual to be deemed competent in all aspects of vascular medicine and be considered a specialist in vascular medicine, another 12 months of training (in addition to the 24 months required for board eligibility in cardiovascular medicine), typically during a third or fourth year, should be solely devoted to vascular medicine. The fundamental components of this training are described in the previous text and in Table 3. The physician who plans to perform peripheral catheter-based therapeutic interventions will be required to complete additional time and training in these special procedures, as discussed later in this document.

Table 3. Training to Achieve Competence in Vascular Medicine*

- Inpatient vascular medicine—2 to 3 months
- Noninvasive vascular laboratory—3 to 4 months
- Vascular surgery—1 to 2 months
- Peripheral angiography and intervention†—1 to 2 months
- Elective rotations (vascular pathology, magnetic resonance and computed tomographic imaging, hematology, rheumatology)—1 to 2 months
- Outpatient vascular medicine—½ to 1 day per week

*These guidelines are for individuals who have completed 24 months of core cardiovascular medicine training or 3 years of internal medicine training. †Individuals planning to perform peripheral catheter-based therapeutic interventions will be required to complete training in these special procedures (Table 5).

Alternative Routes to Achieve Competence

Advances in vascular biology and greater opportunities to diagnose and treat patients with vascular diseases have engendered enthusiasm to increase the number of physicians with special expertise in vascular medicine. The development of formal training programs described in the previous text may ultimately fulfill the need for vascular medicine specialists, but this is unlikely in the near future. Therefore, established internists, cardiovascular physicians, and vascular surgeons wishing to achieve competence in vascular medicine should have the opportunity to supplement their training and experience and acquire those skills requisite for expertise in vascular medicine. One method to obtain these cognitive and clinical skills would be to train under the supervision of a competent vascular medicine specialist. This may include spending, in the aggregate, two to three months of vascular consultation, three to four

months in a noninvasive vascular laboratory, and additional months dedicated to other vascular imaging techniques, including magnetic resonance angiography and conventional angiography, approximating one year in total. This experience can be realized via dedicated sabbaticals or longitudinal development programs that enable individual practitioners to acquire supervised training one to two times per week until the recommended period of time is completed. In addition, the alternative pathway for achieving competence should provide for the acquisition of new knowledge via self-directed learning, and attendance at seminars and conferences. Other training strategies are possible, but all should result in the acquisition of the skills and competencies outlined in Table 1.

Maintaining Expertise

Expertise in vascular medicine must be maintained. It is the responsibility of the practicing physician to engage in satisfactory and suitable ongoing medical education. The vascular medicine physician should attend continuing medical education programs sufficient to acquire new knowledge and maintain proficiency in vascular medicine. These programs should include the same areas of concentration required of trainees, such as vascular biology, clinical evaluation and management of vascular diseases, the noninvasive vascular laboratory, and other imaging modalities. Maintenance of expertise can also be accomplished by arranging sabbaticals or focused programs at institutions with vascular medicine training programs.

CATHETER-BASED PERIPHERAL VASCULAR INTERVENTIONS

Justification for Recommendations

Physicians from several subspecialty backgrounds, such as cardiovascular medicine, vascular medicine, interventional radiology, and vascular surgery, have the interest and potential expertise to perform invasive endovascular procedures. Yet there currently exists no common pathway, whether through a formal Accreditation Council for Graduate Medical Education (ACGME) certification process or otherwise, defining how physicians from these or certain other subspecialty training backgrounds should acquire the training and skills necessary to achieve competence in performance of catheter-based peripheral vascular interventions. Moreover, although various guidelines documents have been published in an attempt to set minimum requirements for training (13–17), a compelling need exists for the minimum requirements to conform to a uniform standard. Standards must take into account the current knowledge regarding the relative complexity of intervention in various vascular beds, as well as the constellation of pre-existing skills, knowledge, and training of physicians from different subspecialties. Furthermore, it has become evident, as intervention has become more complex, that each vascular territory presents unique challenges. Although skills acquired in one territory may be applied to another, training that is specific to the target bed is necessary to achieve competence. Similarly, there is reason to consider the concept of restricted (vs. unrestricted) competence, i.e., the ability to perform endovascular procedures in certain vascular territories, but not others.

Guidelines are currently in effect within subspecialty societies that require training programs to include endovascular procedures within their curricula. However, these guidelines are nonuniform regarding the exposure required, they do not distinguish between different vascular territories, and they lack a standardized mechanism for evaluation of competence. Accordingly, the existence of even a formal curriculum within a training program does not guarantee the ability of a trainee to develop adequate skills to establish competence. Thus, a need exists to better define the optimal mechanism of training and the minimum number of procedures required to achieve competence.

Finally, the management of vascular disease is undergoing a major paradigm shift toward less-invasive therapies. There is a cadre of previously trained physicians who are very experienced in managing patients with vascular diseases, and many of these physicians desire to develop expertise in newer, less invasive strategies. Thus, there is a need to identify minimum training requirements and standards for performing new procedures and techniques. It is appropriate that these requirements to achieve competence be uniform across multiple specialty lines, to ensure similar standards and to facilitate objective assessment of outcomes and quality of care.

Minimal Knowledge and Skills Required for Expertise

The ability to perform catheter-based interventions safely and effectively requires specific knowledge about vascular biology and vascular diseases as well as technical skills (Table 4). Knowledge about vascular biology and pathophysiology includes familiarity with the normal mechanisms that regulate blood vessel function and hemostasis, as well as the molecular and cellular processes that result in atherosclerosis and thrombosis, as previously discussed. Similarly, the interventionalist must possess the cognitive skills requisite to evaluate and treat patients with vascular diseases, especially occlusive diseases, aneurysmal disease, arterial dissection, and arterial and venous thromboembolism; this is because patients with these disorders constitute the majority of those referred for catheter-based interventions. The interventionalist should also be knowledgeable about less commonly encountered problems such as vasculitis and neurovascular compression syndromes. The vascular interventionalist should be able to interpret noninvasive vascular tests, such as pressure measurements, duplex ultrasound studies, computed tomography, and magnetic resonance angiography, because all of these modalities play a large role in catheter-based interventions. The interventionalist must understand the natural history of specific vascular diseases and be knowledgeable about the utility, accuracy, and

Table 4. Minimal Knowledge and Skills Required for Competence in Peripheral Catheter-Based Interventions

The vascular interventionalist should be knowledgeable about each of the following:
• Mechanisms that regulate blood vessel function and hemostasis
• Pathophysiology, clinical manifestation, natural history, evaluation, and treatment of peripheral arterial disease, renal artery stenosis, mesenteric ischemia, extracranial cerebrovascular disease, aneurysmal disease, arterial dissection, and arterial and venous thromboembolism
• Noninvasive vascular tests such as segmental blood pressure measurements, arterial and venous duplex ultrasonography, and computed tomographic and magnetic resonance angiography
• Accuracy and limitations of diagnostic tests
• Radiation physics, safety, and radiographic imaging equipment
• Principles of image acquisition and display
• Advantages, disadvantages, and potential complications of iodinated and noniodinated contrast agents
• Advantages, disadvantages, potential outcomes, and complications of interventional procedures
• Indications, alternatives, and contraindications for catheter-based interventions
The vascular interventionalist should have the following technical skills:
• Ability to safely gain vascular access from multiple sites (femoral, popliteal, and upper extremity arteries, as well as femoral, upper extremity, and neck veins)
• Ability to obtain hemostasis including application of compression and vascular closure devices
• Ability to manipulate guidewires and catheters
• Ability to place and deploy angioplasty equipment (e.g., balloons, atherectomy devices, stents, distal protection devices)
• Ability to recognize and treat procedure-related complications (e.g., dissection, pseudoaneurysms, embolism, vessel perforation or occlusion, stent thrombosis, adverse hemodynamic events)
• Ability to perform catheter-directed thrombolysis/thrombectomy
• Ability to perform vascular interventions in each of the following: aorta and lower extremity arteries, brachiocephalic and upper extremity arteries, mesenteric and renal arteries, central and peripheral veins, and pulmonary arteries

limitations of diagnostic approaches, and be cognizant of the advantages, disadvantages, potential outcomes, and complications of all relevant diagnostic and therapeutic procedures.

Individuals performing catheter-based vascular interventions must be aware of the risk versus benefit ratio for each procedure. Indications and contraindications for interventions at each anatomic site must be clearly understood and considered in the context of the clinical scenario. The vascular interventionalist must be able to make judgments regarding the effect of local and general anesthesia and be knowledgeable about conscious sedation and the delivery of cardiorespiratory and hemodynamic support during the intervention. Also, the interventionalist should be familiar with the use of adjunctive medications such as antiplatelet, antithrombotic, thrombolytic, vasodilator, and vasopressor drugs.

Technical skills are mandatory for the timely performance of effective and safe endovascular procedures. Catheter-based interventions require both knowledge of radiation physics and safety and skills in operating radiographic imaging equipment. The vascular interventionalist should be able to safely gain vascular access from multiple sites such as femoral (retrograde, antegrade, ipsilateral, and contralateral), popliteal (retrograde or antegrade), and upper extremity (axillary, brachial, and radial) arteries as well as from femoral, upper extremity (brachial), and neck (jugular) veins. Expertise includes the ability to perform and interpret high-quality diagnostic angiography utilizing both nonselective and selective techniques and to execute the technical aspects of endovascular procedures. Knowledge and expertise regarding methods to achieve hemostasis and alternatives to manual compression such as compression devices and vascular closure devices are required.

The vascular interventionalist must be able to choose and place appropriate interventional devices at the treatment site, retrieve them if necessary, and close access sites after the intervention. The interventionalist must be able to manipulate guidewires and catheters, be knowledgeable about placement of balloons and stents, and be able to size and deploy devices. The ability to recognize and to manage procedure-related complications such as access site complications (bleeding, arteriovenous fistula, pseudoaneurysm, and infection), vessel rupture or occlusion, distal embolization, acute renal failure, and stent misdeployment and migration is required. The vascular interventionalist should be able to discuss results and recommendations for future care with the patient and family members, and to discharge the patient from the hospital with appropriate follow-up arrangements.

Overview of Peripheral Vascular Procedures

PTA, stents, stent-grafts, thrombolysis. Percutaneous transluminal angioplasty (PTA), the use of catheters to recannalize and dilate occluded arteries, was first described in the 1960s by Charles Dotter. Balloon catheters to perform PTA were first used by Andreas Gruntzig in the early 1970s (18,19). The principle underlying PTA is expansion of an obstructed vascular lumen, which is achieved either by cracking atherosclerotic plaque, by distending the vascular wall eccentrically, or by creating a neolumen. Important considerations in using balloon catheters are selecting the appropriate diameter and length of the balloon. The interventionalist must be knowledgeable about the physical properties of balloons, including the mean and rated burst pressure, the compliance characteristics of the material, its trackability over a guidewire through tortuous vessels, and the compatibility of the supporting catheters, wires, and sheaths with balloons and stents. The interventionalist should be skilled in using balloon catheters to achieve an optimal diameter after PTA in order to reduce both the likelihood of restenosis and the risk of complications.

Expertise in catheter-based revascularization procedures also mandates skills in the use of stents as their utility continues to increase, to the point at which treatment of a vascular stenosis with balloon dilation alone is unusual. This is due both to the acute result achieved with stent placement and the subsequent reduction in restenosis seen in many

vascular beds with stent placement. Stents fall into two major categories: self-expanding and balloon expandable. Balloon-expandable stents generally allow more precise placement and have greater radial strength than self-expanding stents. Self-expanding stents are generally more flexible and will conform to the vessel wall more readily than balloon-expandable stents. Interventionalists should be knowledgeable about both types. Additional key considerations with stents are hoop strength (i.e., resistance to compression), type of metal, coating, specific design, and metal-to-open-space ratio. Drug-eluting stents can deliver pharmacologic agents directly into the artery. A large number of stent choices are available, and the final choice of stent for any indication should be at the discretion of the operator.

The vascular interventionalist should be familiar with stent grafts, which are either covered or lined with graft material. Several stent grafts have been approved for use for repair of infrarenal abdominal aortic aneurysms. Stent grafts have also been used for repair of thoracic aortic aneurysms and dissections, and for subclavian, renal, iliac, and popliteal aneurysms. They have potential application for emergency management of arterial injury. The larger aortic stent grafts generally require femoral or iliac artery surgical access due to their larger outer diameter, but smaller diameter covered stents may be introduced percutaneously. Stent graft technology continues to evolve, and longer-term (i.e., more than five years) outcomes are just beginning to emerge.

The endovascular interventional specialist should be skilled in catheter-directed thrombolysis and thrombectomy (mechanical and pharmacological), because these techniques have an important role in the treatment of both arterial and venous occlusions. Pharmacological thrombolysis is usually performed with a selective infusion, in which the active agent is directly infused into the thrombus to facilitate the action of the drug. The duration of local arterial infusion therapy may be from hours to days because the volume of thrombus is generally greater in larger peripheral vessels than in coronary arteries. Mechanical thrombolysis or catheter-directed thrombectomy results in direct thrombus removal and can be achieved with devices ranging from coronary guiding catheters to purpose-specific thrombus aspiration catheters. Mechanical thrombectomy enables rapid thrombus removal and can be used when thrombolytic agents are contraindicated. Expertise to perform catheter-directed thrombolysis/thrombectomy requires an understanding of, and familiarity with, the relevant tools (including medications), techniques, possible pitfalls, and expected results and complications.

Minimal Skills for Intervention in Specific Regional Circulations

Minimum skills for performing endovascular interventions in any regional circulation include familiarity with guiding catheters, arterial sheaths, guidewires, balloon catheters, catheter directed thrombolysis (mechanical and pharmacological), and stents. In addition, performance of catheter-based vascular interventions specific for each regional circulation requires specific cognitive and technical skills.

The cognitive skills required to perform catheter-based *aortoiliac* and lower extremity intervention includes familiarity with the normal vascular anatomy and its common variations. The operator should understand the etiology and pathophysiology of limb ischemia, especially that related to atherosclerosis, thrombosis, or embolism, and also of vasculitis, vasospasm, atheroembolism, and unusual causes of limb ischemia such as extrinsic compression and adventitial cysts. An understanding of the clinical manifestations of aortoiliac and lower extremity ischemia is required. The interventionalist should be able to interpret relevant diagnostic tests including limb segmental pressure measurements, duplex arterial ultrasonograms, magnetic resonance angiograms, computed tomographic angiograms, and conventional invasive contrast arteriograms.

The endovascular interventional specialist should have a broad understanding and appreciation of treatment alternatives available to the patient, including the relative risks and benefits for medical therapy versus percutaneous revascularization or surgical revascularization. Knowledge regarding the indications for aortoiliac and lower extremity revascularization is required. Indications for revascularization should be based upon a combination of clinical and anatomic considerations. The interventionalist should be familiar with the outcomes associated with stenotic versus occlusive lesions, lesion length and location, number and patency of run-off vessels, and vascular calcification. Clinical expertise requires the ability to render opinions on the merits of catheter-based interventions if medical therapy fails, or if there is limb-threatening ischemia, nonhealing ischemic ulcers, or ischemic rest pain. Additional clinical factors relate to quality of life issues specific to individual patients, such as work or recreational requirements that might favor revascularization over conservative therapy. Familiarity with the contraindications to aortoiliac and lower extremity percutaneous revascularization is required for the safe performance of intervention.

The knowledge required to perform catheter-based *renal artery* intervention includes an understanding of the normal anatomy and its common variations such as accessory renal branches and familiarity with vascular anomalies and the usual location and appearance of a transplanted kidney. The vascular interventionalist should be cognizant of the various etiologies of renal artery stenosis, including atherosclerosis, fibromuscular dysplasia, and other causes of renovascular disease such as polyarteritis nodosa, arteriovenous fistulae, and thrombosis and embolism. The vascular interventionalist should understand the pathophysiology and clinical manifestations of renal artery stenosis and be able to understand and utilize relevant findings of diagnostic tests, including nuclear scintigraphy, duplex ultrasonography, computed tomographic angiography, and magnetic resonance angiography. Moreover, the interventionalist should

be knowledgeable about adjunctive medical therapies that may be employed to treat the clinical consequences of renal artery disease and optimize outcome. Expertise in catheter-based interventions requires knowledge about indications and contraindications for renal artery revascularization.

Catheter-based *mesenteric artery* intervention requires knowledge of the normal anatomy of the celiac artery, superior mesenteric artery, and inferior mesenteric artery and its common variants and collaterals such as the marginal artery of Drummond, a collateral vessel to the superior mesenteric artery. The operator should be cognizant of the etiologies and pathophysiology of mesenteric ischemia such as atherosclerosis, arterial thrombosis or embolism, vasculitis, celiac trunk compression from the median arcuate ligament, and mesenteric vein thrombosis. The vascular interventionalist should be familiar with the clinical manifestations of mesenteric ischemia and knowledgeable about the indications for endovascular and surgical therapies for both acute and chronic mesenteric ischemia.

The knowledge required to perform catheter-based *brachiocephalic* intervention includes an understanding of the normal aortic arch, brachiocephalic, and cerebral vascular anatomy and its common variations. The operator should have knowledge of the pathophysiology and natural history of diseases affecting these vessels, including atherosclerosis, arteritis, fibromuscular dysplasia, aneurysmal disease, and dissection. An understanding of the etiologies of stroke and its relationship to thromboembolism and atheroembolism is necessary. The operator should be knowledgeable in the selection and appropriate utilization of noninvasive studies in this patient population, including carotid duplex and transcranial Doppler ultrasound studies, brachiocephalic and cerebral magnetic resonance angiography, and computerized tomographic images. The endovascular interventional specialist should be knowledgeable about treatment alternatives, including the relative risks and benefits of medical therapy and surgical revascularization as compared to percutaneous revascularization. Specific considerations should be given to the symptomatic status of the patient, risk factors specific to percutaneous revascularization (excessive vessel tortuosity) therapy or surgical treatment (repeat procedures, contralateral occlusion, severe coronary disease, prior neck radiation), and lesion-specific factors such as heterogeneity of plaque, presence of intraluminal thrombus, stenosis severity, lesion length, and lesion calcification. The performance of high-quality diagnostic brachiocephalic and cerebral angiography requires knowledge of the appropriate angiographic projections and of digital subtraction imaging. Skills for performing brachiocephalic intervention include familiarity with appropriate catheter shapes and sizes, guidewires, balloon catheters, stents, and emboli protection devices. It is acknowledged that carotid artery stenting, in particular, is in a rapid phase of evolution and adoption by the medical community. The recommendations in this document, while reflecting the broad consensus of the expert opinion on the committee, may need to be updated and augmented in future documents.

The cognitive skills required to perform catheter-based *venous* intervention includes an understanding of the normal venous anatomy and its common variants. The operator should know the pathophysiology and natural history of diseases affecting central veins and upper and lower extremity veins, including those disorders caused by venous thrombosis, congenital anomalies, trauma, and external compression. It is necessary for the interventionalist to understand non-invasive studies including duplex venous ultrasonography, magnetic resonance venography, and computed tomographic imaging. The interventionalist should be familiar with the indications for venous revascularization including but not limited to superior vena cava syndrome, extensive upper or lower extremity venous thrombosis, and pulmonary embolism. Specific consideration should be given to the symptomatic status of the patient when determining the risks and benefits of the procedure. A required technical skill for the performance of percutaneous venous intervention is the ability to safely gain venous access from multiple sites including the femoral, brachial, or jugular venous approach, and the ability to achieve hemostasis. Performance of high-quality diagnostic venography is required. The interventionalist should have competence to perform pharmacologic and mechanical thrombolysis/thrombectomy. Knowledge of the risks and relative benefits of medical treatment, percutaneous revascularization, and surgical management of venous obstructive disorders is required.

Performance of catheter-based intervention of the *pulmonary artery* and its branches requires knowledge of pulmonary vascular anatomy. The interventional specialist should be cognizant of the etiology, pathophysiology, and natural history of diseases affecting the right ventricular outflow tract, pulmonic valve, and pulmonary arteries, such as pulmonary embolism, congenital anomalies, and vasculitis. It is necessary for the interventionalist to understand non-invasive studies including duplex venous ultrasonography, ventilation and perfusion (V/Q) scans, magnetic resonance imaging, and computed tomographic imaging. The interventionalist should be familiar with the indications for pulmonary arterial revascularization, including acute massive pulmonary embolism and pulmonary hypertension secondary to chronic pulmonary embolism, strictures, congenital stenoses, and vasculitis. Specific considerations should be given to the clinical status of the patient when determining the risk and benefits of the procedure.

Required technical skills for the performance of percutaneous pulmonary arterial intervention include the ability to safely gain venous access and to achieve venous hemostasis at the end of the procedure, as previously described. The interventionalist should be able to measure and interpret cardiac and pulmonary hemodynamic parameters and perform high-quality pulmonary angiography. Minimal skills for performing pulmonary artery intervention include familiarity with appropriate catheter shapes and sizes, guidewires,

balloon catheters, and stents. The ability to perform catheter-directed thrombolysis/thrombectomy (pharmacological or mechanical) is required.

Formal Training to Achieve Competence

It is evident that catheter-based interventions are currently performed by individuals with formal training in interventional radiology, interventional cardiology, and vascular surgery. The clinical training afforded in each of these is unique to that subspecialty, but there is also substantial overlap. Just as there are clinical skills specific to each of these subspecialties, there are clinical skills that all who perform catheter-based interventions must possess. A minimum for attaining such skills includes satisfactory completion of an approved fellowship. To meet appropriate educational needs, clinical training in such programs must follow a clear curriculum and must be provided by individuals with documented training in patient care with catheter-based interventions.

Achieving the skill level needed to perform catheter-based interventions requires cognitive and technical training and experience. Training should include the following elements: 1) a formal, preferably ACGME-approved program; 2) mentoring by experienced, qualified physicians; 3) hands-on experience, under supervision, as secondary and primary operator; and 4) documentation of the number of procedures, success and failure rates, complication rates, and outcomes.

Two areas require clarification and quantification: duration of training and number of procedures. Both are, of necessity, somewhat arbitrary, and both are a function of prior training and experience. In the interests of patient care, however, it is imperative that such quantification not be primarily self-serving. To this end, it is obvious that interventional cardiologists, interventional radiologists, and vascular surgeons all bring particular strengths to the performance of catheter-based interventions. As the clinical background of interventional radiologists and cardiologists differ, so too do the interventional capabilities of vascular surgeons differ from these physicians with prior training in catheter-based interventions. Yet for all endovascular interventionalists, a formal, appropriately organized, and supervised training program specifically in catheter-based interventions is imperative.

Training Requirements for Cardiovascular Physicians

The ACC Core Cardiology Training Symposium document provides guidelines for training in catheter-based peripheral interventions (3). For the fellow wishing to acquire competence as a peripheral vascular interventionalist, a minimum of 12 months of training is recommended (Table 5). This period is in addition to the 24 months required for core cardiology training and at least 8 months acquiring experience in diagnostic cardiac catheterization in an ACGME-accredited fellowship program. It is recommended that the trainee perform 300 coronary diagnostic procedures, including 200 procedures with supervised primary responsibility prior to beginning interventional training. The trainee should participate in a minimum of 100 diagnostic peripheral angiograms and 50 noncardiac peripheral vascular interventional cases during the interventional training period. At least 50 of the diagnostic angiograms and 25 of the interventional cases should be as supervised primary operator. The case mix should be evenly distributed among the different vascular beds. Supervised cases of thrombus management for limb ischemia and venous thrombosis, utilizing percutaneous thrombolysis or thrombectomy, should be included. Advanced training in peripheral vascular intervention can be undertaken concurrently with advanced training for coronary interventions. The year devoted to interventional training should include at least one month on an inpatient vascular medicine consultation service, one month in a noninvasive vascular diagnostic laboratory, and one-half to one full day per week in the longitudinal care of outpatients with vascular disease.

Table 5. Formal Training to Achieve Competence in Peripheral Catheter-Based Interventions

Training requirements for cardiovascular physicians
• Duration of training*—12 months
• Diagnostic coronary angiograms†—300 cases (200 as the primary operator)
• Diagnostic peripheral angiograms—100 cases (50 as primary operator)
• Peripheral interventional cases§—50 cases (25 as primary operator)
Training requirements for interventional radiologists
• Duration of training‡—12 months
• Diagnostic peripheral angiograms—100 cases (50 as primary operator)
• Peripheral interventional cases§—50 cases (25 as primary operator)
Training requirements for vascular surgeons
• Duration of training—12 months‖
• Diagnostic peripheral angiograms¶—100 cases (50 as primary operator)
• Peripheral interventional cases§—50 cases (25 as primary operator)
• Aortic aneurysm endografts—10 cases (5 as primary operator)

This table is consistent with current Residency Review Committee requirements. *After completing 24 months of core cardiovascular training and 8 months of cardiac catheterization. †Coronary catheterization procedures should be completed prior to interventional training. ‡After completing general radiology training. §The case mix should be evenly distributed among the different vascular beds. Supervised cases of thrombus management for limb ischemia and venous thrombosis, utilizing percutaneous thrombolysis or thrombectomy, should be included. ‖In addition to 12 months of core vascular surgery training. ¶In addition to experience gained during open surgical procedures.

Training Requirements for Interventional Radiologists

The pathway for interventional radiology training is completion of an ACGME-approved training program in vascular and interventional radiology. In addition, the interventional radiologist should be eligible for or have received the Certificate of Added Qualification (CAQ) given by the American Board of Radiology, as well as maintain recertification requirements.

A minimum of 12 months of training in catheter-based intervention is required (Table 5). This is in addition to the general radiology residency, which includes several months of interventional radiology. During the ACGME-approved fellowship, the trainee must have direct participation in a

minimum of 500 procedures that encompass the full range of vascular and interventional procedures. The year devoted to interventional training should also include time dedicated to the clinical evaluation, treatment, and follow-up of patients with vascular disease and to noninvasive vascular evaluation, treatment, and follow-up of patients with vascular disease and to noninvasive vascular studies (e.g., ultrasound, magnetic resonance angiography, computed tomographic angiography, physiological arterial studies, stress tests). Upon completion of the fellowship, trainees that are American Board of Radiology-certified in diagnostic radiology are CAQ eligible in vascular and interventional Radiology. At the time of CAQ examination, the trainee must have had documented direct participation in a minimum of 700 procedures, of which 100 are diagnostic angiograms (50 with supervised, primary responsibility), 50 are peripheral interventions (25 with supervised, primary responsibility), and 10 catheter-directed thrombolysis/thrombectomy. The case mix should be evenly distributed among the different vascular beds.

Training Requirements for Vascular Surgeons

Contemporary training in vascular surgery requires completion of an ACGME-accredited residency (Fellowship) after completion of an ACGME-accredited residency in surgery. Although the ACGME only requires one year for vascular surgery training, a second year is permitted and the vast majority of training programs are of two years' duration. The major components of vascular surgery training, in addition to performance of vascular operations, include inpatient and outpatient evaluation and management of patients with vascular diseases. This includes critical care management, and interpretation of noninvasive vascular diagnostic laboratory tests, angiograms, and other imaging modalities. The increasing importance and use of catheter-based procedures has been recognized by the ACGME through its Residency Review Committee, which has made training in endovascular techniques a required component of vascular surgery programs. Therefore, training in peripheral catheter-based intervention is one of the major determinants for the second fellowship year. Vascular fellows may obtain this training in one year or throughout both years of a fellowship program.

Vascular surgery fellows acquire unique and extensive experience with the manipulation of blood vessels during open surgical operations. Each trainee is required to perform a specified minimum number and type of open surgical procedures in different anatomic areas as the primary operating surgeon. Required numbers of endovascular procedures have not yet been implemented by the Residency Review Committee, but beginning in 2004, each vascular fellow will be required to perform a minimum of 100 diagnostic and 50 therapeutic endovascular procedures plus 5 to 10 aortic aneurysm endovascular grafting procedures (Table 5). The case mix should be evenly distributed among the different vascular beds. Supervised cases of thrombus management for limb ischemia and venous thrombosis, utilizing percutaneous thrombolysis or thrombectomy, should be included. These requirements are consistent with recommendations and guidelines for endovascular training and hospital credentialling developed and published by the American Association for Vascular Surgery and Society for Vascular Surgery (14).

Definition of Operator and Procedures

During training, an individual may participate in a procedure as an assistant or as a primary operator. A primary operator is the trainee who evaluates the patient, makes decisions and performs the critical catheter manipulation in a case, and provides post-procedural care. Only one trainee may claim credit as the primary operator per case. A faculty member is the responsible attending physician for the procedure, who supervises the technical manipulations and assumes responsibility for all decisions.

Counting of individual procedures for purposes of accrual to achieve competence shall adhere to the following guidelines. Diagnostic peripheral angiography performed during a single visit to the angiography suite, catheterization laboratory, or operating room is counted as a single procedure, whether performed alone or in association with an intervention. Thus, only one diagnostic procedure may be counted per case, even if multiple interventions are performed in conjunction. Peripheral endovascular interventions are to be counted based on the vascular territory approached. Each intervention performed in a specified vascular territory, requiring its own selective access, can be counted as a separate procedure, even when performed during the same case. However, no more than three procedures per patient may be counted for any given case. Examples are as follows: Two procedures would be credited if bilateral iliac artery PTAs were performed in the same sitting, as each requires selective access (whether from the common femoral artery below or over the aortic bifurcation above). Also, two procedures would be credited when both right and left renal arteries are treated with PTA/stent, because each renal artery was accessed separately.

In contrast, performance of sequential PTA/stenting of the infrarenal aorta and the right common and external iliac arteries via right common femoral puncture would count for a single procedure, as only one selective access was required to get to the interventional sites. Finally, contemporaneous intervention in bilateral renal arteries and bilateral iliac arteries would only count for three procedures, because a maximum of three interventions may be credited in any one sitting. For thrombolysis and thrombectomy procedures, a single procedure is considered to include comprehensive management of a thrombotic event, from beginning to end; sequential trips to the laboratory are part of the index case, and thus are not to be counted as additional thrombolysis/thrombectomy cases. Additional interventions such as angioplasty and stenting may be counted separately. Careful

records must be kept documenting procedural details, outcome, and complications.

Alternative Routes to Achieve Competence

Achieving competence in peripheral catheter-based procedures presents a significant challenge for established coronary interventionalists and vascular surgeons who have already completed training and are either board-certified or board-eligible in their subspecialty. Yet there are several compelling reasons to encourage these individuals to achieve competence and to provide them with appropriate mechanisms to do so. Retraining practicing physicians can enhance their ability to deliver current and appropriate therapies to patients with vascular disease. Moreover, strategies to retrain often encourage healthy multidisciplinary interaction, teamwork, and exchange of knowledge among specialty groups. This collaboration benefits patient care and facilitates medical and scientific progress.

Physicians who have previously completed training in interventional cardiology, vascular surgery, or interventional radiology already possess certain cognitive, technical, and clinical skills that provide a foundation for further training. Recognizing the need to balance the existing experience of these physicians with the need to acquire new skill sets, different pathways are possible and may be necessary to acquire competence in peripheral intervention. The particular pathway and requirements to achieve competence may vary for each individual, even among physicians from the same specialty, depending upon that physician's prior training and expertise. Ultimately, the cumulative knowledge base and expertise possessed by the interventionalist should be similar to those standards for new trainees outlined earlier in this document. It must be underscored that, to achieve procedural competence via alternative pathways, the vascular interventionalist must first acquire the cognitive and clinical knowledge requisite to understanding vascular diseases, including the fundamental biology, clinical manifestations, diagnostic tools, pharmacotherapies, and indications and contraindications to intervention. Knowledge of radiation physics and skills in operating imaging equipment is also necessary.

Performance of at least 100 diagnostic peripheral angiograms, and no less than 50 peripheral interventional procedures, is required for competence as is the case for those participating in formal training programs (Table 6). The physician should have been the primary operator for 25 of the peripheral angioplasty procedures. These procedures should be performed under the proctorship of a peripheral vascular interventionalist who is competent to perform the full range of procedures described in this document. A written curriculum with goals and objectives, regular written evaluations of the physician by the proctor, and documentation of procedures with outcomes are required. The cases should be accumulated over a period of not more than 24 months. The physician should demonstrate evidence of adequate didactic and clinical training in the anatomy, pathophysiology, diagnosis, and medical management of peripheral vascular diseases and in endovascular techniques, which may be achieved by acquiring experience in supervised inpatient and outpatient vascular consultation settings, noninvasive vascular laboratories, and angiography/interventional laboratories. The physician should attend category 1 postgraduate education courses in peripheral vascular intervention, hospital conferences including endovascular mortality and morbidity, and document self-directed education. Appropriate documentation of the trainee's experience is required (see the following text). The case mix should be evenly distributed, so as to ensure exposure to diagnosis and intervention in a variety of different vascular beds. Experience heavily weighted toward treatment of one specific site (e.g., renal) to the exclusion of other venues (e.g., infrainguinal) may not provide adequate expertise for the latter. To achieve a balanced experience required for competence, the physician's experience should include no fewer than 20 diagnostic/10 interventional individual supervised cases in each of the vascular territories described earlier in this document including: aortoiliac and brachiocephalic; abdominal visceral and renal; and infrainguinal. In addition, the physician should perform a minimum of five catheter-directed peripheral thrombolytic/thrombectomy cases.

Obtaining competence in the performance of procedures

Table 6. Alternative Routes to Achieving Competence in Peripheral Catheter-Based Intervention*

1. Common requirements
   a. Completion of required training within 24-month period
   b. Training under proctorship of formally trained vascular interventionalist competent to perform full range of procedures described in this document
   c. Written curriculum with goals and objectives
   d. Regular written evaluations by proctor
   e. Documentation of procedures and outcomes
   f. Supervised experience in inpatient and outpatient vascular consultation settings
   g. Supervised experience in a noninvasive vascular laboratory
2. Procedural requirements for competency in all areas
   a. Diagnostic peripheral angiograms—100 cases (50 as primary operator)
   b. Peripheral interventions—50 cases (25 as primary operator)
   c. No fewer than 20 diagnostic/10 interventional cases in each area, excluding extracranial cerebral arteries†
   d. Extracranial cerebral (carotid/vertebral) arteries—30 diagnostic (15 as primary operator)/25 interventional (13 as primary operator)
   e. Percutaneous thrombolysis/thrombectomy—5 cases
3. Requirements for competency in subset of areas (up to 3, excluding carotid/vertebral arteries)
   a. Diagnostic peripheral angiograms per area—30 cases (15 as primary operator)
   b. Peripheral interventions per area—15 cases (8 as primary operator)
   c. Must include aortoiliac arteries as initial area of competency

*The fulfillment of requirements via an alternative pathway is only appropriate if the candidate physician has the cognitive and technical skills outlined in Table 4 and is competent to perform either coronary intervention, interventional radiology, or vascular surgery. These alternative routes for achieving competency are available for up to 5 years following publication of this document. †Vascular areas are: 1) aortoiliac and brachiocephalic arteries; 2) abdominal visceral and renal arteries; and 3) infrainguinal arteries.

and interventions in the extracranial cerebral vessels (i.e., carotid and vertebral arteries) is considered a unique category on the following bases: first, although there is crossover in the technical skills from other vascular territories, unique challenges are associated with cannulating the carotid and vertebral arteries and performing interventions in these circulatory beds; and second, there are obvious special issues related to the distribution and target organ of these vessels, which allow for very narrow safety margins. For those performing carotid or vertebral procedures, suggested requirements for achievement of competence include mastery of the cognitive and clinical skills pertaining specifically to this vascular bed and these procedures. This includes, as with other sites, a complete understanding of the anatomical and pathological characteristics unique to this vascular bed and the ability to interpret relevant angiographic images. To achieve competence, a minimum of 30 diagnostic cerebrovascular angiograms, 15 as supervised primary operator, and a minimum of 25 supervised interventions, at least one-half as primary operator, should be performed, with appropriate documentation, follow-up, and outcomes assessment. The recommended number of procedures reflects the consensus of the expert opinion of the committee. It is acknowledged that catheter-based intervention of the extracranial cerebral arteries is an area of competence that is in evolution. Accordingly, these recommendations may be modified in future documents as experience and clinical evidence regarding its safety and efficacy is acquired. Also, as with procedures in other regional vascular venues, it is anticipated that for some physicians to achieve competence, supervising faculty will recommend additional cases beyond the minimum number.

Physicians who have previously completed training in interventional cardiology or vascular surgery may elect to develop competence in only a subset of anatomic areas. Physicians who desire competence in more than three anatomic areas should pursue training for the full range of procedures in the manner outlined in the preceding paragraph. In order to maximize patient safety, physicians desiring competence in a subset of procedures require, as a minimum, proficiency in the aortoiliac arteries as the foundation for endovascular procedures in other anatomic beds. For physicians seeking to develop competence in a subset of procedures, no fewer than 30 diagnostic/15 interventional cases in any one anatomic area are necessary when seeking selective credentialing in a stepwise fashion, up to a maximum of 2 additional anatomic areas. Training should be performed under the proctorship of a peripheral vascular interventionalist who is credentialed to perform the full range of procedures described in this document. A written curriculum with goals and objectives, regular written evaluations of the physician by the proctor, and documentation of procedures with outcomes is required. The cases should be accumulated over a period of not more than 24 months. The physician should demonstrate evidence of adequate didactic and clinical training in the anatomy, pathophysiology, diagnosis, and medical management of peripheral vascular diseases and in endovascular techniques, which may be achieved by acquiring experience in supervised inpatient and outpatient vascular consultation settings, noninvasive vascular laboratories, and angiography/interventional laboratories. The physician should attend category 1 postgraduate education courses in peripheral vascular intervention, hospital conferences including endovascular mortality and morbidity, and document self-directed education.

In all of the situations described in the preceding text, clinical outcomes of procedures should be documented and comparable to published quality improvement guidelines for vascular interventions. In addition, after fulfilling initial requirements for competence, the log of cases should be continued for at least two years, with appropriate analysis of outcomes and quality assurance, to enable ongoing evaluation of competence.

Importantly, the numbers of procedures proposed in this document represent a minimum threshold for achieving competence. Certain individuals may require additional training to establish competence. Such individuals might include those who do not yet possess adequate basic catheter skills or those who, based on the dispassionate and objective evaluation of the supervising interventionalist, require additional instruction to achieve competence. Additionally, it is acknowledged that the training requirements outlined herein are designed to provide the physician with adequate exposure, knowledge, and judgment to recognize his or her limitations. Likewise, simply fulfilling the criteria described does not necessarily render the physician competent to perform any intervention in a given territory. Certain complex cases or pathological substrates may require that the physician obtain additional training and supervision to achieve advanced levels of competence.

These recommendations for alternative routes to achieve competency are put forward to enable physicians who have completed training in interventional cardiology, vascular surgery, or interventional radiology to acquire skills in procedures that were not part of their formal training program. However, the structure of current training programs in each discipline now permits interested physicians to acquire skills in catheter-based peripheral vascular interventions. Accordingly, it is recommended that alternative routes for achieving competency in catheter-based peripheral vascular interventions be available only for a period of five years following the publication of this document. Thereafter, it is expected that physicians wishing to acquire competency in this area do so through a formal training program as described earlier in this document.

Maintaining Competence

Maintenance of competence in catheter-based peripheral vascular interventions is an ongoing process that ensures continuity and growth of the cognitive, clinical, and technologic skills acquired during training. The physician's cognitive knowledge base in peripheral vascular disease

management and techniques must remain up-to-date. The physician must commit to ongoing education and life-long learning through documented attendance at continuing medical education seminars in the field of expertise, as well as demonstration of routine self-assessment. Technical skills should be maintained via performance of at least 25 peripheral vascular intervention cases annually and with documentation of favorable outcomes and minimal complications.

Demonstration of continued competence must include documentation that applicable medical licensure in state, locale, region, or agency of practice has been maintained and is current. The physician must document that he/she has credentials and/or privileges in the specified areas of expertise at the local hospital and/or practice level. The physician must document appropriate board certification in his/her specific medical specialty or subspecialty as well as appropriate recertification.

Assurance of Competence

Quality assurance and improvement are among the most important processes involved in maintaining and enhancing high-quality health care regardless of which discipline might be involved in treating patients. The quality improvement process is a patient-oriented process, designed to ensure a baseline level of quality and predictable outcomes, and it represents in many ways a safety net for the credentialing process. The number, results, and outcomes of interventional procedures by each operator should be quantified and available for review. An institutional Quality Assurance Committee should exist which is multidisciplinary in nature, involving all of the disciplines that are participating in vascular interventions. In addition, it should include members who are not directly participating in vascular intervention but could provide insight into overall patient care. Composition of the committee should be addressed to assure balance and to avoid dominance of one discipline over the other. The committee should define a list of appropriate indicators that would trigger automatic administrative chart review. Administrative review may be sufficient in many cases, but parameters should be developed that will require chart review by physicians when indicated. The Quality Assurance Committee should ensure uniform quality assurance to all practitioners performing vascular interventional procedures. Finally, when case review finds deviations in standards of care, the committee should be empowered to recommend corrective action, through educational or other methods, directed at ensuring the qualities of patient care.

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