American College of Cardiology/American Heart Association Clinical Competence Statement on Stress Testing

A Report of the American College of Cardiology/American Heart Association/American College of Physicians–American Society of Internal Medicine Task Force on Clinical Competence

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The granting of clinical staff privileges is one of the primary mechanisms used by institutions to uphold the quality of care. The Joint Commission on Accreditation of Healthcare Organizations requires that the granting of initial or continuing medical staff privileges be based on assessment of applicants against professional criteria specified in medical staff bylaws. Physicians and other healthcare providers are thus charged with identifying the criteria that constitute professional competence and with evaluating their peers accordingly. The process of evaluating clinical knowledge and competence is often constrained by the evaluator's own knowledge and ability to elicit the appropriate information, a problem that is compounded by the growing number of highly specialized procedures for which privileges are requested.

The American College of Cardiology (ACC)/American Heart Association (AHA)/American College of Physicians–American Society of Internal Medicine (ACP-ASIM) Task Force on Clinical Competence was formed in 1998 to develop recommendations to attain and maintain 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 called upon 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 healthcare providers entering practice for the first time and/or those who are in practice and undergo periodic review of their practice expertise. Because the assessment of competence is complex and multidimensional, isolated recommendations contained herein may not necessarily be sufficient or appropriate for judging overall competence. Board specialty certification is not a required part of these recommendations but is another measure of expertise.

Introduction

This statement is a revision and extension of the previous ACP/ACC/AHA Task Force Statement on Clinical Competence in Exercise Testing (1). This statement is designed to assist in the assessment of competence in stress testing. The minimum education, training, experience, and cognitive and procedural skills necessary for competent performance and interpretation of exercise testing are specified. When possible, these are based on published data linking these factors with competence in certain procedures or, in the absence of

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such data, on consensus of expert opinion. They are applicable to most practice settings and can accommodate a variety of ways to substantiate competence in the performance of specific cardiovascular procedures.

Committee members were selected from cardiovascular specialists involved in academic medicine and the private practice community. The Writing Committee was broadened to include an exercise physiologist, as well as members of the American Academy of Family Physicians, the American Society of Echocardiography (ASE), and the American Society of Nuclear Cardiology (ASNC). Representation by an outside organization does not necessarily imply endorsement. In addition to content peer reviewers, "official" reviewers were provided by the ACC, AHA, ACP-ASIM, ASE, ASNC, and the American Board of Internal Medicine (ABIM). This document was approved for publication by the governing bodies of the ACC and the AHA. In addition, the governing boards of the ASE and the ASNC formally endorsed this document.

The ACC/AHA/ACP-ASIM Task Force on Clinical Competence makes every effort to avoid any actual or potential conflicts of interest that may 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 are asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest. These statements are reviewed by the ACC/AHA/ACP-ASIM Task Force on Clinical Competence, reported orally to all members of the Writing Committee at the first meeting, and updated at each meeting or as changes occur.

Document Format

This document addresses competence for performing a broad variety of stress tests. This work discusses the cognitive and training skills necessary for competent performance of exercise and pharmacological stress and includes consideration of stress echocardiography and radionuclide cardiac imaging. In recognition that the performance of many complex stress tests (eg, stress radionuclide cardiac imaging) involves a "division of labor," this document will describe the specific skills necessary to supervise* the study, interpret the images, and integrate the component results of the study. Furthermore, this work describes the cognitive and training requirements necessary for competence in administering stress testing to children and adolescents. Accordingly, this document is presented in 4 sections: 1) exercise electrocardiographic (ECG) testing, 2) stress echocardiography, 3) stress radionuclide cardiac imaging, and 4) pediatric exercise testing.

Several different modes of physiological stress are now commonly used in stress testing. Section 1 will emphasize the skills needed to perform dynamic exercise tests (eg, treadmill). Section 2 will elaborate on the skills and training necessary to perform adrenergic-stimulating agent (eg, dobutamine) stress testing. Section 3 will develop the cognitive skills and training necessary to perform vasodilating-agent (eg, adenosine) stress testing. Finally, section 4 addresses the differences of many of the testing standards between the adult and pediatric populations and provides information on the skills necessary to perform metabolic measurements during stress testing.

*For the purposes of this article we have defined the 3 levels of supervision for diagnostic tests as follows: 1) "personal supervision" requires a physician's presence in the room; 2) "direct supervision" requires a physician to be in the immediate vicinity or on the premises or the floor and available for emergencies; and 3) "general supervision" requires the physician to be available by phone or by page.

Maintaining Competence: Quality Assurance

This Writing Committee strongly recommends that a comprehensive program of quality assurance be established in each center to assist in the maintenance of competence in the performance of all stress tests. When possible, the results of stress tests should be compared with the findings at cardiac catheterization, cardiac surgery, and necropsy to assess the validity of the test findings. Periodic review of a random sample of stress studies that have been interpreted by an individual physician should be performed by a qualified unbiased expert, either from the physician's own institution or, when necessary, from another laboratory. This review would help to confirm that the specific stress examinations were clinically indicated, were technically complete and of adequate technical quality, and were interpreted correctly and reported in an effective manner to healthcare providers and to the patient's medical record.

Section 1: Exercise ECG Testing

Overview of the Procedure

Exercise testing has been used in clinical practice for many years, and its use has contributed significantly to the management of many patients. In its current form, clinical exercise testing consists of the continuous monitoring of an ECG (generally a 3-lead or a 12-lead system) with frequent recordings of 12-lead tracings. Additional tracings are taken according to clinical circumstances. Frequent blood pressure determinations are made before, during, and after exercise of progressively increasing intensity (usually with a treadmill or cycle ergometer) to any of a number of test end points.

In many instances, exercise testing may be combined with other procedures, such as myocardial perfusion imaging, radionuclide ventriculography, echocardiography, magnetic resonance imaging, or metabolic measurements. If a physician is responsible for both exercise testing and imaging, clinical competence in both areas is required. In other cases, one physician may be responsible for the exercise test and another for imaging. In such cases, staff privileges are granted accordingly. As discussed below, exercise testing is frequently conducted with a division of labor, by which one individual is competent to supervise the study and a second individual is competent to interpret the study.

Because exercise testing entails a very small but definite risk, and data confirm that up to 1 myocardial infarction or death per 2500 tests (2) occurs, it should be performed only under the following conditions: with appropriate indications and careful consideration of contraindications, under the supervision of a properly trained physician or individual (eg, an exercise physiologist), and with appropriate technique and safety measures. The interpreting physician or individual should know that the positive and negative predictive values of the test can vary considerably according to the prevalence of the condition in the population being tested (Bayes' theorem) and that the sensitivity and specificity vary according to the criteria used to determine a "positive," "negative," or "indeterminate" result. The individual performing the test must understand the many factors that can result in false-positive, false-negative, or indeterminate results.

The clinical indications for exercise testing are broad and varied. In general, the procedure is used to answer a specific question and should not be performed if the information gained may be obtained with other techniques that have been or will be performed, including the history and physical examinations. Exercise testing should be conducted when it is anticipated that the results will affect patient management. It is important that the individual performing an exercise test know the indications for and diagnostic accuracy of other tests used in the evaluation of patients with known or suspected cardiovascular diseases. Such tests include radionuclide ventriculography, nuclear magnetic resonance imaging, echocardiography, electron beam computed tomography, other imaging methods, ambulatory electrocardiography, and cardiac catheterization, and exercise testing combined with myocardial perfusion imaging, first-pass or equilibrium radionuclide angiography, or echocardiography.

For the purpose of this statement, performance of exercise testing includes that the individual know the indications for and contraindications to the test, recognize normal end points and abnormal responses or complications that may require that the test be discontinued, manage complications of the test, and interpret the test results. In most patients, exercise testing can be safely supervised by properly trained nurses, physician assistants, exercise physiologists, physical therapists, or medical technicians working under the direct supervision of the physician, who should be in the immediate vicinity or on the premises or the floor and available in case of emergency situations (3,4). It is recommended that non-physicians who supervise the actual exercise test have certain cognitive skills (see Table 1, part I), and they may be certified in exercise testing by organizations such as the American College of Sports Medicine (5). In general, the physician should be present to observe the patient continuously (ie, personally supervise) when the test is performed on a patient with a recent (within 7 to 10 days) history of documented acute coronary syndrome, severe left ventricular dysfunction, severe valvular stenosis (eg, aortic stenosis), or complex arrhythmia. In all instances, the healthcare provider should screen the patient for indications and contraindications immediately before the test.† Competent performance of exercise testing requires significant cognitive knowledge, including clinical evaluation of the patient, knowledge of the pathophysiology of the disease or condition for which the test is performed, and knowledge of electrocardiography, cardiac arrhythmias, and electrophysiology, including normal and abnormal responses to different types and levels of exercise.

†There may be other circumstances determined by the clinical situation of the patient that would require the physician to be personally present. All of these situations are so broad that they are beyond the scope of this document.

TABLE 1. Cognitive Skills Needed to Competently Perform Exercise Tests

I. Cognitive skills needed to competently supervise exercise tests

- Knowledge of appropriate indications for exercise testing
- Knowledge of alternative physiological cardiovascular tests
- Knowledge of appropriate contraindications, risks, and risk assessment of testing (not limited to Bayes' theorem and sensitivity/specificity, including concepts of absolute and relative risk)
- Knowledge to promptly recognize and treat complications of exercise testing
- Competence in cardiopulmonary resuscitation and successful completion of an AHA-sponsored course in advanced cardiovascular life support and renewal on a regular basis
- Knowledge of various exercise protocols and indications for each
- Knowledge of basic cardiovascular and exercise physiology, including hemodynamic response to exercise
- Knowledge of cardiac arrhythmias and the ability to recognize and treat serious arrhythmias
- Knowledge of cardiovascular drugs and how they can affect exercise performance, hemodynamics, and the ECG
- Knowledge of the effects of age and disease on hemodynamic and ECG responses to exercise
- Knowledge of principles and details of exercise testing, including proper lead placement and skin preparation
- Knowledge of end points of exercise testing and indications to terminate exercise testing

II. Additional cognitive skills needed to competently interpret exercise tests

- Knowledge of specificity, sensitivity, and diagnostic accuracy of exercise testing in different patient populations
- Knowledge of how to apply Bayes' theorem to interpret test results
- Knowledge of electrocardiography and changes in the ECG that may result from exercise, hyperventilation, ischemia, hypertrophy, conduction disorders, electrolyte disturbances, and drugs
- Knowledge of conditions and circumstances that can cause false-positive, indeterminate, or false-negative test results
- Knowledge of prognostic value of exercise testing
- Knowledge of alternative or supplementary diagnostic procedures to exercise testing and when they should be used
- Knowledge of the concept of metabolic equivalent (MET) and estimation of exercise intensity in different modes of exercise

Justification for Recommendations

The number of procedures that must be performed under supervision and the duration of training vary depending on the individual's aptitude, other training, and the clinical complexity of their patients undergoing stress testing. The following recommendations for minimum criteria for competence are based on the ACC's Guidelines for Training in Adult Cardiovascular Medicine (6) and the expert opinion of cardiovascular consultants.

Indications, Contraindications, and Complications

Indications and contraindications for stress testing fall outside the scope of this document but are included in the ACC/AHA Practice Guidelines in Exercise Testing list of specific indications for exercise testing in cardiology patients (7). This guideline divides recommendations into classifications as follows. Class I represents those conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective. Class II represents conditions for which there is conflicting evidence and/or a divergent opinion about the usefulness/efficacy of a procedure or treatment. In class IIa, the weight of evidence/opinion is in favor of the usefulness/efficacy. In class IIb, the usefulness/efficacy is less well established by evidence/opinion. Class III conditions are those in which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful.

It is important to note that ≈90% of middle-aged men with a history consistent with typical angina have significant coronary artery disease when studied by coronary arteriography (7). In such patients, an exercise test adds only slightly to the diagnostic accuracy of the clinical impression, although it may provide important information regarding prognosis and work capacity. In contrast, the prevalence of significant coronary artery disease as measured by angiography in women with a history of typical angina pectoris may be as low as 60% to 70%. The general pretest probability of coronary artery disease by age, sex, and symptoms is shown in the Practice Guidelines for Exercise Testing (7,8).

Minimum Training Necessary for Competence

It is important to distinguish between those skills and knowledge necessary for supervision of the test and those skills and knowledge necessary to interpret the entire exercise test. Table 1, part I lists the cognitive skills necessary to supervise exercise tests competently. Individuals who interpret exercise tests should also have the cognitive skills listed in Table 1, part II.

Many physicians acquire the skills necessary for supervision and/or interpretation of exercise testing during a fellowship in cardiovascular disease. Some internal medicine and family practice residency programs provide training in exercise testing, often as an elective. A minimum of 4 weeks or the equivalent should be devoted to this training to achieve competence in both supervision and interpretation.

Because of the variable backgrounds of physicians and the diversity of their training experiences, multiple pathways to acquire competence are possible. The clinical and institutional setting in which the training occurs, the case mix, backup, and collaboration available to trainees performing the procedures, and the number of procedures performed under supervision must all be considered when privileges are granted.

The number of procedures necessary to ensure competence has not been established by objective criteria. The majority opinion of this committee and its consultants is that the trainee should participate in at least 50 procedures during training. It is recognized that not all training or practice environments are the same, and a local credentials committee may deem a greater or smaller number of procedures appropriate.

Physicians who did not receive formal training for the supervision or interpretation of exercise testing during a residency or fellowship but who are currently performing exercise testing should have gained appropriate experience under the supervision of a physician or healthcare provider qualified in exercise testing. Such postgraduate training may have included didactic courses and workshops, personal tutorials, and importantly, exercise testing performed under the supervision of a qualified physician. For physicians who finished training without the opportunity for such formal training but who have performed exercise testing on a regular and substantial basis for more than 3 years (minimum 150 procedures), experience may be considered individually in lieu of formal training. In any setting, training must result in the acquisition of the cognitive skills outlined in Table 1.

While acquiring the knowledge and skills of exercise testing as part of a formal training program or subsequently, the physician should be supervised by an effective teacher who is an expert in the clinical use of exercise testing and who performs this on a regular basis. The trainee's experience should be documented in writing and confirmed by the supervisor. Trainees who have acquired the additional cognitive skills necessary to interpret exercise ECG tests (see Table 1, part II) should obtain specific confirmation from their supervisor.

The completion of a short course or workshop that offers a limited cognitive background in cardiology or inadequate hands-on experience with the procedure will not by itself result in competence.

Maintenance of Competence

Continuing competence in exercise testing requires regular, continued performance of exercise testing. Performance of only a rare test can lead to missed or inappropriate diagnoses and decreased overall accuracy and may lead to a higher rate of complications. The appropriate number of exercise tests that individuals should perform to maintain competence in the supervision and interpretation of these tests has not been established by evidence-based studies. On the basis of a prior survey of practicing general internists (9) and unpublished data from a 1998 survey of cardiovascular experts by this committee, we recommend that physicians perform at least 25 exercise tests per year to maintain their competence. A program of quality assurance should be in place at each center to ensure systematic review and critique of a significant sample of exercise ECG cases. In addition, successful completion of a course in advanced cardiovascular life support and renewal on a regular basis is recommended.

Section 2: Stress Echocardiography

Overview of the Test

Exercise Echocardiography

Imaging modalities such as echocardiography can be combined with exercise ECG in an attempt to increase the sensitivity and specificity of stress testing, as well as to determine the extent of myocardium at risk for ischemia. Echocardiographic images at rest are compared with those obtained while the patient performs supine or upright stationary cycling or immediately after treadmill exercise. Images must be obtained within 1 to 2 minutes after exercise, because abnormal wall motion normalizes rapidly after exercise is discontinued. Rest and stress images are compared side by side in a cine loop display that is gated during systole from the QRS complex. Myocardial contractility normally increases with exercise, whereas ischemia causes hypokinesis, akinesis, or dyskinesis of the affected segments. A test is considered positive if wall motion abnormalities develop with exercise in previously normal territories or worsen in an already abnormal segment (10). The diagnostic accuracy and prognostic value of exercise echocardiography are fully described in other sources (11–13). Complications during exercise echocardiography are no different from those during exercise ECG testing, because the echocardiographic procedure itself has no known risks.

Pharmacological Stress Echocardiography

Pharmacological agents can be used to increase cardiac work in lieu of exercise or cause coronary arterial vasodilation to increase myocardial blood flow. Adrenergic-stimulating agents, such as dobutamine, increase myocardial contractility, heart rate, and blood pressure. Dobutamine is infused intravenously starting at 5 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and, if tolerated, increased every 3 minutes thereafter by 5 to 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$ until a maximal dose of 40 to 50 $\mu g \cdot kg^{-1} \cdot min^{-1}$ is reached or an end point is achieved. Atropine may be given if an adequate heart rate is not achieved or other end points have not been reached at peak dobutamine dose. End points include new or worsening wall-motion abnormalities, adequate heart rate response, worsening arrhythmia, moderate angina, intolerable side effects, and significant increase or decrease in blood pressure. ECG, heart rate, blood pressure, and echocardiographic images are obtained throughout the infusion. Echocardiographic images are then gated during systole and displayed in a quad screen format that allows side-by-side comparison of baseline, low and intermediate doses of dobutamine, and peak dobutamine (recovery images may also be displayed). A new or worsening wall-motion abnormality constitutes a positive test for ischemia (14). Indications for termination of stress echocardiography with adrenergic agents are fully described in the practice guidelines for the clinical application of echocardiography (11). Complications during dobutamine infusion include nausea, headache, tremor, and anxiety; angina and atypical chest pain; and atrial and ventricular arrhythmias (15). Myocardial infarction and death, although rare complications, have been reported. Intravenous β-adrenergic blockers can be administered for prolonged ischemic responses and/or tachyarrhythmias that persist after discontinuation of dobutamine.

Vasodilators such as dipyridamole and adenosine can also be used as stress agents to assess coronary perfusion during echocardiography. These agents cause maximal coronary arteriolar vasodilation, resulting in increases in flow to the territory supplied by the normal epicardial coronary arteries. If this increase in flow is sufficient, because the obstructed artery does not allow an increase in flow, blood is directed away from the territory supplied by the obstructed artery, causing the “steal phenomenon.” Echocardiographic images are obtained at baseline and after vasodilator infusion. As in routine stress echocardiographic testing, a new or worsening wall-motion abnormality constitutes a positive test for ischemia. Side effects are similar with adenosine and dipyridamole but are reported more frequently with adenosine. Symptoms include flushing, chest pain, headache, dyspnea, and atrioventricular block and can be reversed with aminophylline (16).

Clinical Utility of Stress Echocardiography

The indications for stress echocardiography are outlined in detail elsewhere (7,11). The addition of echocardiographic imaging to exercise is particularly useful when the ECG changes of ischemia are obscured by baseline abnormalities (eg, left ventricular hypertrophy or resting repolarization changes). Imaging also provides information regarding the location of ischemic myocardium and the size of the territory at risk. Exercise or pharmacological stress echocardiography provides greater diagnostic accuracy than exercise ECG alone, and thus these are useful procedures when the results of the latter test are equivocal or indeterminate. Patients unable to undergo exercise stress testing for reasons such as deconditioning, peripheral vascular disease, orthopedic disabilities, neurological disease, and concomitant illness can often benefit from pharmacological stress testing. Indications for these tests include establishing a diagnosis of coronary artery disease, determining myocardial viability before revascularization, assessing prognosis after myocardial infarction or in chronic angina, and evaluating perioperative cardiac risk.

With the addition of Doppler techniques, stress echocardiography can also be used in selected patients with valvular heart disease to assess left ventricular function during exercise (17) and/or evaluate changes in transvalvular gradient during exercise (18,19), particularly in patients whose symptoms are out of proportion to the severity of the lesion at rest.

Contraindications to exercise echocardiography are similar to those for exercise ECG testing. Similarly, adrenergic-stimulating agents should be avoided in patients with unstable angina, hypokalemia, uncontrolled hypertension (resting systolic blood pressure $>$200 mm Hg or diastolic blood pressure $>$110 mm Hg), uncontrolled congestive heart failure, and uncontrolled dysrhythmias. Vasodilator agents should not be used in patients with second- or third-degree atrioventricular block (without permanent pacemakers) and patients with chronic asthma or severe chronic obstructive lung disease (7).

Minimum Training Necessary for Competence

Stress echocardiography requires direct supervision during the testing procedure, interpretation of the echocardiographic images, and integration and interpretation of the composite test data. In the case of exercise echocardiography, these roles may be performed by a single physician or as many as 3 individuals with competence in each area. Pharmacological stress testing, particularly with adrenergic agents, is often performed by a single physician, because recognition of the end points of such testing requires competence in both stress testing and echocardiography.

The cognitive skills required to attain competence in direct supervision of exercise echocardiographic tests are the same as those outlined for exercise ECG testing (see Table 1). The cognitive skills required for echocardiographic interpretation and integration of composite test data are summarized in Table 2. Such skills are acquired after completion of 6 months of basic echocardiographic training, which includes perfor-

TABLE 2. Cognitive Skills Required for Performance of Stress Echocardiography

I. Exercise echocardiography

A. Skills required for supervision of exercise echocardiographic testing (see Table 1, part I)

- Knowledge of the indications of exercise echocardiography
- Knowledge of the limitations of exercise echocardiography

B. Skills required to interpret echocardiographic images acquired during stress echocardiography

- Ability to independently perform and interpret an echocardiographic and Doppler study that is diagnostic, complete, and quantitatively accurate
- Ability to recognize common cardiovascular pathological entities, including myocardial, pericardial, and valvular entities and diseases of the great vessels
- Ability to name and locate left ventricular wall segments
- Ability to identify and quantify wall-motion abnormalities of the left ventricle
- Ability to identify, locate, and quantify changes in left ventricular wall motion
- Ability to quantify stenotic and regurgitant valvular abnormalities
- Ability to distinguish adequate from inadequate echocardiographic data
- Ability to produce a cogent written report of the echocardiographic findings

C. Skills required to integrate exercise testing and echocardiographic data for composite final report

- Knowledge of specificity, sensitivity, and diagnostic accuracy of exercise echocardiographic testing in different patient populations
- Knowledge of how to apply Bayes' theorem to interpret test results
- Knowledge of electrocardiography and changes in the ECG that may result from exercise, hyperventilation, ischemia, hypertrophy, conduction disorders, electrolyte disturbances, and drugs
- Knowledge of coronary anatomy and relation to echocardiographic findings
- Ability to apply Doppler data to the physiological changes that occur during exercise
- Knowledge of conditions and circumstances that can cause false-positive, indeterminate, or false-negative test results
- Knowledge of prognostic value of exercise echocardiographic testing
- Knowledge of alternative diagnostic procedures to exercise testing
- Knowledge of the concept of MET and estimation of exercise intensity in different modes of exercise

mance and interpretation of at least 300 examinations within 1 year, 100 of which were performed for wall-motion analysis (6,20). Specialized training in stress echocardiography requires participation in at least 100 supervised stress examinations and interpretations (beyond the basic 300 resting echocardiography examinations) (6,20), of which 50 include direct "hands-on" supervision of exercise stress and 50 include direct supervision during infusion of adrenergic-stimulating pharmacological stress agents. These examinations often involve the management of high-risk patients and entail the performance of echocardiographic procedures that cannot be readily repeated if the initial study is not of diagnostic quality. The trainee must acquire a full understanding of the principles, indications, applications, risks, and limitations of stress echocardiography. The numbers of examinations listed are usually necessary but may not be sufficient to adequately obtain the cognitive skills outlined in Table 2. The training supervisor should be the judge of the level of competence achieved by the trainee (20).

Echocardiographic training should be acquired under the supervision of the laboratory director, designated faculty members, and cardiac sonographers. This training should be done in a laboratory that performs a minimum of 40 stress echocardiograms per month (20). Training in stress echocardiography is best accomplished under the close supervision of a fully qualified expert who regularly performs and interprets these procedures. The training supervisor should have level 3 experience (6), with independent interpretation of >200 stress echocardiography studies, and should maintain the skills that are outlined below (20). Optimal evaluation of competence should be performed by direct observation of the trainee to perform and interpret the stress echocardiogram, or it may take the form of a practical or written examination, or both (6). Observational evaluation should be done on a daily basis by the director of the laboratory and/or associates and must involve both practical and reading sessions.

Competence in interpretation of stress echocardiography usually can be accomplished during formal structured experience in an established echocardiography laboratory during cardiology fellowship training. Training for persons not currently in formal training programs should be based on several factors that include the timing of the most recent formal echocardiographic training, the duration of practice and current activity as an echocardiographer, and the dedication of the individual to acquiring the necessary cognitive skills (6). The physician's background experience should be equivalent to that described above for fellowship trainees in echocardiography. Additional expertise in interpretation of stress echocardiograms may be obtained through a combination of on-site visits to an active laboratory (defined above) and overreading of the trainee's interpretations by an established stress echocardiographer (defined above). Such training in stress echocardiography requires participation in the same number of supervised stress examinations and interpretations as outlined above for fellowship training.

Maintenance of Competence

The maintenance of competence in stress echocardiography requires the regular performance of such examinations. There are no scientific studies that address the optimal number of stress echocardiographic examinations required to maintain proficiency in this area. The ASE suggests that such can be accomplished by the performance of 15 studies per month (20). However, it is the consensus of this committee that an individual should perform and/or interpret at least 100 stress echocardiographic studies per year to maintain competence. The committee believes that the physician who does stress echocardiography less frequently will have difficulty maintaining the technical and cognitive skills required of such testing and will not be able to keep abreast of technical developments in the field. Finally, a program of quality assurance should be in place at each center to ensure

TABLE 3. Additional Cognitive Skills Necessary to Perform, Interpret, and Report Pharmacological Stress Echocardiography

- Knowledge of the different types of pharmacological stress agents
- Knowledge of advantages and disadvantages of the different pharmacological stress agents
- Knowledge of the indications for pharmacological stress echocardiography and use of the different types of pharmacological stress agents
- Knowledge of the contraindications of pharmacological stress echocardiography with different types of pharmacological stress agents
- Knowledge of the limitations of pharmacological stress echocardiography with different types of pharmacological stress agents
- Knowledge of the pharmacokinetics of the different pharmacological stress agents
- Knowledge of the physiological responses to different pharmacological stress agents
- Knowledge of the side effects of different pharmacological stress agents and how to manage them
- Knowledge of the complications of different pharmacological stress agents and how to manage them
- Competence in cardiopulmonary resuscitation and successful completion of an AHA-sponsored course in advanced cardiovascular life support and renewal on a regular basis
- Knowledge of cardiovascular drugs and how they affect responses to pharmacological stress agents
- Knowledge of electrocardiography and changes that may occur in response to pharmacological stress agents
- Knowledge of the end points of pharmacological stress echocardiography and indications for termination of a stress echocardiographic examination
- Knowledge of the sensitivity, specificity, and diagnostic accuracy of pharmacological stress echocardiographic testing in different patient populations
- Knowledge of the prognostic value of pharmacological stress echocardiography
- Knowledge of coronary anatomy and relation to echocardiographic findings
- Ability to apply Doppler data to the physiological changes that occur during pharmacological stress
- Knowledge of the relationship of imaging results to the presence or absence of myocardial viability

systematic review and critique of a significant sample of stress echocardiographic cases.

Pharmacological Stress Echocardiography

Pharmacological stress testing, particularly with adrenergic-stimulating agents, is often performed by a single physician, because recognition of the end points of such testing requires cognitive skills as listed in Table 2 for supervision of stress testing (I A) and interpretation of echocardiographic images (I B), plus those listed in Table 3.

Section 3: Stress Radionuclide Cardiac Imaging

Overview

Radionuclide cardiac imaging has become established as an important adjunct to exercise or pharmacological stress for the evaluation of patients with known or suspected coronary artery disease (21,22). It adds valuable diagnostic and prognostic information for making clinical management decisions regarding the need for cardiac catheterization, coronary revascularization, or medical treatment. A major advantage of radionuclide cardiac imaging is the ability to obtain this information using nonexercise stress (23–27). The most common nuclear cardiac imaging technique used with stress testing is myocardial perfusion imaging, which involves injection of a radionuclide tracer such as ^{201}Tl or a ^{99m}Tc-based organic agent such as sestamibi or tetrofosmin at the time of peak coronary hyperemia induced by exercise, pharmacologically induced vasodilation (with intravenous dipyridamole or adenosine), or adrenergic stimulation (such as with dobutamine). The common feature of the different radionuclide perfusion agents is that they are taken up by myocardium in proportion to coronary blood flow and can be imaged with a nuclear imaging camera. Thus, areas of reduced uptake seen on cardiac imaging correspond to hypoperfused or ischemic myocardium. Stress images are then compared with resting or delayed images to distinguish hypoperfused viable versus nonviable or infarcted myocardium.

In addition to myocardial perfusion, radionuclide cardiac imaging techniques can also be used to evaluate the effect of stress on regional and global ventricular function (28,29). Ventricular performance during stress has been demonstrated to have important diagnostic and prognostic implications that can affect patient management decisions. In patients with nonischemic heart diseases, ventricular function rather than perfusion is the first-order determinant of prognosis and can be accurately assessed by radionuclide techniques. For these purposes, blood-pool radionuclide angiography provides the greatest accuracy and reproducibility. This technique is based on the proportionality between ventricular blood volume and radionuclide tracer activity in the ventricular blood pool. It has the advantage of being relatively insensitive to the geometric irregularities of the ventricles that commonly are manifest in patients with heart disease and that affect calculations of volume derived from area-length methods used with other imaging modalities such as echocardiography.

Radionuclide cardiac imaging can be performed by planar techniques, but for myocardial perfusion imaging, it is now most commonly acquired with a camera and software equipped to perform tomography (single photon emission computed tomography, or SPECT) (30,31). This allows for better localization of perfusion defects and better correlation with angiographic coronary anatomy. Interpretation is performed by physicians who have received specific training in nuclear cardiology. Although interpretation must be made directly by physicians, computer software is now available to allow quantification of images, which can serve as supplemental information for a final interpretive conclusion (30,31).

The 4 basic components of the stress radionuclide cardiac imaging study include the following: 1) performance of the stress test; 2) handling of the radioisotope and acquisition, processing, and display of images; 3) interpretation of the stress ECG; and 4) interpretation of the cardiac images. These may be supervised by 1 or more physicians, depending on their training and experience. Supervision of the stress component demands knowledge and experience of the specific stressor involved: exercise, vasodilator, or adrenergic-stimulating agent. The healthcare professionals supervising the test must have knowledge of the indications and contraindications for each of the modes of stress and understand the advantages and disadvantages of each. The stress test itself should be under direct supervision of a physician. The actual imaging can be performed under the general supervision of an appropriately trained and experienced physician.

Radionuclide cardiac imaging should be performed by individuals properly trained to handle the imaging agents, with supervision by physicians trained in radioisotope handling. Radionuclide cardiac imaging may be performed at a hospital or in an office-based setting provided that such trained personnel are involved with the procedure.

Interpretation of the cardiac images may be made by physicians who receive their training in either a cardiology, nuclear medicine, or radiology training program. Physicians must understand the causes of image artifacts, be able to recognize them at the time of interpretation, and understand how to correct them (32). They must be able to create a meaningful report that effectively communicates the results of the study so that the referring physician can make appropriate management decisions based on the findings.

The clinical indications for stress radionuclide cardiac imaging fall primarily into 2 broad categories: diagnosis of coronary artery disease and risk stratification. In certain situations, stress radionuclide ventriculography is indicated for diagnostic evaluation and risk stratification of patients with nonischemic diseases, such as valvular heart disease and drug toxicity states. Guidelines for the clinical use of stress nuclear cardiac imaging are described in detail in the report of the ACC/AHA collaboration with the ASNC (16). As with all testing, it is important to understand exactly what question is being asked of a test. This will determine the proper conditions of testing (eg, on or off cardiac medications) and what stress or agent to use (eg, exercise versus pharmacological stress).

As with exercise testing in general, performance and supervision of stress radionuclide cardiac imaging includes a general knowledge of indications and contraindications of the test, including exercise, vasodilator, and adrenergic stress. In selected patients, exercise or vasodilator stress can be performed safely by properly trained nonphysician healthcare professionals under direct physician supervision. In all instances, before testing, the patient should be screened for contraindications or high risk that would require personal supervision by a physician.

Minimum Training Necessary for Competence in Performing and Interpreting Stress Radionuclide Cardiac Imaging

Training required for performance of basic exercise testing is described above. Both the performance of pharmacological stress and the integration of stress (exercise or pharmacological) studies with radionuclide cardiac imaging require training beyond that necessary for standard exercise testing alone.

Specific training and experience for performing and supervising pharmacological stress in conjunction with radionuclide cardiac imaging should be equivalent to level 1 training defined by the ACC Core Cardiology Training Symposium (COCATS) Task Force 2 (Exercise Testing) (33) to include a minimum of 2 months of training. The number of procedures necessary to ensure competence has not been established by objective criteria. However, the COCATS Task Force 2 described the minimum experience required for appropriate level 1 training to be 100 procedures (including both exercise testing and pharmacological stress); of these, at least 50 need to be personally reviewed with a faculty member. It is the consensus of the present committee that training for physicians who desire to perform vasodilator stress studies should include at least 50 cases of vasodilator stress. Interpretation of stress radionuclide cardiac imaging requires training specifically designed to establish competence in nuclear cardiology. Specific training and experience should be equivalent to level 2 training defined by the ACC COCATS Task Force 5 (Nuclear Cardiology) (34). This training is also the minimum required for eligibility to take the certification examination offered by the Certification Board of Nuclear Cardiology. This includes a minimum of 4 to 6 months of training. The number of procedures required to achieve competence has not been established objectively. However, the COCATS Task Force 5 indicated that appropriate level 2 training for nuclear cardiology would include experience in correlative catheterization/angiographic and radionuclide data in a minimum of 30 patients and a minimum of 300 cases consisting of diverse types of procedures interpreted under supervision. In addition**,** hands-on direct experience with at least 35 patients should include pretest evaluation, radiopharmaceutical preparation, performance of the study, administration of the dosage, calibration and setup of the gamma camera, setup of the imaging computer, and processing of the data for display after acquisition. Training for nuclear cardiology procedures may be obtained in multiple programs, including residency/fellowship training programs in cardiology, nuclear medicine, and radiology. Because of the diverse knowledge necessary to achieve clinical competence, it is expected that training in nuclear cardiology may involve cooperation and interaction between the different types of training programs. Ideally, physicians who interpret nuclear cardiology studies will be certified by the Certification Board of Nuclear Cardiology.

Physicians who did not receive formal training during a residency or fellowship but who are currently performing and/or interpreting stress radionuclide cardiac imaging studies should have obtained appropriate experience comparable to level 2 COCATS training under the supervision of a physician qualified in exercise testing, pharmacological stress, and/or image interpretation. Physicians who have not received formal supervised training but who have been performing or interpreting stress radionuclide cardiac imaging studies for more than 3 years on a regular and substantial basis may have their experience considered on an individual basis in lieu of such training. Regardless of type of training obtained, stress radionuclide cardiac imaging studies should be performed or interpreted only by individuals who have acquired the cognitive skills outlined in Table 4.

TABLE 4. Cognitive Skills Needed to Perform Stress Radionuclide Cardiac Imaging

A. Supervision of exercise stress (see Table 1, part I)

B. Supervision of vasodilator or adrenergic-stimulating agent stress

- Knowledge of appropriate indications
- Knowledge of appropriate contraindications
- Knowledge of advantages and disadvantages of different exercise and pharmacological stress for radionuclide cardiac imaging
- Knowledge of complications and ability to recognize and appropriately treat complications, including use of adenosine/dipyridamole antagonists such as theophylline and aminophylline
- Competence in cardiopulmonary resuscitation and successful completion of an AHA-sponsored course in advanced cardiovascular life support and renewal on a regular basis
- Knowledge of various vasodilator, adrenergic stress protocols
- Knowledge of the pharmacokinetics of vasodilator and adrenergic drugs
- Knowledge of basic cardiovascular physiology, including heart rate and blood pressure response to vasodilators and adrenergic-stimulating agents
- Knowledge of electrocardiography and changes that may occur in response to vasodilators or adrenergic-stimulating agents
- Knowledge of cardiac arrhythmias and their treatment, including high-grade ventricular arrhythmia and heart block
- Knowledge of cardiovascular drugs (and other agents, eg, caffeine) and their effects on vasodilator and adrenergic drugs

C. Interpretation and reporting of imaging results

- Knowledge of clinical use and safe handling of radiopharmaceuticals
- Knowledge of computer display, systems, standard formats for display of images (SPECT and planar), normalization of images
- Knowledge of technical sources of error (including motion, attenuation, adjacent/overlap uptake, and reconstruction and count statistic artifacts), ability to recognize such errors and correct them
- Knowledge of image interpretation, including ventricular size, lung uptake (^{201}Tl imaging), perfusion defect assessment (location, extent, severity, reversibility), noncardiopulmonary findings, and integration of findings into final interpretation
- Knowledge of gated SPECT display, quality control, and interpretation of regional and global right ventricular and left ventricular function
- Knowledge of quantitative image analysis
- Knowledge of coronary anatomy and relation to cardiac images
- Knowledge of normal global and regional function, the physiological determinants of these characteristics, and the potential pathophysiological causes of ventricular dysfunction
- Knowledge of reporting systems and ability to generate a coherent, meaningful report that maximizes clinical utility

D. Integration of clinical, stress, and radionuclide cardiac imaging data for final interpretation

- Knowledge of kinetics of uptake of radionuclide tracers that influence timing of injection and imaging
- Knowledge of advantages and disadvantages of different perfusion agents
- Knowledge of physiology of exercise or pharmacological stress that influences timing of stress and injection of radionuclide perfusion agent
- Knowledge of diagnostic information that stress radionuclide cardiac imaging adds to exercise testing
- Knowledge of sensitivity/specificity of stress radionuclide cardiac imaging for diagnosis of coronary artery disease
- Knowledge of improvement in diagnostic accuracy for coronary artery disease compared with exercise testing
- Knowledge of integration of perfusion and function results
- Knowledge of relationship of imaging results to presence or absence of myocardial viability
- Knowledge of prognostic value of stress radionuclide cardiac imaging in ischemic and nonischemic heart diseases
- Knowledge of impact of extent and severity of perfusion defects and reversibility on prognostic implications of imaging results in ischemic heart disease
- Knowledge of how to apply Bayes' theorem to test results
- Knowledge of factors involved with generating preimaging probability of coronary artery disease (including age, sex, symptomatology, and stress ECG results)
- Knowledge of impact of levels of stress, medications, and timing of perfusion agent injection on diagnostic sensitivity/specificity of imaging results
- Knowledge of improvement in diagnostic and prognostic value with radionuclide cardiac imaging compared with exercise testing

Maintenance of Competence

Continued competence in stress radionuclide cardiac imaging requires that studies be performed and/or interpreted on a regular, ongoing basis. Although the minimum annual number of stress radionuclide cardiac imaging studies required to maintain competence has not been established scientifically, it is the consensus of this committee that an individual should perform and/or interpret at least 100 stress radionuclide cardiac imaging studies per year to maintain competence. At least some of these should include stress radionuclide ventriculography if such studies will continue to be interpreted. This rate is consistent with that recommended for stress echocardiography presented elsewhere in this document. A program of quality assurance should be in place at each center to ensure systematic review and critique of a significant sample of stress radionuclide cardiac imaging cases. Furthermore, successful completion of a course in advanced cardiovascular life support with renewal on a regular basis is also necessary for persons who will be performing stress studies.

Section 4: Pediatric Exercise Testing

Overview of the Test

Exercise testing in the pediatric population and in patients with congenital heart defects is fundamentally different from routine adult stress testing. This difference is due to both the population undergoing testing and the types of testing required in each population (7,35,36). Therefore, not surprisingly, many of the standards for testing in the adult population have little relevance for pediatric exercise testing.

Ischemic heart disease is rare in the pediatric population. Most pediatric patients who undergo exercise testing do so to evaluate nonischemic heart disease. The most common reason is the evaluation of exercise performance in preoperative or, more commonly, postoperative congenital heart defects. Other common indications include cardiomyopathy and exercise-induced arrhythmia or syncope. Increasingly, pediatric cardiologists are also being called on in their role as exercise physiologists to evaluate non–cardiac-exercise–related abnormalities such as exercise-induced bronchospasm or other pulmonary and/or musculoskeletal abnormalities (36). Recommendations regarding the indications for exercise testing in the pediatric population have been published previously (7).

Exercise performance and aerobic capacity can be inferred in the pediatric population from endurance time on ergometers. Although this type of testing does not directly measure such values as maximal oxygen consumption or anaerobic threshold, these values can be estimated from such studies. In addition, assessment of ECG changes, the presence of arrhythmias, and blood pressure response to exercise are readily assessed.

Because physical working capacity and aerobic capacity are often the most important measurements in a pediatric exercise testing, direct measurement of metabolism by gas exchange is frequently performed as part of pediatric exercise testing (36,37). Commonly measured values include maximal oxygen consumption, maximal carbon dioxide production, maximal respiratory exchange ratio, and maximal cardiac output, as well as measurements of oxygen consumption at anaerobic threshold. Maximal work rate, heart rate, and blood pressure responses are also measured. Pulmonary function studies that evaluate performance both at rest and during exercise are important. This is not only to assess for pulmonary dysfunction but also because many congenital heart defects have associated pulmonary abnormalities. Resting spirometry is often performed. During exercise, minute ventilation, tidal volume, respiratory rate, and the ratio of physiological dead space to tidal volume are frequently monitored.

Normal values for all the above measurements vary with age and often with sex. Interpretation of these data requires that the physician be familiar with the changes in children's responses to exercise as a consequence of age and pubertal status (35). In addition, the physician needs to be familiar with many of the expected variations in response to exercise seen in various types of congenital heart defects (7,35,36).

In the actual performance of exercise testing in the pediatric population, wide differences in age and size must also be taken into account. Protocols and ergometers must be adapted to children as young as 4 years of age up through adolescence and young adulthood. Equipment needs (such as mask size, dead space in equipment, and size of rebreathing bags) vary with patient size. Protocols frequently used in adult patients to assess myocardial ischemia are often inadequate to assess the working capacity of young children with congenital heart defects. Likewise, a protocol well suited to measure aerobic fitness in a young child may be inadequate to measure aerobic fitness in an adolescent (36).

Recommendations Regarding Training and Competence for Pediatric Exercise Testing

Recommendations regarding clinical competence in pediatric exercise testing present a number of difficulties. There are no large pools of data available nationwide regarding the types of exercise testing performed and the manpower usage in pediatric practice groups. Data available from surveys of adult exercise testing are not generally applicable to the pediatric population. In addition, far fewer pediatric studies are performed, and there are far fewer pediatric cardiologists than adult cardiologists performing exercise tests. It is therefore difficult to make generalized recommendations for a relatively small group of physicians.

To obtain some insight into the type of testing performed in the pediatric population, an informal survey of 10 medium to large academic pediatric cardiac programs was performed for this committee. The centers had a median of 9 cardiologists (range 5 to 27). A median of 380 tests per year (range 100 to 850) was performed at these institutions, with 88% of tests (range 0% to 100%) using metabolic measurements. These studies were usually read by a single physician in each center (range 1 to 9). In the 7 centers with active fellowship programs, the median number of studies observed by an individual fellow in the course of training was 40 (range 18 to 60).

The large number of patients undergoing metabolic exercise testing in this survey would suggest that a very large percentage of pediatric exercise testing is at least in part directed at assessing working capacity and aerobic capacity. These tests are read by a very small number of individuals (usually just 1) at any center. This tends to reflect the very subspecialized body of knowledge in exercise physiology required to accurately interpret metabolic data from pediatric exercise testing. More physicians appear to participate in exercise testing involving nonmetabolic measurements that focus primarily on ECG and blood pressure responses.

Minimum Requirements Needed to Achieve and Maintain Clinical Competence

Exercise Testing Without Metabolic Measurements

The skills necessary to perform this type of stress testing in a pediatric population are similar to those requirements in adult testing for ischemia and arrhythmias. In addition, the healthcare provider must be familiar with the unique ECG, heart

TABLE 5. Cognitive Skills Needed to Supervise and Interpret Nonmetabolic Pediatric Exercise Tests

Knowledge as specifically applies to the pediatric population, including:

- Appropriate indications for exercise testing
- Absolute and relative contraindications to testing
- Appropriateness of the need for physician presence during testing
- Competence in pediatric cardiopulmonary resuscitation and successful completion of an AHA-sponsored course in pediatric advanced life support and renewal on a regular basis
- Knowledge of the type of ergometers used and modifications necessary for pediatric use
- Knowledge of basic cardiovascular and exercise physiology as it applies to various pediatric populations, including
  - a. ECG, heart rate, and blood pressure response to exercise in the healthy pediatric and adolescent population
  - b. Expected response to exercise in various types of patients with congenital cardiac defects who have or have not undergone surgery
  - c. Knowledge of the cardiac arrhythmias expected with exercise in various types of pediatric cardiac abnormalities and their appropriate treatments
- Knowledge of the appropriate end points for pediatric exercise testing

rate, and blood pressure responses in the pediatric populations (35,36,38). These include both differences in healthy children compared with healthy adults and the changes that occur in the healthy pediatric population in response to aging (38). The physician should be familiar with the expected response to exercise in types of patients who routinely undergo exercise testing with the types of congenital heart disease that produce arrhythmias (7,35). The individual responsible for the supervision of the exercise test should be familiar with the indications and contraindications for exercise testing in the pediatric population; they should also be familiar with the indications for termination of a pediatric exercise study (36). (See Table 5.)

Trainees in the task force survey listed above participate in a median of 40 tests during the course of their fellowship. Although these numbers would appear adequate to achieve competence, the caveats listed in the section on adult testing seem to hold true for pediatric testing. Individual training circumstances must be taken into account when adequacy of training is judged.

Requirements for maintenance of clinical competence should be similar to those for physicians who test adults. Because of the generally lower number of studies performed in the pediatric population, the total number of studies a physician performs in the pediatric population may be fewer. It is nevertheless important to perform testing regularly to maintain an adequate level of clinical competence.

Exercise Testing With Metabolic Measurements

Supervision

Because many of the data needed for interpretation of metabolic measurements in an exercise test require posttest computer processing, there are many instances in which it may not be required that the physician who interprets these data be present for the exercise test. The physician who supervises the test, in many instances, does not need to be able to interpret the metabolic data. He/she should be competent to assess all data acquired in a routine nonmetabolic exercise test as outlined in the above section. Most importantly, the monitoring individual should be familiar with all the indications and contraindications for exercise testing, as well as the indications for termination of a pediatric exercise test (36). The need for the presence of a physician familiar with interpretation of metabolic data during an exercise test must be made on an individual basis. There will be tests for which the physician's presence is necessary to ensure proper collection and subsequent interpretation of the metabolic data.

TABLE 6. Cognitive Skills Needed to Interpret Pediatric Exercise Testing With Metabolic Measurements

- Familiarity with the normal age- and sex-appropriate responses to exercise in healthy children for the following:
  - a. Working capacity, including those effects related to types of ergometers used in testing
  - b. Oxygen consumption, including concepts of maximal $\dot{V}O_2$ as relevant to the pediatric population, relationship of $\dot{V}O_2$ to work rate, factors (cardiovascular, pulmonary, and musculoskeletal) that potentially limit maximal $\dot{V}O_2$
  - c. Evaluation of and techniques to assess anaerobic threshold
  - d. Cardiac output, stroke volume, heart rate responses
  - e. Pulmonary function relevant to exercise measured at rest and during and after exercise
- Familiarity with the expected metabolic responses to exercise for various types of congenital and acquired heart defects, including the unique physiology resulting from unrepaired or palliated heart defects

Interpretation

Interpretation of pediatric metabolic exercise testing is a very subspecialized field in exercise testing. As the committee survey indicates, the number of pediatric cardiologists who interpret these studies is quite small. Therefore, it is extremely difficult to set any specific guidelines regarding how to obtain the fund of knowledge necessary for metabolic exercise interpretation. Trainees wishing to learn these skills generally study metabolic exercise testing as an adjunct to the normal clinical skills that must be mastered as a part of a pediatric cardiology fellowship. Pediatric cardiologists who have completed training usually gain this knowledge by a combination of direct mentoring and texts. Minimal recommendations are summarized in Table 6.

It is not possible to give recommendations about specific numbers or types of studies that an individual should perform to achieve clinical competence. In most cases, this decision would appear to be best made by the individual physician who mentors the trainee. These decisions should obviously take into account the clinical circumstances under which the trainee is likely to function subsequent to completion of training.

Requirements for maintaining clinical competence are also difficult to establish. The physician should be familiar with the data outlined in the overview section of this report for pediatric metabolic exercise testing (7,35–39). Given the specialized nature of this fund of knowledge, there are no data that would suggest how many studies per year are necessary to maintain clinical competence. The information from the committee survey is reassuring, however, suggesting that most physicians who interpret pediatric metabolic exercise tests evaluate a substantial number of studies on a yearly basis.

Stress Echocardiography, Nuclear Imaging, and Pharmacological Stress Testing in Pediatric Patients

These studies are performed in very small numbers in the pediatric population. They are performed to evaluate conditions associated with potential coronary insufficiency, such as Kawasaki disease, cardiac transplant graft vasculopathy, the arterial switch operation, and supervalvular aortic stenosis. These conditions may be due to either an acquired or a congenital cardiac abnormality. In most cases, these studies are performed with the same protocols and measurement techniques as in adult studies.

Very few pediatric centers perform significant numbers of these studies. At these centers, the numbers performed may be insufficient to provide adequate training for these types of studies during fellowship. It may also be difficult to maintain clinical competence with such a small number of studies. It would therefore appear advisable that a pediatric cardiologist who wishes to perform these types of procedures have a relationship with an adult cardiology center, which could serve as a resource for additional expertise in both the performance and interpretation of certain studies.

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