JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY VOL. 74, NO. 3, 2019

PUBLISHED BY ELSEVIER

ADVANCED TRAINING STATEMENT

2019 ACC/AHA/ASE Advanced Training Statement on Echocardiography (Revision of the 2003 ACC/AHA Clinical Competence Statement on Echocardiography)

A Report of the ACC Competency Management Committee

Developed in Collaboration With the American Thoracic Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Critical Care Medicine

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The document was approved by the American College of Cardiology Lifelong Learning Oversight Committee, the American Heart Association Science Advisory and Coordinating Committee, and the American Heart Association Executive Committee in December 2018, and by the American Society of Echocardiography Board of Directors in November 2018. For the purpose of transparency, disclosure information for the Lifelong Learning Oversight Committee, the approval body of the convening organization of this document, is available online.

The American College of Cardiology requests that this document be cited as follows: Wiegers SE, Ryan T, Arrighi JA, Brown SM, Canaday B, Damp JB, Diaz-Gomez JL, Figueredo VM, Garcia MJ, Gillam LD, Griffin BP, Kirkpatrick JN, Klarich KW, Lui GK, Maffett S, Naqvi TZ, Patel AR, Poulin M-F, Rose GA, Swaminathan M. 2019 ACC/AHA/ASE advanced training statement on echocardiography (revision of the 2003 ACC/AHA clinical competence statement on echocardiography): a report of the ACC Competency Management Committee. Developed in collaboration with the American Thoracic Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Critical Care Medicine. J Am Coll Cardiol 2019;74:377-402.

This article has been copublished in *Circulation: Cardiovascular Imaging* and the *Journal of the American Society of Echocardiography*, and reprinted in *Catheterization & Cardiovascular Interventions*.

Copies: This document is available on the World Wide Web sites of the American College of Cardiology (www.acc.org), American Heart Association (https://professional.heart.org), American Society of Echocardiography (www.asecho.org), Society of Cardiovascular Anesthesiologists (https://www.scahq.org), and Society of Critical Care Medicine (https://www.sccm.org). For copies of this document, please contact Elsevier Inc. Reprint Department, fax (212) 633-3820, email reprints@elsevier.com.

ISSN 0735-1097/$36.00 https://doi.org/10.1016/j.jacc.2019.02.003

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PREAMBLE

Since publication of its first Core Cardiovascular Training Statement (COCATS) in 1995, the American College of Cardiology (ACC) has defined the knowledge, experiences, skills, and behaviors expected of clinical cardiologists. Subsequent revisions have moved toward competency (outcomes)-based training based on the 6-domain competency structure promulgated by the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Medical Specialties and endorsed by the American Board of Internal Medicine (ABIM). The ACC has taken a similar approach to describe the aligned general cardiology lifelong learning competencies that practicing cardiologists are expected to maintain. Many hospital systems now use the 6-domain structure as part of medical staff privileging, peer review, and professional competence assessments.

Whereas COCATS and the associated Lifelong Learning Competencies for General Cardiologists focus on general clinical cardiology, ACC Advanced Training and associated Lifelong Learning Statements define selected competencies beyond those expected of all cardiologists and that typically require training beyond a standard 3-year cardiovascular disease fellowship. This includes, but is not limited to, those disciplines for which there is an ABIM sub-subspecialty certification. The Advanced Training Statements describe key experiences and outcomes necessary to acquire skills in a defined sub-subspecialty area of cardiology in a structured training program. These are supplemented by Lifelong Learning Statements that address the commitment to sustaining and enriching competency over the span of a career.

The ACC Competency Management Committee (CMC) oversees the development and periodic revision of the cardiovascular training and competency statements. A key feature of competency-based training and performance is an outcome-based evaluation system. Although specific areas of training may require a minimum number of procedures or duration of training to ensure adequate exposure to the range of clinical disorders, the objective assessment of proficiency and outcomes demonstrates the achievement of competency. Evaluation tools include examinations, direct observation, procedure logbooks, simulation, conference presentations, and multisource (360°) evaluations. For practicing physicians, these tools also include professional society registry or hospital quality data, peer review processes, and patient satisfaction surveys. A second feature of competency-based training is recognition that learners gain competency at different rates. For multiyear training programs, assessment of representative curricular milestones during training can identify learners or areas that require additional focused attention.

The recommendations in ACC cardiovascular training statements are based on available evidence and, where evidence is lacking, reflect expert opinion. The writing committees are broad-based, and typically include early-, mid-, and later-career specialists, general cardiology and sub-subspecialty training directors, practicing cardiologists, people working in institutions of various sizes and in diverse practice settings across the United States, and nonphysician members of the cardiovascular care team. All documents undergo a rigorous process of peer review and public comment. Recommendations are intended to guide the assessment of competence of cardiovascular care providers beginning independent practice as well as those undergoing periodic review to ensure that competence is maintained.

This Advanced Training Statement addresses the competencies required of sub-subspecialists in adult echocardiography and complements the training in echocardiography required of all trainees during the standard 3-year general cardiovascular fellowship. The statement focuses on the core competencies reasonably expected of all individuals trained at this level. Furthermore, the statement identifies selected competencies of Level III echocardiographers that go beyond core expectations that may be achieved by some advanced trainees either during formal fellowship training or through subsequent training experiences. This document provides examples of appropriate measures for assessing competence in the context of training.

The work of the writing committee was supported exclusively by the ACC without commercial support. Writing committee members volunteered their time to this effort. Conference calls of the writing committee were confidential and attended only by committee members. To avoid actual, potential, or perceived conflict of interest resulting from relationships with industry (RWI) or relationships with other entities held by writing committee members or peer reviewers of the document, individuals were required to disclose all current healthcare-related relationships, including those existing 12 months before initiation of the writing effort. The ACC Competency Management Committee reviewed these disclosures to identify products (marketed or under development) pertinent to the document topic. Based on this information, the writing committee was selected to ensure that the Chair and a majority of members had no relevant RWI. Authors with relevant RWI were not

permitted to draft initial text or vote on recommendations or curricular requirements to which their RWI might apply. RWI was reviewed at the start of all meetings and conference calls and updated as changes occurred. Relevant RWI for authors is disclosed in Appendix 1. To ensure transparency, comprehensive RWI for authors, including RWI not pertinent to this document, is posted online. Employment information and affiliations of the peer reviewers are shown in Appendix 2. There are no RWI restrictions for participation in peer review, in the interest of encouraging comments from a variety of constituencies to ensure that a broad range of viewpoints inform final document content. Reviewers are required, however, to disclose all healthcare-related RWI and other entities, and their disclosure information is posted online. Disclosure information for the ACC Competency Management Committee is available online, and the ACC disclosure policy for document development is posted online.

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1. INTRODUCTION

1.1. Document Development Process

1.1.1. Writing Committee Organization

The writing committee consisted of a broad range of members representing ACC, the American Heart Association (AHA), the American Society of Echocardiography (ASE), the American Thoracic Society, the Society of Cardiovascular Anesthesiologists, the Society for Cardiovascular Angiography and Interventions, and the Society of Critical Care Medicine, identified because they perform ≥1 of the following roles: cardiovascular training program directors; Level III echocardiography-trained program directors; echocardiography laboratory directors; experts at early, mid-, and later-career stages; cardiovascular sonographers; scientists who do echocardiography research; multimodality imagers; general cardiologists; Level III trained echocardiography specialists representing both the academic and community-based practice settings as well as small, medium, and large institutions; specialists in all aspects of echocardiography, including interventional, mechanical circulatory support, cardiac resynchronization therapy, ventricular assist devices, and pulmonary arterial hypertension; specialists in cardiac anesthesiology, interventional cardiology, and critical care medicine; physicians experienced in training and working with the ACGME/Residency Review Committee, the ABIM Cardiovascular Board and Competency Committee, and the National Board of Echocardiography (NBE); and physicians experienced in defining and applying training standards according to the 6 general competency domains promulgated by the ACGME and the American Board of Medical Specialties and endorsed by the ABIM. This writing committee met the College's disclosure requirements for relationships with industry as described in the Preamble.

1.1.2. Document Development and Approval

The writing committee chairs, CMC chairs, and CMC liaison convened to plan the writing effort, selected authors on the basis of the criteria specified in Section 1.1.1, and drafted the preliminary competency table for writing committee feedback. The writing committee convened by conference call and email to finalize the document outline, develop the initial draft, revise the draft on the basis of committee feedback, and ultimately approve the document for external peer review.

The document was reviewed by 17 official representatives from the ACC, AHA, ASE, American Thoracic Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Critical Care Medicine, as well as by 39 additional content reviewers, including both cardiovascular and imaging training program directors. The list of peer reviewers, employment information, and affiliations for the review process are included in Appendix 2. The document was simultaneously posted for public comment from May 14, 2018 to May 24, 2018, resulting in comments from 9 Level II and Level III echocardiographers from various academic institutions, including representation from cardiovascular and imaging training program directors and echocardiographers in early, mid- and later-career stages. A total of 625 comments were submitted on the document. All comments were reviewed and addressed by the writing committee. A member of the ACC Competency Management Committee served as lead reviewer to ensure a fair and balanced peer review resolution process. Both the writing committee and the ACC Competency Management Committee approved the final document to be sent for organizational approval. The ACC, AHA, and ASE approved the document for publication with endorsement from the American Thoracic Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Critical Care Medicine. This document is considered current until the ACC Competency Management Committee revises or withdraws it from publication.

1.2. Background and Scope

The original 1995 American College of Cardiology recommendations for training in adult cardiology evolved from a core cardiology training symposium (1). After several iterations, COCATS 4 (2) focuses on trainee outcomes that require delineation of specific components of competency

within the subspecialty, definition of the tools necessary to assess training, and establishment of milestones documenting the trainee's progression toward independent practice. Ultimately, the goal is for the trainee to develop the professional skill set to be able to evaluate, diagnose, and treat patients with acute and chronic cardiovascular conditions.

Each COCATS 4 document includes individual Task Force reports that address subspecialty areas in cardiology, each of which is an important component in training a fellow in cardiovascular disease. The Task Force 5 report of that document addresses training in echocardiography (3) and updates previous standards for general cardiovascular training for fellows enrolled in cardiovascular fellowship programs. It addresses faculty, facilities, and equipment. It also addresses training components, including didactic, clinical, and hands-on experience, and the number of procedures and duration of training. However, the COCATS 4 Task Force 5 report did not provide detailed guidelines for Level III echocardiography training or competencies.

In contrast to COCATS, this document focuses on training requirements for cardiology fellows seeking Level III training in echocardiography. For training standards related to pediatric echocardiography, readers should refer to the SPCTPD/ACC/AAP/AHA Training Guidelines for Pediatric Cardiology Fellowship Programs Task Force 2: Pediatric Cardiology Fellowship Training in Noninvasive Cardiac Imaging (4).

1.2.1. Role of Echocardiography in Contemporary Practice

Echocardiography is essential to the practice of cardiology. It is the most widely used and readily available imaging technique for assessing cardiovascular anatomy and function. Clinical application of ultrasound encompasses M-mode, 2-dimensional (2D), 3-dimensional (3D), pulsed, tissue, continuous wave, and color-flow Doppler imaging. Echocardiography provides diagnostic and prognostic information on cardiovascular anatomy, function, hemodynamic variables, and flow disturbances. Moreover, these cardiovascular parameters can be assessed at rest, as well as during conditions of increased hemodynamic demand such as exercise. Advanced applications of echocardiography, including 3D imaging, strain imaging, and use of ultrasound enhancing agents (also known as "echo contrast agents") to improve left ventricular endocardial definition and to assess perfusion, as well as the use of real-time imaging to guide invasive procedures, have all become important in the clinical care of patients.

All cardiologists should have a basic understanding of echocardiographic techniques—their strengths, limitations, and appropriate use. Although it is expected that most, if not all, fellows will achieve Level II competency in echocardiography during their 3 years of general cardiology training, this document describes the more focused, in-depth experience required for Level III competency.

1.2.2. Levels of Training

COCATS 4 was charged with updating previously published standards for training fellows in cardiovascular medicine and establishing consistent training criteria across all aspects of cardiology, including echocardiography (2). For the cardiovascular fellowship, the following 3 levels of training have been delineated for training in echocardiography.

Level I training, the basic training required for trainees to become competent consultants, is required by all fellows in cardiology and can be accomplished as part of a standard 3-year training program in cardiology. For echocardiography, Level I training is defined as an introductory or early level of competency in performing and interpreting transthoracic echocardiography (TTE) that is achieved during fellowship training but is not sufficient to provide independent interpretation of results.

Level II training refers to additional training in ≥1 area that enables some cardiologists to perform or interpret specific diagnostic tests and procedures or render more specialized care for patients with certain conditions. Level II training in selected areas may be achieved by some trainees during the standard 3-year cardiovascular fellowship, depending on their career goals and use of elective rotations. Level II echocardiography training is required to provide independent interpretation of echocardiograms.

Level III training, the focus of this document, typically requires additional experience beyond the basic cardiovascular fellowship to acquire specialized knowledge and skill in performing, interpreting, and training others to perform specific procedures or render advanced, specialized care for procedures at a high level of skill. Level III training in echocardiography is required of individuals who intend to perform and interpret complex studies in special populations, lead a research program, direct an academic echocardiography laboratory, and/or train others in advanced aspects of echocardiography. Many of the competencies defined in this document overlap with those acquired during Level II training. For individuals seeking advanced echocardiography training, the intent is to gain these competencies at a deeper level during Level III training.

Although Level III training in echocardiography may be achieved within a standard 3-year fellowship, for many individuals—especially those seeking expertise in multimodality imaging—an additional period of postgraduate training will be required. Fellows pursuing Level III

training during the 3-year fellowship must devote all available elective time to echocardiography, usually precluding acquisition of Level II competency in any other imaging modality. As indicated in the COCATS 4, Task Force 5 report, training in echocardiography for at least 9 cumulative months is generally required to ensure sufficient exposure to the range, volume, and diversity of clinical experience necessary for Level III competency. Ultimately, determination of whether a fellow has achieved Level III knowledge and skill should be based on the assessment of competencies defined in this training statement. For those who elect advanced training in echocardiography beyond the 3-year fellowship, the additional time may be dedicated solely to advanced echocardiography or part of a multimodality imaging training program. Although most trainees will achieve Level III training during a cardiology or advanced imaging fellowship program, the committee recognizes that selected individuals may acquire Level III competency after fellowship. Such an approach must adhere to the same rigorous standards (e.g., requirements for resources, clinical volume, faculty, evaluation) defined in this document. Level III training in echocardiography must always take place in laboratories with Level III trained faculty and with the necessary infrastructure to provide the advanced training experience.

1.2.3. Methods for Determining Procedural Numbers

The recommended number of procedures performed and interpreted by trainees under faculty supervision has been developed on the basis of the experience and opinions of the members of the writing group and previously published competency statements, COCATS documents, and policies of the ACGME and NBE. In addition, the writing committee surveyed both cardiovascular and imaging training program directors for additional insight into procedural volumes. Of 234 directors of ABIM-recognized cardiovascular training programs surveyed, 67 responded; of 25 directors of imaging training programs surveyed, 11 responded. The procedural volumes and number of technical experiences suggested in this document were considered the minimum necessary to expose trainees to a sufficient range and complexity of clinical material and allow supervising faculty to evaluate the competency of each trainee. These procedural numbers (see Section 4.2.) are intended as general guidance and are based on the needs and progress of typical trainees in typical programs. Those considering these thresholds should bear in mind that procedural volumes are proxies for acquiring the technical proficiency and analytic skills essential for clinical mastery of echocardiography, which is the fundamental objective of advanced training.

2. GENERAL STANDARDS

2.1. Faculty

Engaged faculty committed to teaching are critical to the success of an advanced echocardiographic training program. The echocardiographic laboratory in which the training of cardiovascular fellows occurs must be under the direct supervision of a full-time qualified, Level III trained laboratory director. The Level III fellowship training will be under the supervision of a Level III NBE-certified echocardiography program director who may or may not be the laboratory director. The participating faculty should include specialists with broad and varied knowledge of all imaging modalities and echocardiographic techniques, including newly developed echocardiographic technologies. It is recommended that the majority of echocardiography faculty be Level III trained in echocardiography and board certified by the NBE. It is also recommended that anesthesiologists involved in training cardiology fellows in perioperative and interventional procedures have the equivalent of Level III training and certification by the NBE. Exposure to and close working relationships with these faculty will allow for a diverse and comprehensive training experience. In addition to developing, implementing, supervising, mentoring, and evaluating the fellows' clinical and research education, faculty should be involved in research and/or education.

2.2. Facilities and Equipment

To provide advanced training in echocardiography, the laboratory environment must be located in an institution with an accredited general cardiovascular training program and should offer a broad range of outpatient and inpatient clinical diagnoses, including acquired and congenital heart diseases. The trainee should have access to both ultrasound equipment and offline workstations for performance and interpretation of 2D and 3D TTE and transesophageal echocardiography (TEE), Doppler echocardiography, contrast echocardiography, stress echocardiography, and strain imaging. The laboratory should perform echocardiography for a sufficient diversity of disease and corresponding volume to provide adequate exposure for the trainee. The training site's resources should allow correlation with other diagnostic data and patient outcomes. Intraprocedural echocardiography, including intraoperative, interventional, and electrophysiology laboratory procedures, should be available to the trainee. Direct experience with other cardiovascular imaging modalities and Level III experts in these modalities provides an important opportunity to understand the strengths and limitations of echocardiography relative to other techniques.

The laboratory should conform to continuing quality improvement guidelines (e.g., ASE Recommendations for Quality Echo Lab Operations) (5). Accreditation of the laboratory through the Intersocietal Accreditation Commission for Echocardiography is required. The training environment should also provide the trainee with participation in quality improvement initiatives, structured reporting, process improvement, application of Appropriate Use Criteria (AUC), and laboratory operations. It is recognized that some institutions may not be able to offer experience in all recommended procedures or adult congenital heart disease. Rotations at other sites with a high volume of structural procedures and/or congenital heart disease would be appropriate to accomplish these aspects of training (6). The echocardiography program director is responsible for verifying the quality of the training. Intersocietal Accreditation Commission accreditation is preferred for those additional sites but not required.

2.3. Additional Resources

Level III trainees should have the opportunity to interact regularly with other members of the healthcare team to enhance learning and patient care. Collaborative interaction with experienced cardiac sonographers who are committed to training fellows and students in the optimization of machine settings and acquisition of high-quality images is critical to success. Trainees should also have routine exposure to cardiologists from other subspecialties, as well as practitioners in other fields, to address and treat the multiple comorbidities often encountered in patients undergoing echocardiographic evaluation. Key specialists with whom echocardiographers frequently interact include surgeons, infectious disease specialists, pulmonologists, neurologists, anesthesiologists, and intensivists.

With the emergence of specialists in critical care echocardiography, Level III trainees should master the principles of critical care echocardiography and understand the impact of hemodynamic changes, loading conditions, heart-lung interactions, and related physiology on echocardiographic findings. This training may be provided by intensivists trained in the use of critical care echocardiography. As part of this interface, Level III trainees will learn to provide subspecialty consultations using point-of-care ultrasound performed in the intensive care unit, emergency department, and operating rooms, often under intense time pressures in unstable patients. In addition, communication skills with referring physicians and the entire healthcare team should be encouraged as part of Level III training.

3. TRAINING COMPONENTS

3.1. Didactic Program

Didactic instruction may take place in a variety of formats, including lectures, online modules, journal clubs, grand rounds, clinical case presentations, research conferences, simulator-based training, and patient safety or quality improvement conferences. A didactic program is intended to provide the advanced trainee with an understanding of ultrasound physics, instrumentation, echocardiographic image formation and optimization, and clinical application of echocardiography (including advanced application of ultrasound enhancing agents, strain imaging, 3D echocardiography, stress imaging, and TEE). It should incorporate relevant content, including anatomy, pathology, and hemodynamics, and it should cover advanced medical knowledge and patient care relevant to the competencies outlined in Section 4.1. In particular, instruction in the use of echocardiography in structural heart interventions and cardiac surgery should be included. Some of this training may be incorporated into the didactic program for general cardiovascular training. However, Level III didactic teaching should be provided within a multimodality imaging framework to emphasize appropriate and coordinated use of all cardiac imaging modalities. Given that fellows who complete advanced training in echocardiography will be prepared to direct an echocardiography laboratory and train others in advanced aspects of echocardiography, didactic education should include exposure to the principles of laboratory operations (e.g., budgeting, manpower and equipment assessment, accreditation, relationships with industry, sonographer supervision, continuous quality improvement) as well as the opportunity to gain experience in teaching.

3.2. Clinical Experience

Echocardiography plays an integral role in the diagnosis and management of a wide variety of acquired and congenital cardiac disorders. Therefore, exposure to the entire spectrum of heart diseases in diverse patient populations should be available to the trainee. Although a minimum number of clinical cases is suggested (see Section 4.2.), these criteria merely serve as proxies for clinical experience. In terms of the overall quality of the educational experience and depth of understanding, the number of echocardiographic studies in which the trainee participates is less important than the range of pathologies encountered (5) and the quality of supervision and instruction. The trainee must develop expertise in understanding clinical contexts in order to communicate echocardiographic results in a way that is clinically relevant to the referring physician. For the acquisition of technical skills, such as TEE or stress echocardiography,

this document provides minimum procedure volumes beyond those required for Level II training. The criteria described herein are similar to those in other publications on this topic. If the case mix available for the trainee is skewed, additional cases and experience beyond the numbers quoted may be required to ensure appropriate training (7).

Although Level III training can be achieved during the standard 3-year cardiology fellowship, additional training may be necessary or desirable to acquire specialized knowledge and competencies in performing, interpreting, and training others to perform specific procedures. Level III training in echocardiography requires rigorous clinical experiences in diverse clinical settings using the various echocardiographic modalities. This would include extensive experience in TTE and TEE using both 2D and 3D approaches; expertise in stress echocardiography; and familiarity with new echocardiographic tools such as speckle tracking echocardiography, which is used for strain and strain rate analyses.

In addition to experience with the use of echocardiography across the broad spectrum of cardiovascular disease, exposure to echocardiographic evaluation of congenital heart disease is essential. The sites of Level III training should include outpatient and inpatient settings, intensive care units, interventional cardiac laboratories and intraoperative locations. In each setting, trainees should participate in supervised procedures with graduated responsibility and autonomy in procedural performance, ultimately to achieve clinical independence and the ability to function as a first-line proceduralist for a portion of the training period, with appropriate oversight from an attending echocardiographer. Level III trainees are expected to acquire and interpret images using online and offline analytic tools and to communicate their findings to the ordering physician/service effectively through a comprehensive written report (8,9). In addition, trainees should be aware of the potential risks associated with echocardiography and learn how to recognize, treat, and, where possible, avoid complications. The trainee must review imaging studies and associated clinical outcomes regularly. The trainee should develop expertise in conscious sedation for TEE, pharmacologic options for stress testing, and use of ultrasound enhancing agents. Familiarity with the indications for echocardiography and the implementation of the AUC for echocardiography is an important component of training (10).

3.3. Hands-On Procedural Experience

The echocardiographic examination is an operator-dependent procedure in which it is possible to introduce confounding artifacts or to omit data of diagnostic importance. It is interactive, requiring real-time recognition of specific diagnostic findings to obtain a study that is both comprehensive and clinically useful. The ability of the trainee to perform a hands-on examination independently is initially developed during Level II training. The trainee should also develop sufficient technical skills in using an echocardiographic instrument to answer clinical questions during Level II fellowship training. Such training is important not so much to develop true technical expertise but to better understand the diagnostic capabilities and potential pitfalls of the echocardiographic examination. It also helps trainees to learn tomographic cardiac anatomy and integrate planar views into a 3D framework. Highly skilled cardiac sonographers with broad experience in performing echocardiographic examinations are necessary to facilitate this training. In contrast, Level III training requires that the trainee be able to train both fellows and sonographers in image acquisition and optimization at the level of a skilled cardiac sonographer. Therefore, fully developed image acquisition skills are an essential competency for the Level III trainee. No additional procedure numbers are recommended as a minimum for Level III TTE acquisition. Rather, the focus of this competency is on an expert level of image acquisition, the ability to consistently perform a complete and comprehensive study, and the acquisition of skills and knowledge to train others in the field. This level of expertise may require further TTE experience during Level III training.

Clinical exposure to a broad range of cardiac pathologies and sufficient hands-on experience are essential for the advanced trainee to gain the requisite technical competency (see Section 4.2.). As part of the hands-on aspect of the echocardiographic training program, experience with hand-carried ultrasound devices is desirable. These devices extend the clinical utility of echocardiography by allowing the operator to offer a “visual physical examination” in a manner that can be applied practically in the clinical setting (11). Their appropriate application requires that the operator have a fundamental understanding of echocardiographic principles, cardiac anatomy/physiology, and resultant echocardiographic correlates. The operator must also understand the limitations of these devices. Therefore, participation in a didactic echocardiographic educational program and hands-on training with conventional echocardiographic equipment best prepares the cardiovascular fellow to utilize hand-carried ultrasound in the clinical setting as a teaching tool and an adjunct to physical examination.

3.4. Diagnosis and Management of Emergencies and Complications

Emergency echocardiography is defined as the use of echocardiographic techniques for the rapid diagnosis of unstable patients, life-threatening conditions, or procedural/surgical complications, usually in a hospital setting. The study may be TTE or TEE and comprehensive or

targeted and may utilize either a full-sized ultrasound system or a hand-carried unit.

A unique feature of emergency echocardiography is the requirement that the examination be performed/interpreted by an individual able to acquire the needed information, formulate an accurate interpretation, integrate the ultrasound data with the clinical scenario, and immediately communicate the relevant information to the healthcare team. Because bedside echocardiography is often the only practical diagnostic modality available to such patients, its value cannot be overstated (12).

Given the profound implications of emergency echocardiographic findings in the management of unstable patients, cardiologists who provide this service must be highly trained and experienced echocardiographers. They should be fully trained in all aspects of TTE and TEE techniques, with particular focus on the recognition and assessment of life-threatening conditions such as left ventricular dysfunction, cardiac tamponade, right heart failure, acute valvular regurgitation, and aortic dissection (13–16). In unstable patients particularly, the assessment of fluid status, management of vasopressors, and recognition of left atrial hypertension as a cause for respiratory failure are critical for management. In addition, a level of clinical expertise is highly desirable so that the echocardiographic findings can be fully and rapidly integrated with other clinical data. Beyond general training in TTE and TEE, Level III experience in emergency echocardiography requires specific participation in the interpretation of a number of studies from patients with unstable and/or life-threatening situations. In laboratories with a diverse and complex patient population, it would be expected that this exposure would be achieved as a matter of course.

3.5. Diagnosis and Management of Rare Clinical Conditions and Syndromes

Level III trainees should be familiar with the echocardiographic findings of less common conditions involving the cardiovascular system. These include complex congenital heart defects (both repaired and unrepaired), the full spectrum of acquired and genetic cardiomyopathies, and the various etiologies of cardiac masses. Competency in interpreting complex and postoperative congenital heart disease may require training beyond Level III (3,6,17–19). This additional training may occur at another site with a high volume of complex congenital heart disease. The Level III trainee should also be aware of syndromes (e.g., Down and Pierre Robin syndromes) or conditions (e.g., vascular ring or aortic arch anomaly) that may pose challenges for esophageal intubation and require anesthesia assistance (19). The Level III trainee should be able to interpret the echocardiographic findings in these less common conditions and know the indications to proceed with alternative imaging modalities as a complement to or in place of echocardiography.

3.6. Research and Scholarly Activity

One important purpose of Level III training is to develop the skills necessary for a career that includes cardiovascular research and education (20). The trainee would be expected to work with faculty in clinical, imaging science, and/or translational research. Formal training in research methodology, including biostatistics, clinical trial design, research ethics, and grant writing should be available for those fellows who plan to be involved in research activities. Research should lead to presentations at local, regional and/or national meetings, publication in peer reviewed scientific journals, and/or grant support. Alternatively, Level III trainees at programs that are not designed to support original research activities are expected to actively participate in quality improvement and educational projects. All trainees should develop and maintain habits of self-learning, by both conducting regular case-review and journal review sessions and attending regional and national scientific meetings. Level III training programs are expected to evaluate progress in scholarly development. Periodic meetings and review of presentations, manuscripts, and/or other scholarly activities should be conducted to provide feedback and implement corrective action plans if necessary, to ensure that trainees achieve predefined goals.

4. TRAINING REQUIREMENTS

4.1. Development and Evaluation of Core Competencies

Advanced training competencies for Level III echocardiographers are organized using the 6 domains promulgated by the ACGME/ABMS and endorsed by the ABIM: Medical Knowledge, Patient Care and Procedural Skill, Systems-Based Practice, Practice-Based Learning and Improvement, Professionalism, and Interpersonal and Communication Skills. The ACC has used this structure to define and depict the components of the clinical competencies for cardiology. The curricular milestones for each competency and domain also provide a developmental roadmap for fellows as they progress through various levels of training. The ACC has adopted this format for its competency and training statements, career milestones, lifelong learning, and educational programs. Of note, the ACC has developed a framework around competencies related to Systems-Based Practice, Practice-Based Learning and Improvement, Professionalism, and Interpersonal and Communication Skills that recognizes their universality and provides for common language across all Advanced Training Statements.

Table 1 depicts the 6 competency domains and their associated curricular milestones for training in

TABLE 1 Competency Components and Curricular Milestones for Level III Training in Echocardiography

MEDICAL KNOWLEDGE		Milestones: All	Milestones: Add*
Physics			
1.	Know the physics of ultrasound, including understanding of optimal machine and transducer settings, effect of change in frequency of transducers and transducer types, and effects on resolution (temporal, lateral, and linear).	X	
2.	Know the basis of image formation, beam focus, and resolution, and causes of artifacts.	X	
3.	Know the physics of Doppler ultrasound as used for blood flow and tissue applications, including Doppler equation, angle corrections, differences when compared with the hemodynamic data derived from other imaging modalities, and causes of artifacts.	X	
4.	Know the physics of harmonic imaging and ultrasound enhancing agents, including optimizing left ventricular opacification and perfusion.	X	
5.	Know the physics of 3-dimensional ultrasound, including optimization of resolution.	X	
6.	Know the physics of strain and strain rate imaging, including applications based on speckle tracking and tissue Doppler imaging.	X	
7.	Know the basic principles (e.g., physics, image formation, causes of artifacts) of other commonly used noninvasive cardiovascular imaging modalities (i.e., nuclear cardiology, cardiovascular computed tomography, cardiovascular magnetic resonance).	X	
Hemodynamics			
8.	Know normal cardiac physiology and the pathophysiology of diseased cardiac states.	X	
9.	Know the echocardiographic correlates of pressure assessments in the heart, including complex valvular lesions and diastolic assessment in complex disease.	X	
10.	Know the limitations of various hemodynamic measurements and how to reconcile discrepant indices.	X	
11.	Know complex and advanced hemodynamics and the relationship between Doppler findings and other imaging and invasively measured intracardiac pressures.	X	
General Competencies for All Conditions			
12.	Know the echocardiographic findings (transthoracic echocardiography and transesophageal echocardiography) of simple and complex acquired disease, including postoperative findings.	X	
13.	Know the principles of hemodynamics in normal and abnormal conditions.	X	
14.	Know the advantages and limitations of echocardiography in relation to other imaging modalities.	X	
15.	Know the correlation of echocardiography with other noninvasive and invasive techniques for assessing cardiac structure and function.	X	
16.	Know the causes of discordant findings and the procedures to reconcile those discrepancies.	X	
17.	Know the limitations of all imaging and invasive assessment and the appropriate use of imaging in each condition.	X	
18.	Know the importance of serial comparisons and the principles of assessing serial change.	X	
19.	Know the indications for emergent and urgent echocardiographic evaluation of patients.	X	
Ventricular Disease (Transplant and Devices)			
20.	Know the methods of assessing left and right ventricular systolic and diastolic function utilizing all the various ultrasound modalities.	X	
21.	Know the application of strain imaging to cardio-oncology, cardiomyopathies of both ventricles, and detection of subclinical disease.	X	
22.	Know the distinct patterns of regional strain that suggest specific cardiac diseases.	X	
23.	Know the imaging of temporary and durable ventricular assist devices, including normal and abnormal function and the ability to identify malposition and malfunction of devices.	X	
24.	Know the use of ramp protocols for left ventricular assist devices.	X	
25.	Know the protocols to optimize dual chamber pacemaker and biventricular pacemaker function.	X	
26.	Know the methods to assess the transplanted heart, including orthotopic organ function, methods and importance of serial assessment, and evaluation of perioperative complications.	X	
27.	Know the imaging approaches (transthoracic echocardiography and transesophageal echocardiography) for assistance of venoarterial and venovenous extracorporeal membrane oxygenation cannula placement and for confirmation of appropriate position.		X

TABLE 1 Competency Components, continued

MEDICAL KNOWLEDGE	Milestones: All	Milestones: Add*
28. Know the approach for echocardiographic assessment during trial of weaning from venoarterial extracorporeal membrane oxygenation and other forms of circulatory support as well as ramp protocols for extracorporeal membrane oxygenation.		X
Atrial Anatomy and Physiology		
29. Know the approaches to assessing anatomic variants of the left atrial appendage and the pulmonary veins.	X	
30. Know the approaches to assessing atrial structure and function, including 2- and 3-dimensional imaging; spectral Doppler; and speckle tracking, including strain and strain rate analysis.	X	
Pulmonary Hypertension		
31. Know the echocardiographic methods for assessing pulmonary arterial systolic, diastolic, and mean pressure as well as pulmonary vascular resistance, and for establishing the causes of any abnormalities.	X	
32. Know the echocardiographic methods for assessing right heart function, ventriculoarterial coupling, and ventricular interdependence.	X	
Valvular Disease		
33. Know the comprehensive anatomic evaluation of all valvular heart diseases utilizing all the various ultrasound modalities.	X	
34. Know the comprehensive hemodynamic evaluation of all valvular lesions (transthoracic echocardiography and transesophageal echocardiography), including serial and complex lesions.	X	
35. Know the echocardiographic findings that establish the etiology of valvular lesions.	X	
36. Know the key imaging parameters that are important in determining indications and eligibility for surgical and nonsurgical interventions.	X	
37. Know the appropriate imaging techniques to guide valvular repair and replacement procedures, including 3-dimensional assessment of intracardiac device interaction with valves.	X	
Pericardial Disease		
38. Know the methods for assessing the presence of pericardial disease (including tamponade, constrictive, and effusive-constrictive physiology) and the determination of its etiology and severity.	X	
Stress Testing		
39. Know the Appropriate Use Criteria for stress echocardiography and criteria for selection of exercise versus pharmacological stress.	X	
40. Know the pharmacokinetics, contraindications, and side effects of pharmacological stress agents and the procedures for monitoring safety.	X	
41. Know the use of ultrasound enhancing agents for left ventricular opacification and myocardial perfusion in conjunction with echocardiographic stress testing.	X	
42. Know the indications and limitations of stress echocardiography in comparison with other stress testing modalities.	X	
43. Know the indications and the criteria for assessing diastolic function during stress testing.	X	
44. Know the indications and parameters for diagnosing significant and complex valvular heart disease by stress echocardiography, including hemodynamic assessment of low flow states.	X	
Diseases of the Aorta		
45. Know the transthoracic and transesophageal echocardiographic findings of complex aortic disease (acute and chronic).	X	
46. Know the echocardiographic findings that indicate the need for immediate surgical intervention.	X	
Adult Congenital Heart Disease		
47. Know the findings of complex pre- and postoperative adult congenital heart disease, including anatomic and hemodynamic assessments.	X	
Critical Care and Perioperative		
48. Know the echocardiographic findings to diagnose cause of undifferentiated shock, including evidence-based echocardiographic measures of fluid responsiveness and implications in management of volume expansion, hemodynamic assessment via echocardiographic methods to assess the etiologies of acute cor pulmonale, and treatable causes of cardiac arrest.	X	

TABLE 1 Competency Components, continued

		Milestones	
MEDICAL KNOWLEDGE		**All**	**Add***
49.	Know the echocardiographic findings and hemodynamic assessment of patients with pathologic heart-lung interactions and those on mechanical ventilation, including patients in shock and those who cannot be weaned from ventilation.	X	
50.	Know the indications for perioperative or periprocedural transthoracic and transesophageal echocardiography and the findings representing acute and subacute complications.	X	
Research			
51.	Know the methods to design, conduct, analyze, and prepare for publication the results of original investigative work that involves application of echocardiographic techniques.	X	

Evaluation Tools: chart review, direct observation, in-training exam, preliminary report review, trainee portfolios

	PATIENT CARE AND PROCEDURAL SKILLS	**All**	**Add***
1.	Skills to perform and interpret a comprehensive transthoracic echocardiography examination, including 3-dimensional imaging.	X	
2.	Skills to perform and interpret a comprehensive transesophageal echocardiography examination, including 3-dimensional imaging.	X	
3.	Skills to render and manipulate 3-dimensional images both during the procedure and off line.	X	
4.	Skills to administer conscious sedation and monitor patients during and after TEE procedures.	X	
5.	Skills to perform and interpret myocardial mechanical function via strain imaging (including longitudinal, circumferential, and radial strain and serial assessments) as well as tissue Doppler, including ability to recognize and eliminate artifacts.	X	
6.	Skills to perform and interpret rapid assessments of hemodynamically unstable (undifferentiated shock) patients requiring assessment of volume status; ventricular function; fluid responsiveness; extravascular lung water; and tamponade physiology, including large pleural effusions.	X	
7.	Skill to review images from other cardiovascular imaging modalities for purposes of correlating with echocardiographic findings.	X	
8.	Skills to acquire and interpret echocardiographic images during cardiovascular interventions such as pericardiocentesis and endomyocardial biopsy.	X	
9.	Skills to acquire and interpret echocardiographic images to optimize temporary and permanent ventricular assist device function and to diagnose device malfunctions and complications.	X	
10.	Skills to acquire and interpret echocardiographic images to assist structural heart interventions.		X
11.	Skills to acquire and interpret echocardiographic images using all techniques to assess and diagnose complex adult congenital heart disease and assist in interventions.		X
12.	Skill to guide insertion of mechanical support devices, including surgical and transcatheter devices.		X
13.	Skill to assist in the performance and interpretation of intracardiac echocardiography during structural or electrophysiological procedures.		X

Evaluation Tools: chart review, direct observation, fellow-acquired image review, multisource evaluation, simulation

	SYSTEMS-BASED PRACTICE	**All**	**Add***
1.	Incorporate risk-benefit analysis and cost, resource, and value considerations into care of patients with cardiovascular disease.	X	
2.	Identify and address financial, cultural, and social barriers to adherence with care recommendations.	X	
3.	Participate in practice-based continuous quality improvement and safety initiatives.	X	
4.	Participate in hospital-based and regional systems of care for patients with urgent and emergent cardiovascular conditions.	X	
5.	Work in collaborative fashion with physicians and healthcare professionals in other disciplines to optimize the care of patients with complex and multisystem disease.	X	

Evaluation Tools: chart review, direct observation, multisource evaluation

TABLE 1 Competency Components, continued

		Milestones	
PRACTICE-BASED LEARNING AND IMPROVEMENT		**All**	**Add***
1.	Identify personal knowledge gaps and seek educational and training opportunities to improve knowledge, skills, and performance.	X	
2.	Utilize clinical practice guidelines, Appropriate Use Criteria, Medline searches, and other information tools at the point of care to improve clinical decision-making.	X	
3.	Solicit and incorporate feedback from patients, colleagues, and other healthcare team members to improve clinical performance.	X	
4.	Use hospital and registry data to assess appropriateness, quality, and safety of cardiovascular care.	X	
5.	Develop habits and practice of lifelong learning, including regular review of journals and practice guidelines/Appropriate Use Criteria/consensus statements and attendance at scientific and certified medical education meetings.	X	
6.	Skills to conduct literature searches, abstract and interpret data, and apply results to clinical care.	X	
Evaluation Tools: conference presentation, direct observation, multisource evaluation, reflection and self-assessment			
PROFESSIONALISM		**All**	**Add***
1.	Demonstrate respect, consideration, and empathy for patients, families, and all members of the healthcare team.	X	
2.	Practice within the scope of personal expertise, training, and technical skills.	X	
3.	Appropriately seek and integrate advice from consultants in a timely manner.	X	
4.	Know evidence-based clinical practice guidelines, consensus statements, Appropriate Use Criteria, and performance measures relevant to scope of practice.	X	
5.	Identify, disclose, and manage relationships with industry and other entities to minimize bias and undue influence on clinical decision making.	X	
6.	Demonstrate high ethical standards in personal and professional conduct.	X	
7.	Take responsibility for, and follow through on, professional commitments and obligations in a timely fashion.	X	
8.	Identify potential for impaired professional performance in oneself and colleagues and take action to mitigate.	X	
9.	Attend to one's own health, wellbeing, and abilities to maximize personal and professional performance.	X	
Evaluation Tools: chart review, conference presentation, direct observation, multisource evaluation, reflection and self-assessment			
INTERPERSONAL AND COMMUNICATION SKILLS		**All**	**Add***
1.	Communicate with patients and families in an effective and timely manner across a broad range of ethnic, social, cultural, socioeconomic, and religious backgrounds.	X	
2.	Engage patients in shared decision making based upon balanced presentation of potential risks, benefits, and alternatives, factoring in patients' values and preferences.	X	
3.	Complete medical records and communicate results of diagnostic and therapeutic measures to patients and collaborating healthcare professionals in an effective and timely manner.	X	
4.	Effectively lead and collaborate in interdisciplinary and cardiovascular care teams, treating all team members with respect.	X	
Evaluation Tools: chart review, direct observation, multisource evaluation			

*Add indicates additional competencies that extend beyond the core expectations that may be achieved by some Level III-trained echocardiographers based on career focus, either during or following formal fellowship training (see text for details).

TABLE 2 Minimum Procedural Volume Typically Necessary for the Development and Demonstration of Level III Echocardiography Competencies

Procedure/Technical Skill	Level III Numbers*	Notes
Transthoracic echocardiography performed†	150	Represents no change beyond Level II
Transthoracic echocardiography, interpreted†	750	Represents an additional 450 studies beyond Level II
Transesophageal echocardiography, performed and interpreted‡	150	Represents an additional 100 studies beyond Level II
3-dimensional echocardiography§		
For valve disease, rendering/image manipulation	50 (TEE or TTE)	
For ventricular volumes, function, ejection fraction	50 (TTE)	
Contrast echocardiography§	100 (TTE)	
Strain and strain rate quantification§	50	
Stress echocardiography‖ Includes 25 for noncoronary indications	200	Represents an additional 100 studies beyond Level II

*Numbers are based on consensus, are intended as general guidance, based on the educational needs and progress of typical Level III echocardiography trainees, and represent the cumulative experience that may occur at any time during training. Competency to perform each procedure must be based on evaluation by the supervising echocardiography laboratory director and may exceed or be below the threshold number shown in this table.
†The experience represented by these numbers must include exposure to a broad range of adult patient ages, pathologies, modalities, and therapies, including complex congenital heart disease, mechanical circulatory support devices/transplant, ultrasound enhancing agents, and 3D and speckle tracking to achieve the competencies outlined in Table 1 (Competency Components and Curricular Milestones for Level III Training in Echocardiography). Additional training may occur in centers with a high volume of complex congenital heart disease or mechanical assist devices/transplant to achieve the outlined competencies.
‡The range of experience must include exposure to a broad range of indications, settings, and pathologies, inclusive of operative and intraprocedural studies and the use of 3D echocardiography to achieve the competencies outlined in Table 1 (Competency Components and Curricular Milestones for Level III Training in Echocardiography).
§Exposure to these studies is not expected to be additional but rather to occur during the course of exposure to TEE, TTE, and stress studies.
‖Exposure to a broad range of indications and pathologies, including valvular disease and diastolic stress testing, as well as coronary disease is required. A significant number of studies must be abnormal. The use of ultrasound enhancing agents in an appropriate number of stress echocardiographic studies is strongly recommended.
TEE indicates transesophageal echocardiography and TTE, transthoracic echocardiography.

echocardiography, as well as examples of evaluation tools suitable for assessing competence in each domain. The focus of this document is on delineation of the core competencies expected of all Level III trainees in echocardiography. These competencies are indicated under the column labeled “All”. Certain less common or highly specialized areas are not required of all Level III trained individuals; these are indicated under the column labeled “Add” (Additional). These additional competencies may be obtained during or after the general training fellowship, depending on the trainee’s career focus and the opportunities available at the training program. This designation reflects differences in clinical practice (e.g., a cardiologist who practices at an institution that does not perform a particular advanced procedure may choose not to gain expertise in this area). Although the competency components included in the “All” column should be achieved by all trainees and are appropriate areas for assessment, not every component need be individually assessed in every trainee. Rather, as with all educational activities, assessment is a sampling process that should be tailored to the needs of the individual trainee and program.

4.2. Procedural and Technical Experience

Advanced training in echocardiography implies a high level of medical knowledge and technical skill in the performance and interpretation of all forms of cardiovascular ultrasound. A competency-based approach to training relies on a variety of tools to assess progress toward, and ultimate achievement of, each component of competency. Level III training represents the highest level of knowledge, experience, skill, and behavior in a given field.

For a procedural area, such as echocardiography, achieving this level of competency depends on both the quality and volume of training. Creating a high-quality training experience involves didactic instruction, self-directed learning, mentoring, case-based education, and exposure to a wide range of pathologies. Volume, a less important but more easily quantified metric, can be measured by the number and diversity of studies to which the trainee is exposed. As such, a prescribed volume of studies is necessary, but volume alone is an insufficient metric to guarantee satisfactory achievement of full competence in each specific area. Competence to perform each procedure is ultimately based on successful completion of all training requirements and favorable evaluation by the echocardiography program training director.

The minimum procedural volumes typically necessary for the development and demonstration of Level III competencies in each area are listed in Table 2. Numbers reflect writing committee consensus on the minimum experience required to provide most trainees with a sufficient variety of clinical situations and to allow faculty enough opportunity to evaluate the trainee’s emerging competency. Whenever possible, an attempt was made to

harmonize these numbers with previously published training guidelines. Procedural volume represents a surrogate for a broad, diverse clinical training experience and will vary depending on the specific clinical services available at the training institution and the career goals of the trainee.

4.2.1. Level III General Training Requirements

By entering a Level III training program, fellows express their interest in and commitment to a given field. To provide the optimal training experience, certain principles should be followed. First, training should be flexible and, to the degree possible, permit individuals to pursue a program that best fits their long-term goals and career focus. To this end, the training program should strike a balance between gaining competency through diverse and high-volume clinical exposure and providing the opportunity for the fellow to pursue other equally important goals, including the development of research, education, and leadership skills. The procedural volume requirements described in this document should be viewed as general guidelines rather than absolute rules. An individualized program tailored to the career goals of the fellow should allow some flexibility, presuming competency is established.

To obtain Level III competency, the trainee must first fulfill the requirements for Level II certification (3) and then gain additional experience in performing and interpreting both routine and specialized echocardiographic studies. Level III training should not only include acquiring expertise in the technical aspects of advanced echocardiographic imaging methods (such as 3D, strain, and contrast imaging), but should also provide a structured educational program that enables the trainee to best apply these methods in the treatment of specialized patient populations. Ideally, the trainee will participate in the appropriate selection, intraprocedural guidance, and postprocedural monitoring of patients undergoing valvular interventions, repair of acquired/congenital heart defects, and mechanical circulatory support.

Level III training must also include acquiring the necessary skills for leading a training or research echocardiographic laboratory, including understanding its administrative aspects, implementing a continuous quality improvement program (including accreditation activities), and fostering an environment that promotes innovation through the ongoing education of the physicians and staff. Although it is not expected that all Level III trainees will pursue careers as independent investigators, all training programs must be structured to promote participation in scholarly activities. At a minimum, Level III trainees must develop the skills to conduct regular journal review sessions, organize clinical care conferences, prepare oral presentations, and/or write manuscripts for publication.

TABLE 3 Minimum Procedural Volume Typically Necessary for the Development and Demonstration of Level III Echocardiography Competencies for Additional, Optional Special Cardiovascular Ultrasound Procedures

Procedure/Technical Skill	Numbers*
Echocardiographic guidance of interventional procedures,† which includes:	**75**
Structural valvular interventions‡	30
Transseptal catheterization guidance	10
Percutaneous closure of septal defects/perivalvular leaks	15
Alcohol septal ablation	10
Placement of devices to exclude the left atrial appendage	10
Ventricular assist device placement and assessment	**20**
Intraoperative transesophageal echocardiography,† which includes:	**75**
Surgical valve repair or replacement	50
Intracardiac echocardiography	**10**

*These numbers are for training in particular procedures that are not required for general Level III competency, although exposure is recommended. Training and development of competency in these areas will depend on specific trainee interest and institutional availability. Numbers are based on consensus and intended as general guidance based on the educational needs and progress of typical Level III echocardiography trainees. Competency to perform each procedure must be based on evaluation by the supervising echocardiography laboratory director and may exceed or be below the threshold number shown in this table.

†These procedures may be counted toward the total TTE or TEE numbers in Table 2 provided a complete study is performed.

‡The Level III trainee should successfully complete both right-sided and left-sided procedures if the goal is to obtain competency in the full range of structural heart disease interventions.

TEE indicates transesophageal echocardiography and TTE, transthoracic echocardiography.

4.2.2. Special Ultrasound Procedures

Special procedures are those that require specialized training across a broad array of clinical settings in which echocardiography is integral to the diagnosis and management of patients and in the guidance of invasive procedures and surgeries (21). The specialized procedures that may be included in Level III training are listed in **Table 3**. It is recognized that exposure to these procedures depends on the range of clinical services offered at the trainee's institution and the individual career focus of the trainee. Not all fellows will develop competence in all these areas. The minimum procedural volume typically necessary for the development and demonstration of Level III echocardiography competencies for special cardiovascular ultrasound procedures is provided in **Table 3**. Exposure to these procedures is essential, but competency in any or all of these is not required for Level III training.

For adequate exposure to special procedures, advanced training should occur in a laboratory that is performing at least 7,500 studies annually (3). Level III training in

special ultrasound procedures provides a full understanding of the principles, indications, risks, and technical limitations of the techniques. In addition to special expertise, mastery of these procedures involves the ability to integrate the information from the procedures into clinical practice, which includes accurate and timely reporting of the echocardiographic findings. Each special procedure can only be learned at a high-volume laboratory with an adequate volume of cases under the supervision of Level III trained and NBE-certified experts who perform and interpret a large number of such procedures in an accredited lab according to specific guidelines applicable to the procedure. Specific recommendations for the various procedures follow. AUC, where available, should also be understood and applied.

4.2.2.1. Transesophageal Echocardiography

TEE is best learned in a laboratory that performs a high volume of diagnostic studies and provides a diverse range of pathologies. Although the technical expertise needed to perform TEE may be acquired in a lower-volume setting, low volume limits exposure to the critical and unusual abnormalities uniquely identified by TEE. Training should include exposure to TEE examinations performed for a broad array of indications, including but not limited to assessment of native and prosthetic valve disease, aortic disease, acquired or congenital structural heart disease, and evaluation of masses (e.g., thrombus or vegetation). Level III training requires the performance and interpretation of a minimum of 150 TEEs. This count can include studies performed as part of structural heart and/or intraoperative TEE interventions (see **Table 3**) provided these are complete TEEs of which the trainee performs the significant portion. The growing availability of TEE simulation to supplement clinical experience is an increasingly important and practical way to enhance TEE skills but cannot be used as a substitute for the number of required clinical studies.

Competence in TEE requires a thorough understanding of its use in both outpatient and inhospital clinical settings (e.g., multispecialty intensive care unit, emergency department, and operating room). Patient suitability in these settings can influence the choice of TTE versus TEE as the first diagnostic imaging modality. The trainee should be competent in weighing and communicating the risks and benefits of the TEE exam and occasionally deferring such an exam. Independent performance of TEE also requires knowledge of and experience in the administration of conscious sedation, which includes potential complications and their management. Additional competence in TEE should include a thorough knowledge of absolute contraindications, relative contraindications, and complications. Collection of clinical performance data and grading for competency assessment permits a more objective assessment of echocardiography training (22).

4.2.2.2. 3D Echocardiography

Three-dimensional echocardiography is a technically complex modality used in characterizing structural heart disease and in planning and guiding certain interventional and surgical procedures (23). Level II training in echocardiography provides a basic understanding of the principles of 3D echocardiography and recognition of the clinical situations in which 3D representation can add incremental value over 2D imaging. Level II training should prepare fellows to apply 3D echocardiography appropriately and expose them to basic image acquisition and interpretation. Because of the evolving nature and complexity of 3D echocardiography, independent performance, processing, and interpretation of 3D echocardiography is part of Level III training under the supervision of a Level III expert. The Level III trainee should interpret approximately 100 3D echocardiograms (either TTE or TEE) of which at least half should include the acquisition and rendering of images involving valvular, structural, or congenital patients. These studies may also satisfy the suggested minimum requirements for TTE, TEE, or other special procedures as long as they include all the necessary components.

Training should be performed in a laboratory in which 3D echocardiography is used routinely in a variety of applications, including assessment of chamber volumes, valvular heart disease, and congenital heart defects. Competence to perform 3D echocardiography independently requires demonstration of skills in image acquisition, image processing (3D image set manipulation and display), interpretation of 3D TTE and TEE echocardiograms, and accurate communication of findings. Ability to independently measure cardiac dimensions and volumes from 3D images in valvular and congenital heart disease under direction of a Level III expert is also an important component of Level III training. Level III trainees should become competent in the use of 3D echocardiography in procedural planning for both surgical and transcatheter interventions as well as in the guidance of these procedures and the immediate assessment of their outcomes (23).

4.2.2.3. Contrast Echocardiography

Both the use of agitated saline contrast in the evaluation of patients with suspected right-to-left shunts and the use of microbubble contrast agents (ultrasound enhancing agents) for identification of endocardial borders and detection of intracardiac thrombi are considered standard requirements for Level II training in echocardiography (3). Level III training in contrast echocardiography should also include instruction on the chemical composition and

physical properties of ultrasound enhancing agents, advanced ultrasound equipment settings, safety issues, and protocols for cardiac mass detection and characterization (24).

The individual completing Level III training should have the requisite skills to perform and interpret contrast-enhanced echocardiograms at rest and during exercise as well as pharmacological stress. It is recommended that at least 100 contrast echocardiograms be interpreted to achieve Level III training. This experience should be tailored to recognize the value and limitations of ultrasound contrast imaging relative to alternative imaging modalities in various clinical scenarios for optimal and cost-efficient patient care (25).

4.2.2.4. Strain Echocardiography and Myocardial Mechanics

Level III training in echocardiography includes expertise in emerging techniques that measure myocardial mechanics, particularly strain echocardiography. These modalities have demonstrated clinical utility in a variety of clinical settings (26). Strain and strain rate imaging are useful in the measurement of global and regional systolic and diastolic function, regional timing of myocardial contraction, and global and regional myocardial strain, strain rate, torsion and other measures of deformation (27). Trainees who aspire to Level III training in echocardiography should have a complete understanding of the physical principles of myocardial mechanics, aspects of imaging myocardial mechanics, methods to process images to obtain strain and strain rate measurements, and technical limitations and indications for the use of strain to assess myocardial mechanics (28,29). The comparison of serial strain measurements for surveillance must be understood, along with the limitations and pitfalls of such comparisons. This level of competency is expected to require interpretation of at least 50 studies that involve strain and strain rate assessment.

4.2.2.5. Stress Echocardiography

Training in stress echocardiography entails exposure to a mix of exercise and pharmacological stress testing, including patient selection, stress modality selection, stress test supervision, and integration of all diagnostic information. Interpretation of wall motion before and during stress is challenging, and optimal utility of the test requires integration of echocardiographic results with all available data. Basic competence in stress echocardiography can be achieved during Level II training and requires interpretation of at least 100 studies. For advanced Level III training in stress echocardiography, further exposure and training are required. A minimum of 200 stress echocardiograms should be interpreted (100 additional above Level II) under the supervision of a Level III trained physician. It is further recommended that approximately 25 of these are studies performed for noncoronary indications (30). Beyond interpretation, advanced training in stress echocardiography should include the advantages, limitations, and risks of different stress imaging approaches; monitoring of the stress test; and integration of stress echocardiographic results in patient management (31).

In addition to the above, Level III experience includes advanced training in and understanding of: 1) the application of stress echocardiography for evaluation of abnormal hemodynamic responses in patients with valvular heart disease such as aortic stenosis, mitral regurgitation, or mitral stenosis; 2) the role of the "diastolic" stress test in the evaluation of the dyspneic patient (30,32); 3) the role of stress echocardiography in evaluation of patients with hypertrophic cardiomyopathy and pulmonary hypertension; 4) the use of stress echocardiography for assessment of myocardial viability; and 5) the role of ultrasound enhancing agents for left ventricular opacification and myocardial perfusion echocardiographic techniques.

4.2.2.6. Echocardiography During Interventional Procedures

Echocardiography plays an essential role in patient selection, preprocedural planning, intraprocedural monitoring, immediate results assessment, and follow-up of patients with structural and congenital heart disease undergoing catheter-based interventions (33,34). Interventional procedures that may require echocardiographic guidance (TTE, TEE, or intracardiac echocardiography [ICE]) include transcatheter valve replacement or repair, atrial and ventricular septal defect closure, patent foramen ovale closure, left atrial appendage exclusion, balloon valvuloplasty, closure of prosthetic perivalvular leaks, alcohol septal ablation, patent ductus arteriosus closure, pulmonary vessel angioplasty or stenting, pericardiocentesis, endomyocardial biopsy, and radiofrequency catheter ablation. The skill to guide interventional procedures for complex congenital heart disease may require training beyond Level III. Competency in this complex and evolving field requires thorough knowledge and understanding of the interventional procedure performed as well as of relevant cardiac anatomy and associated hemodynamics. Echocardiographers should be familiar with all aspects of the interventional devices used and able to recognize device-related complications. Effective heart team communication is critical to success for these interventional procedures. A high level of expertise in probe manipulation is essential to guide the interventionalist using real-time 2D and 3D imaging. Echocardiographers guiding interventional procedures should attend structural heart disease team meetings and participate in case discussions.

Competency for independent performance is demonstrated by the ability to completely characterize the cardiovascular anatomy and hemodynamics relevant to each specific interventional procedure, and to provide both immediate guidance to operators during device-related procedures and feedback regarding the satisfactory completion of the intervention. Given the growing number of interventional procedures that rely on echocardiographic guidance and monitoring, the Level III trainee should ideally participate in a range of different procedures. It is recognized that this range will largely be dictated by the interventions offered at the training institution. The minimum procedural volume typically necessary for the development and demonstration of Level III echocardiographic competencies is provided in **Table 3**. The numbers themselves are not meant to be absolute requirements. For example, after performing and interpreting 30 structural valvular interventions requiring transseptal access, a smaller number of atrial septal closures may be adequate to establish competency. Thus, Level III competency ideally should be achieved by training with experienced physicians at centers where these advanced procedures are performed in sufficient volume (33,34). Additionally, as ICE becomes an important modality for guiding these procedures, the trainee must have familiarity and may require expertise in this area (see Section 4.2.2.8. Intracardiac Echocardiography).

As the use of mechanical circulatory support becomes more prevalent, the echocardiographer can expect to be called to assist with these patients even in centers without such a program. Therefore, mechanical circulatory support management, including optimal positioning and functioning and assessing for complications, is a critical skill set to be acquired during Level III training. However, the skill to guide placement of surgical and percutaneous devices can only be achieved in centers with mechanical support programs and is noted as requiring additional training in the competency table.

4.2.2.7. Intraoperative TEE

Competence in intraoperative TEE requires additional training beyond that described previously (35). Experience in the operating room should include the examination and evaluation of patients during valve replacement and repair procedures and monitoring of patients undergoing routine coronary bypass surgery (17,21). In addition, exposure to a wide range of cardiac surgical procedures is recommended. These include procedures for mechanical circulatory support, robotic or minimally invasive procedures, and hybrid techniques, where TEE guidance is important for specific portions of the procedure, such as identification of intracardiac catheters, cannulae, devices, and guidewires (36).

Guidelines for training in advanced intraoperative TEE have been developed primarily for the cardiovascular anesthesiologist who has not had prior training in routine TEE (21). For the advanced cardiology fellow who has performed at least 150 TEE studies as part of Level III training, competency in intraoperative TEE requires that at least 75 studies be intraoperative, of which at least 50 should be cases involving structural or valvular procedures. Training to guide intraoperative repair in complex congenital heart disease may require additional training. The 75 intraoperative studies can be part of the 150 total TEEs provided these are complete studies of which the trainee performs the significant portion. There may also be additional TEE studies, but in either case, all should be personally performed, interpreted, and reported under the supervision of a qualified expert, who should be a Level III trained echocardiographer or physician certified by the NBE in advanced perioperative TEE (36). Competency in intraoperative TEE also requires an understanding of various cardiac surgical techniques, cardiopulmonary bypass, and the impact of the conduct of surgery and the effect of anesthetic agents on intraoperative changes in hemodynamics as assessed by echocardiography. Exposure to TEE studies in noncardiac surgery cases is also recommended to incorporate the range of indications for intraoperative echocardiography.

Exposure to multidisciplinary discussions regarding the care of cardiac surgical patients is highly recommended to gain an understanding of the unique intraoperative challenges described above. Intraoperative monitoring of procedures for patients with congenital heart disease requires specific training that is often best acquired in a pediatric training laboratory (19).

4.2.2.8. Intracardiac Echocardiography

ICE is a specialized technique most often performed for interventional procedure guidance. ICE is increasingly used as the sole imaging technique to guide certain interventional and electrophysiology procedures, including transseptal puncture, transcatheter interatrial and interventricular communication closure, mitral and pulmonary valve interventions, left atrial appendage exclusion, endomyocardial biopsy, and radiofrequency catheter ablation (37,38). The ICE probe is inserted through a femoral, subclavian or internal jugular vein by the proceduralist (interventional cardiologist or electrophysiologist) and advanced into one of the right-sided cardiac chambers. Most ICE studies are performed, and often interpreted by, the proceduralist, at times in close collaboration with a Level III trained echocardiographer. In some cases, the echocardiographer manipulates the probe after it is introduced into the cardiac chambers and interprets the images. ICE probe manipulation and image acquisition and interpretation differ significantly from

other echocardiographic techniques and warrant dedicated training. When participating in a procedure in which ICE is used, close collaboration and clear communication with the proceduralist are required. Level III competency in ICE requires intimate knowledge of the cardiac anatomy, familiarity with the ICE probe manipulation, and successful interpretation of the images obtained. Training in ICE should be obtained under the direct supervision of expert physicians in a high-volume center where this modality is used routinely. Training in ICE is an example of a Level III competency that requires additional training beyond the standard Level III training, and may be attained by some, but not all, Level III echocardiographers. Suggested minimum experience is listed in **Table 3**.

4.3. Training in Multiple Modalities

Graduates who complete Level II or Level III training in echocardiography should also have acquired Level I training in other noninvasive imaging modalities. The person who acquires Level III echocardiography skills, therefore, will possess an expert skill level in echocardiography and, at minimum, a basic understanding of the clinical utility, appropriate use, and complementary aspects of other imaging modalities. Although Level III echocardiography trainees are not required to become multimodality imaging experts, they must develop an understanding of each of these imaging methods, their strengths and limitations, and the proper selection of the most appropriate imaging modality for common clinical conditions (25). Their training in multimodality cardiac imaging should be directed by faculty who have achieved Level III training. Fellows who acquire Level III echocardiography training in a dedicated 4th year may also acquire Level II skills in 1 or more additional modalities. Several key areas should be emphasized in the curriculum: selection of the best imaging test for a clinical scenario, understanding quality improvement processes related to imaging, and physics and imaging processing techniques.

5. LEADERSHIP AND ADMINISTRATIVE COMPETENCIES

In addition to clinical competency, Level III trained echocardiographers are expected to function effectively as leaders in allied efforts to assure high-quality care and promote individual and population health. Some of these activities and attributes fall outside the realm of clinical knowledge and skill and instead involve administrative roles in clinical practice, hospitals, health systems, professional societies, or other organizations. Developing a familiarity with Intersocietal Accreditation Commission requirements for echocardiography and participation in the Intersocietal Accreditation Commission accreditation process are examples of how an advanced echocardiography fellow can gain some experience in laboratory administration. The intention of training is to provide a foundation of leadership and administrative skills that would be enhanced and refined throughout one's career after fellowship. Specific competencies expected of all general cardiologists and cardiovascular specialists, including those whose careers involve greater involvement in administrative, managerial, or advocacy positions, are delineated in Table 24 of the 2016 ACC Lifelong Learning Competencies for General Cardiologists (39).

6. EVALUATION OF PROFICIENCY

Evaluation of a trainee's proficiency in advanced training in echocardiography involves multiple assessments by instructors of the trainee's ability to thoughtfully apply, comprehensively perform, and accurately interpret advanced echocardiographic studies. These assessments include global evaluations, direct observations (including review of fellow-acquired images, generation of the preliminary report, and consenting), case logs, chart review (including adherence to utilization guidelines, AUC, and patient outcomes), the trainee's portfolio (including scholarly productivity and quality improvement projects), and assessment of leadership skills. The trainee's organization of and participation in didactic conferences and case presentations also provides opportunities for instructors to evaluate the trainee's proficiency. Self-assessment programs through the ACC and ASE are also available to the trainee.

Clinical judgment, case management, and procedural skills must be evaluated regularly for every trainee. Quality of care; judgments or actions that result in complications; and interactive behaviors with physicians, patients, and laboratory support staff should be considered. Trainees must maintain records of participation and advancement using an electronic database or logbook that is Health Insurance Portability and Accountability Act (HIPAA) compliant and contains pertinent clinical information.

Under the guidance of the echocardiography program director, faculty should verify and document each trainee's performance and confirm satisfactory achievement. The program director is responsible for confirming experience and competence and reviewing the overall progress of individual trainees to ensure achievement of selected training milestones and identify areas in which additional focused training may be required. On a periodic basis throughout the course of training, the program director should review the trainee's case logbook to ensure the adequacy of the trainee's exposure to a broad spectrum of cardiac pathology and the trainee's

experience in applying advanced imaging echocardiographic techniques to evaluate same. When Level III echocardiography training is conducted within the general 3-year cardiology fellowship, coordination of feedback and assessment with the general cardiology program director and the clinical competency committee is essential. Lastly, following completion of advanced training in echocardiography, the advanced trainee is expected to become certified by the NBE in comprehensive adult echocardiography.

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ACKNOWLEDGEMENT We gratefully acknowledge the contribution of Deborah A. Agler, RDCS, who served as a member of the writing committee from October 2017 to March 2018.

REFERENCES

1. Alpert JS. Guidelines for training in adult cardiovascular medicine core cardiology training symposium (COCATS) June 27–28, 1994. J Am Coll Cardiol. 1995;25:1–2.

2. Halperin JL, Williams ES, Fuster V, et al. ACC 2015 core cardiovascular training statement (COCATS 4) (revision of COCATS 3). J Am Coll Cardiol. 2015;65:1721–3.

3. Ryan T, Berlacher K, Lindner JR, et al. COCATS 4 task force 5: training in echocardiography. J Am Coll Cardiol. 2015;65:1786–99.

4. Srivastava S, Printz BF, Geva T, et al. Task force 2: pediatric cardiology fellowship training in noninvasive cardiac imaging. J Am Coll Cardiol. 2015;66:687–98.

5. Picard MH, Adams D, Bierig SM, et al. American Society of Echocardiography recommendations for quality echocardiography laboratory operations. J Am Soc Echocardiogr. 2011;24:1–10.

6. Stout KK, Daniels CJ, Aboulhosn JA, et al. 2018 AHA/ACC guideline for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2019;73:e81–192.

7. Eisenberg MJ, Rice S, Schiller NB. Guidelines for physician training in advanced cardiac procedures: the importance of case mix. J Am Coll Cardiol. 1994;23:1723–5.

8. Douglas PS, Hendel RC, Cummings JE, et al. ACCF/ACR/AHA/ASE/ASNC/HRS/NASCI/RSNA/SAIP/SCAI/SCCT/SCMR 2008 health policy statement on structured reporting in cardiovascular imaging. J Am Coll Cardiol. 2009;53:76–90.

9. Patel AR, Sugeng L, Lin BA, et al. Communication and documentation of critical results from the echocardiography laboratory: a call to action. J Am Soc Echocardiogr. 2018;31:743–5.

10. Douglas PS, Garcia MJ, Haines DE, et al. ACCF/ASE/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 appropriate use criteria for echocardiography: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, and Society for Cardiovascular Magnetic Resonance. Endorsed by the American College of Chest Physicians. J Am Coll Cardiol. 2011;57:1126–66.

11. Seward JB, Douglas PS, Erbel R, et al. Hand-carried cardiac ultrasound (HCU) device: recommendations regarding new technology: a report from the Echocardiography Task Force on New Technology of the Nomenclature and Standards Committee of the American Society of Echocardiography. J Am Soc Echocardiogr. 2002;15:369–73.

12. Tavazzi G, Neskovic AN, Hussain A, et al. A plea for an early ultrasound-clinical integrated approach in patients with acute heart failure: a proactive comment on the ESC guidelines on heart failure 2016. Int J Cardiol. 2017;245:207–10.

13. Callaway CW, Soar J, Aibiki M, et al. Part 4: advanced life support: 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation. 2015;132:S84–145.

14. Lancellotti P, Price S, Edvardsen T, et al. The use of echocardiography in acute cardiovascular care: recommendations of the European Association of Cardiovascular Imaging and the Acute Cardiovascular Care Association. Eur Heart J Acute Cardiovasc Care. 2015;4:3–5.

15. Neskovic AN, Hagendorff A, Lancellotti P, et al. Emergency echocardiography: the European Association of Cardiovascular Imaging recommendations. Eur Heart J Cardiovasc Imaging. 2013;14:1–11.

16. O'Gara PT, Adams JE 3rd, Drazner MH, et al. COCATS 4 task force 13: training in critical care cardiology. J Am Coll Cardiol. 2015;65:1877–86.

17. Hahn RT, Abraham T, Adams MS, et al. Guidelines for performing a comprehensive transesophageal echocardiographic examination: recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. J Am Soc Echocardiogr. 2013;26:921–64.

18. Simpson J, Lopez L, Acar P, et al. Three-dimensional echocardiography in congenital heart disease: an expert consensus document from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr. 2017;30:1–27.

19. Ayres NA, Miller-Hance W, Fyfe DA, et al. Indications and guidelines for performance of transesophageal echocardiography in the patient with pediatric acquired or congenital heart disease: report from the task force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr. 2005;18:91–8.

20. Harrington RA, Barac A, Brush JE Jr., et al. COCATS 4 task force 15: training in cardiovascular research and scholarly activity. J Am Coll Cardiol. 2015;65:1899–906.

21. Cahalan MK, Stewart W, Pearlman A, et al. American Society of Echocardiography and Society of Cardiovascular Anesthesiologists task force guidelines for training in perioperative echocardiography. J Am Soc Echocardiogr. 2002;15:647–52.

22. Bick JS, Wanderer JP, Myler CS, et al. Standard setting for clinical performance of basic perioperative

transesophageal echocardiography: moving beyond the written test. Anesthesiology. 2017;126:718–28.

23. Lang RM, Badano LP, Tsang W, et al. EAE/ASE recommendations for image acquisition and display using three-dimensional echocardiography. Eur Heart J Cardiovasc Imaging. 2012;13:1–46.

24. Porter TR, Mulvagh SL, Abdelmoneim SS, et al. Clinical applications of ultrasonic enhancing agents in echocardiography: 2018 American Society of Echocardiography guidelines update. J Am Soc Echocardiogr. 2018;31:241–74.

25. Narula J, Chandrashekhar YS, Dilsizian V, et al. COCATS 4 task force 4: training in multimodality imaging. J Am Coll Cardiol. 2015;65:1778–85.

26. Plana JC, Galderisi M, Barac A, et al. Expert consensus for multimodality imaging evaluation of adult patients during and after cancer therapy: a report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2014;27:911–39.

27. Claus P, Omar AMS, Pedrizzetti G, et al. Tissue tracking technology for assessing cardiac mechanics: principles, normal values, and clinical applications. J Am Coll Cardiol Img. 2015;8:1444–60.

28. Yu CM, Sanderson JE, Gorcsan J 3rd. Echocardiography, dyssynchrony, and the response to cardiac resynchronization therapy. Eur Heart J. 2010;31:2326–37.

29. Mor-Avi V, Lang RM, Badano LP, et al. Current and evolving echocardiographic techniques for the quantitative evaluation of cardiac mechanics: ASE/EAE consensus statement on methodology and indications. J Am Soc Echocardiogr. 2011;24:277–313.

30. Lancellotti P, Pellikka PA, Budts W, et al. The clinical use of stress echocardiography in non-ischaemic heart disease: recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr. 2017;30:101–38.

31. Pellikka PA, Nagueh SF, Elhendy AA, et al. American Society of Echocardiography recommendations for performance, interpretation, and application of stress echocardiography. J Am Soc Echocardiogr. 2007;20:1021–41.

32. Oh JK, Kane GC. Diastolic stress echocardiography: the time has come for its integration into clinical practice. J Am Soc Echocardiogr. 2014;27:1060–3.

33. Silvestry FE, Kerber RE, Brook MM, et al. Echocardiography-guided interventions. J Am Soc Echocardiogr. 2009;22:213–31. quiz 316–7.

34. Zamorano JL, Badano LP, Bruce C, et al. EAE/ASE recommendations for the use of echocardiography in new transcatheter interventions for valvular heart disease. J Am Soc Echocardiogr. 2011;24:937–65.

35. National Board of Echocardiography. Requirements for advanced perioperative transesophageal echocardiography certification. Available at: http://echoboards.org/docs/AAdvPTE_Cert_App-2017.pdf. Accessed December 7, 2017.

36. Mahmood F, Shernan SK. Perioperative transoesophageal echocardiography: current status and future directions. Heart. 2016;102:1159–67.

37. Bartel T, Muller S, Biviano A, et al. Why is intracardiac echocardiography helpful? Benefits, costs, and how to learn. Eur Heart J. 2014;35:69–76.

38. Kim SS, Hijazi ZM, Lang RM, et al. The use of intracardiac echocardiography and other intracardiac imaging tools to guide noncoronary cardiac interventions. J Am Coll Cardiol. 2009;53:2117–28.

39. Williams ES, Halperin JL, Arrighi JA, et al. 2016 ACC lifelong learning competencies for general cardiologists: a report of the ACC Competency Management Committee. J Am Coll Cardiol. 2016;67:2656–95.

KEY WORDS ACC/AHA/ASE Training Statement, clinical competence, echocardiography, fellowship training, multimodality imaging, Level III, advanced training

APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)—2019 ACC/AHA/ASE ADVANCED TRAINING STATEMENT ON ECHOCARDIOGRAPHY

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*No financial benefit.

†Dr. Figueredo was employed by Einstein Medical Center Philadelphia as the Chair of Cardiology, Associate Chair of Medicine, and Director of the Cardiovascular Diseases Fellowship Programs and by Sidney Kimmel Medical College of Thomas Jefferson University as a Professor of Medicine during most of this writing effort.

‡Significant relationship.

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ACC indicates American College of Cardiology; AHA, American Heart Association; ASE, American Society of Echocardiography; GE, General Electric; JRC-DMS, Joint Review Committee on Education in Diagnostic Medical Sonography; and NBE, National Board of Echocardiography.

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This table represents the individuals, organizations, and groups that peer reviewed this document. A list of healthcare-related disclosures for each reviewer is available online.

ACC indicates American College of Cardiology; AHA, American Heart Association; ASE, American Society of Echocardiography; COCATS, Core Cardiovascular Training Statement and VA, Veterans Affairs.

APPENDIX 3. ABBREVIATION LIST

3D = 3-dimensional

ABIM = American Board of Internal Medicine

ACGME = Accreditation Council for Graduate Medical Education

COCATS = Core Cardiovascular Training Statement

ICE = intracardiac echocardiography

NBE = National Board of Echocardiography

RWI = relationships with industry

TEE = transesophageal echocardiography

TTE = transthoracic echocardiography