

Task Force 2: Pediatric Cardiology Fellowship Training in Noninvasive Cardiac Imaging¹

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Pediatric Training Statement: Noninvasive Cardiac Imaging

Task Force 2: Pediatric Cardiology Fellowship Training in Noninvasive Cardiac Imaging¹

Endorsed by the Society of Pediatric Echocardiography

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1. Introduction

1.1. Document Development Process

The Society of Pediatric Cardiology Training Program Directors (SPCTPD) board assembled a steering committee that nominated 2 chairs, 1 SPCTPD steering committee member, and 4 additional experts from a wide range of program sizes, geographic regions, and subspecialty focus. Representatives from the American College of Cardiology (ACC), American Academy of Pediatrics (AAP), and American Heart Association (AHA) participated. The steering committee member was added to provide perspective to each task force as a “non-expert” in that field. Relationships with industry and other entities were not deemed relevant to the creation of a general cardiology training statement; however, employment and affiliation information for authors and peer reviewers are provided in Appendices 1 and 2, respectively, along with disclosure reporting categories. Comprehensive disclosure information for all authors, including relationships with industry and other entities, is available as an online supplement to this document

(http://jaccjacc.acc.org/Clinical_Document/Ped_TS_TF2_Comprehensive_RWI_Supplement.pdf).

The writing committee developed the document, approved it for review by individuals selected by the participating organizations (see Appendix 2), and addressed their comments. The final document was approved by the SPCTPD, AAP, and AHA, as well as endorsed by Society of Pediatric Echocardiography in February 2015, and approved by the ACC in March 2015. This document is considered current until the SPCTPD revises or withdraws it.

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1.2. Background and Scope

For over 25 years, noninvasive cardiac imaging has been the mainstay of anatomic and physiologic assessment in pediatric cardiology and congenital heart disease. An ACC/AAP/AHA combined task force published pediatric noninvasive cardiac imaging training guidelines in 2005, including guidelines for training in transthoracic (TTE), transesophageal (TEE), and fetal echocardiography, as well as in cardiac magnetic resonance imaging (MRI) (1). These guidelines, which were also endorsed by the American Society of Echocardiography and the Society of Pediatric Echocardiography, established standard goals, training methods, and expected levels of expertise for core and advanced levels of pediatric cardiology fellowship training.

With continued advancement in the field of noninvasive imaging since the publication of these guidelines, the scope of training, expected level of expertise, and knowledge of existing information technology (IT) infrastructure supporting these imaging modalities have evolved. Use of imaging techniques such as cardiac MRI, 3-dimensional (3D) echocardiography, and new applications such as strain imaging have become more commonplace in everyday practice. Additionally, the noninvasive imaging work environment has incorporated methods to evaluate and maintain quality and to establish performance standards (2). There has also been a recent initiative to develop tools for assessment of quality and accuracy in performing and reporting pediatric echocardiograms.

Our revised training recommendations describe the program resources and environment that are required for training pediatric cardiology fellows, together with a competency-based system promulgated by the American College of Graduate Medical Education (ACGME), to implement specific goals and objectives for training pediatric cardiology fellows. This system categorizes competencies into 6 core competency domains: Medical Knowledge, Patient Care and Procedural Skills, Systems-Based Practice, Practice-Based Learning and Improvement, Professionalism, and Interpersonal and Communication Skills, along with identification of suggested evaluation tools for each domain. Competencies unique to noninvasive imaging, along with suggested evaluation tools, are listed in Appendix 3 (see the Training Guidelines for Pediatric Cardiology Fellowship Programs Introduction for additional competencies and evaluation tools that apply to all Task Force reports).

Echocardiography herein refers to all ultrasound-based imaging techniques used to assess cardiac anatomy and function. This is inclusive of 2D, 3D, and 4D imaging of the heart and related structures, functional assessment ranging from M-mode assessment, 2D, 3D, and speckle tracking to assess global and regional deformation, color Doppler imaging, as well as pulsed and continuous-wave spectral Doppler imaging for flow, hemodynamics, and tissue motion. Cardiac MRI refers to anatomic and

functional cardiovascular MRI for assessment of congenital heart disease (CHD) in children and adults, as well for assessment of acquired forms of heart disease in children.

1.3. Levels of Expertise – Core and Advanced

Innovations in the field of echocardiography have led to noninvasive diagnosis of complex CHD, frequently precluding the need for diagnostic catheterization. Therefore, physicians performing these procedures should be skilled in all aspects of echocardiography. Those choosing noninvasive imaging for a career should be trained in advanced transthoracic echocardiography, as well as some combination of transesophageal echocardiography, fetal echocardiography, and/or cardiac MRI.

Two levels of fellowship training are discussed in this statement: core and advanced. Guidelines for core level of training should be considered as minimum, mandated reference standards for a fellow to achieve competency in noninvasive cardiac imaging during standard 3-year pediatric cardiology fellowship training. The training should allow for independent and accurate use of TTE imaging to diagnose simple congenital heart disease, as well as acquired pediatric heart disease. A thorough education in TTE, as well as exposure to TEE, fetal echocardiography, and cardiac MRI is essential for core pediatric cardiology training. Education in TEE, fetal echocardiography, and cardiac MRI during the core training period should allow for familiarity with techniques, indications, and limitations. Echocardiography skills for the diagnosis of more complex congenital heart disease, as well as expertise in other advanced imaging modalities inclusive of fetal, TEE, MRI and their applications will be considered as requirements for advanced noninvasive imaging training, as described below. It is anticipated that fellows may, but are not required to, obtain levels of competence above the minimum core requirements in these advanced imaging skills (including diagnosis of complex congenital heart disease, fetal, TEE, and/or cardiac MRI) during their core noninvasive imaging fellowship experience.

2. Program Resources and Environment

2.1. Echocardiography

The echocardiographic facility (laboratory) required for core pediatric cardiology fellowship training must encompass inpatient and outpatient services. The training facility should include neonatal, pediatric, and/or cardiac intensive care units, an invasive/interventional catheterization laboratory, and a pediatric cardiac surgical program. The echocardiography laboratory should perform an adequate volume of studies with expert faculty dedicated to echocardiography, so as to provide trainees with teaching and exposure to both normal and abnormal examinations in patients across a wide age range, from fetal patients to the growing population of adults with congenital heart disease. The pediatric echocardiography

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laboratory should be under the supervision of a designated pediatric cardiologist who has primary responsibility for supervision of the laboratory. The equipment and inventory should be maintained to ensure high-quality performance, and to comply with regulations and guidelines for patient safety for sedation. Trainees should have access to patients with a broad spectrum of congenital and acquired cardiac pathologies. A recent survey of pediatric cardiology fellowship program directors (conducted by the Noninvasive Task Force comprised of the authors of this document) demonstrated that this framework for training exists in the echocardiography laboratories of most of the current training programs (Appendix 4).

2.2. Cardiac MRI

Training in pediatric cardiac MRI should occur within a pediatric cardiology fellowship program and/or a radiology training program accredited by the ACGME and staffed by qualified physicians with dedicated expertise in pediatric or congenital cardiac MRI. The MRI laboratory should serve a hospital or hospitals with both inpatient and outpatient services. The training facility should include neonatal and pediatric/cardiac intensive care units, an invasive/interventional catheterization laboratory, and a pediatric cardiac surgical program. The MRI laboratory should perform an adequate volume of cardiac studies so as to provide trainees with exposure to both normal and abnormal examinations in patients across a wide age range, from neonatal patients to the growing population of adults with CHD. The MRI laboratory should be supervised by a pediatric cardiologist and/or radiologist with special expertise in pediatric and congenital cardiac MRI. The equipment and inventory should be maintained to ensure high quality performance, and to comply with regulations and guidelines for patient safety with sedation. Core and advanced fellowship trainees should have access to pediatric patients with a broad spectrum of congenital and acquired cardiac pathologies, as well as to adults with various forms of CHD.

3. Core Training: Goals and Methods

3.1. Echocardiography

During their core fellowship training experience, all pediatric cardiology fellows should be able to achieve technical competence in performing a TTE and should acquire the knowledge base to interpret and report the studies. It is important to have an environment that supports this training. The echocardiography laboratory should have sufficient volume to expose clinical pediatric cardiology fellows to a full range of cardiac pathologies, and sufficient attending staff to supervise them and teach the necessary skills. In order to allow adequate supervision of fellows as they are trained in

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echocardiography, the following considerations with respect to the infrastructure of the training environment should be ensured:

- Adequate ratio of clinical volume to the number of sonographers to ensure that each fellow will be able to perform and interpret the minimum number of echocardiograms required for core fellowship training.
- Adequate ratio of clinical volume to the number of attending staff to ensure that each fellow will receive adequate instruction.
- Sufficient time allocation per study to allow for the training experience.
- Standard protocol implementation for image acquisition and reporting of studies (as discussed below).
- System of real-time fellow supervision, instruction, and evaluation by dedicated pediatric/congenital echocardiography staff.
- Quality assessment and improvement processes, including tools to detect and review diagnostic errors or discrepancies and to correlate findings with other imaging modalities.
- Comprehensive teaching program that includes didactic conferences, case review sessions, etc.
- Mentored research opportunities for fellowship trainees.

Standard echocardiographic imaging and measurement protocols are essential in a teaching pediatric echocardiography laboratory in order to maintain quality and uniformity of complete TTE, TEE, and fetal examinations. Imaging protocol guidelines for performance of pediatric TTE, TEE, and fetal echocardiograms have been published by the American Society of Echocardiography (3-8). Besides imaging protocols, the echocardiography laboratory should have in place a comprehensive normative data set or Z score database encompassing the full range of body sizes and ages encountered in a pediatric / congenital laboratory against which to compare measurements performed in the laboratory; this can be accomplished through 1 of several currently available pediatric echocardiography normative databases.

3.1.1. Transthoracic Echocardiography

During their core noninvasive imaging experience, the trainee should perform and interpret a sufficient number of echocardiograms to attain proficiency with the following parameters:

- In order to allow the certifying faculty to render a *credible assessment of a fellows' level of competency*, the fellow trainee should perform and interpret a minimum of 150 echocardiograms and review and interpret an additional 100 echocardiograms during the 3 years (see Appendix 5). These numbers should be considered as minimum numbers to allow for *assessment* and not as minimum numbers for the fellow to be considered as *competent* in TTE, which may be greater.

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- The trainee should be exposed to a wide range of diagnoses, including pre- and post-surgical evaluation of simple and complex congenital and acquired heart diseases that span the age spectrum from neonates to adults.
- The trainee should be familiar with their institutional sedation and monitoring policies for echocardiograms in both the inpatient and outpatient settings.
- There should be a didactic teaching schedule that incorporates such topics as basic principles of ultrasound, the segmental approach to diagnosis of congenital heart disease, and the use of echocardiography for quantitative assessment and hemodynamic evaluation.
- There should be direct demonstration of echocardiographic cases and one-on-one supervision in addition to didactic teaching.
- The trainee should have access to echocardiography-pathology correlates, either through direct exposure to heart specimens, at conferences, or through electronic media.
- Attending cardiologists and senior sonographers that teach imaging skills to fellows should be aware of the training goals. These instructors should discuss the goals with the trainee at the beginning of the rotation, and they should provide ongoing evaluation.
- There should be conferences and discussions detailing anatomic and surgical correlates.
- The utility and limitations of echocardiography and other imaging modalities such as cardiac MRI, cardiac computed tomography (CT), and cardiac catheterization should be taught.
- The trainee should both be aware of and be exposed to the process for continued quality improvement and echocardiographic laboratory accreditation.
- Although the ability to perform and/or interpret fetal and TEE studies is not a core training requirement, there should be exposure to these modalities during core fellowship training for all trainees.
- Core fellows should be involved in the review process and didactic lectures regarding fetal and TEE studies, including indications for these exams and their limitations.

3.1.2. Transesophageal Echocardiography

Fellows completing 3 years of core cardiology training are not expected to perform or interpret TEE. However, those with an interest in pursuing a career in noninvasive imaging may wish to obtain experience in TEE during the latter part of their core training. Moreover, during the course of their 3-year training, fellows will often encounter situations in which they are required to order, review, and/or present TEE studies. Hence they should be familiar with the general aspects of the procedure, including its

advantages and limitations (5), as well as the individual TEE views and how they are utilized to evaluate congenital and acquired heart disease.

Recommended goals for core fellowship training in TEE therefore include knowledge of the following:

- Indications and use of TEE in the operating room, interventional (cardiac catheterization) laboratory, intensive care unit, and outpatient settings
- Strengths and limitations of TEE
- Contraindications and potential complications of TEE
- Familiarity with the TEE views obtainable from the major esophageal/gastric positions: these include the mid esophageal, upper esophageal, transgastric, and deep transgastric, as well as supplementary views such as of the descending aorta (7)

In order for the trainee to be knowledgeable of the above, there must be a provision in the program to incorporate these topics into the general curriculum. This could be achieved in multiple ways, including didactic lectures, case discussions between cardiology fellows and pediatric cardiologists (or other qualified physicians) with expertise in pediatric/congenital heart TEE, video and “hands-on” demonstrations, and/or multidisciplinary meetings such as combined cardiac surgery and cardiology conferences.

3.1.3. Fetal Echocardiography

Fellows completing 3 years in general cardiology training are not required to perform or interpret fetal echocardiograms but all fellows are required to be knowledgeable about the subject (8-11). As with TEE, some trainees may wish to attain a higher level of competency in performing and interpreting fetal echocardiography during core fellowship.

The following represents recommended minimum knowledge for core training in fetal echocardiography.

- Indications for, and limitations of, fetal echocardiography
- Gestational age at which to refer for a fetal echocardiogram
- Normal physiology of fetal and transitional circulation
- Alterations in fetal circulation associated with CHD that impact outcome
- Fetal arrhythmia evaluation, management, outcomes, and utility of fetal echocardiographic monitoring
- Extracardiac anomalies in the fetus that impact prenatal and perinatal outcome
- Existing innovations in perinatal management

In order for the trainee to be knowledgeable of the above, there must be a provision in the program to incorporate these topics into the general curriculum. This could be achieved in multiple ways, including didactic lectures, video and “hands-on” demonstrations, journal club, and/or multidisciplinary meetings such as combined perinatal and cardiology conferences.

3.2. Cardiac MRI

Guidelines for training in pediatric cardiac MRI were published as part of the 2005 Pediatric Cardiology noninvasive cardiac imaging guidelines document (1), from which these revised training guidelines have been adapted. Guidelines to achieve clinical competence in cardiac MRI and CT as part of *adult* cardiology fellowship training have also been published (12-14). There is significant variation amongst institutions with respect to availability of pediatric cardiac MRI and in the expertise of pediatric cardiologists, adult cardiologist, and radiologists in performing pediatric/congenital cardiac MRI. Thus, the training guidelines described below are suggested requirements. Similarly, institutions may also chose to include knowledge of cardiovascular CT indications, advantages, and disadvantages for imaging children and adults with CHD as part of their core pediatric cardiology fellowship curriculum, and may chose to include some level of competency in interpretation of cardiovascular CT as part of advanced noninvasive cardiac imaging training, depending on the level of institutional expertise and equipment availability.

Fellows completing 3 years of general pediatric cardiology training are not required to perform or interpret cardiac MRIs. However, the graduating pediatric cardiology fellow is required to be knowledgeable about cardiac MRI. He or she would be expected to refer patients for cardiac MRI when appropriate, and should be able to view cardiac MRI images and incorporate diagnostic cardiac MRI reports as components of a patient’s clinical evaluation. With this in mind, the following are guidelines for core training in cardiac MRI.

- Familiarity with basic principles used to generate MRI images
- Awareness of current indications and contraindications for cardiac MRI:
 - In patients with CHD, including children and adults
 - In children with acquired heart disease, such as for assessment of ventricular volumes, mass, and/or function
- Ability to read basic cardiac magnetic resonance images acquired in infants, children, and young adults with either structurally normal or abnormal hearts

In order for a pediatric cardiology fellowship trainee to satisfy these core cardiac MRI training guidelines, there must be provisions within the core fellowship training program that incorporate these

topics into the general curriculum. This could be achieved in several ways, including: 1) case discussions with direct interaction between the core pediatric cardiology fellow and pediatric cardiologists or cardiac radiologists who have special expertise in cardiac MRI, including advanced cardiac MRI fellowship trainees, during the acquisition and interpretation of cardiac MRIs; 2) didactic lectures, videos, continuing medical education conferences, and “hands-on” demonstrations, and 3) multidisciplinary meetings, such as combined cardiology, radiology, and/or pathology conferences.

4. Advanced Training: Goals and Methods

The goal for advanced training in cardiac imaging is to train fellows to be competent to assume positions as independent noninvasive imaging physicians. Advanced noninvasive cardiac imaging training should include research, teaching, and education components specific to imaging, in addition to advanced clinical expertise in imaging. As with core fellowship training, numerical benchmarks for advanced fellowship trainees are less important than competency-based benchmarks; procedural numbers listed below are considered as guides to establish sufficiently broad-based criteria for faculty to make educated, non-biased assessments of fellowship competency in these advanced imaging modalities.

Advanced training may include all or any combination of TTE, TEE, fetal echocardiography, and cardiac MRI. To achieve competence in advanced pediatric and congenital cardiac noninvasive imaging, an additional 6 to 12 months of training is required beyond the core 3-year training period. The duration of training would depend upon the goal of training, requiring at least 6 months in order to achieve advanced competency in echocardiography (inclusive of TTE, TEE, and fetal echocardiography) or cardiac MRI alone, and may extend over 12 months to achieve ‘advanced’ competence in noninvasive imaging for both echocardiography and cardiac MRI. Since the Accreditation Council for Graduate Medical Education (ACGME) does not currently recognize this advanced training, the suggested training guidelines are not as standardized as are those for core imaging training. Advanced imaging training may vary based on the particular training program and on the individual trainee, due to 1) variability among institutions with regards to structure, method, and focus of training modality (e.g., TTE, TEE, fetal echocardiography, cardiac MRI) and 2) variability in goal competency levels to be achieved by the particular advanced fellow for each of these modalities. For example, an advanced imaging fellow might focus his/her training more on perfecting fetal imaging skills rather than on cardiac MRI. However, the following are recommended general goals for advanced echocardiographic training; specific guidelines and objectives for fetal echocardiography, TEE, and cardiac MRI are listed separately. Although advanced training guidelines for each of the above imaging modalities will be discussed individually, the following methods are common to all:

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- Teaching and supervising junior fellows and sonographers
- Active involvement in research and teaching: a scholarly activity project should be defined at the onset of advanced training and should be monitored closely, culminating with a presentation at a national meeting and submission of a manuscript for publication in a peer-reviewed journal
- Increasing level of independence in performing and interpreting studies, clinical decision making, and in the advanced fellow's interaction with surgeons, interventionalists, and referring physicians

The advanced imaging fellow should understand the process of running an echocardiographic/noninvasive imaging laboratory, as well as its individual components such as staffing, scheduling, reporting, quality assurance procedures, and billing.

4.1. Echocardiography

- Independently perform and interpret TTEs in patients of all ages and diagnostic complexity. *It is expected that mastering diagnostic imaging of complex CHD may require additional years of experience and supervision following completion of advanced training.*
- Independently utilize echocardiographic data to guide clinical decisions in children and young adults with congenital and acquired heart disease.
- Know quantitative methods of systolic and diastolic ventricular function assessment.
- Know how to interpret and report regional ventricular function.
- Observe and be familiar with applications and limitations of 3D imaging and myocardial deformation assessment.
- Be able to supervise sonographers and junior fellows and help them acquire core skills.
- Develop and/or participate in noninvasive imaging-related research, with a goal of project completion as evidenced by presentation at a national meeting and manuscript publication.
- Be familiar with echocardiographic imaging implications and uses of telemedicine.

4.1.1. Transthoracic Echocardiography

- Perform and interpret at least 100 TTE examinations and review and interpret at least 100 TTE exams performed by others in patients with more complex anatomy, over a wide age range inclusive of infants and adults. Such examinations should include repaired, palliated, and unrepaired congenital heart disease (CHD), as well as pediatric forms of acquired heart disease.
- Be proficient in advanced quantitative and hemodynamic assessment using 2D, 3D, and myocardial deformation imaging techniques.

4.1.2. Transesophageal Echocardiography

The goal of advanced training is to enable the trainee to achieve competence in the performance and interpretation of TEE for the evaluation of congenital and acquired heart disease in pediatric patients. In addition to the core knowledge of TEE outlined above, the following guidelines are recommended for advanced training:

- The trainee should perform and interpret at least 50 studies in pediatric and adult congenital patients. Such patients should comprise a varied spectrum of patient ages and sizes, from neonates to young adults. The studies should be performed under the direct supervision of a dedicated pediatric cardiologist-echocardiographer or other qualified physician with specialized expertise in pediatric/congenital heart TEE (5).
- Trainees should understand oropharyngeal anatomy and the technique of esophageal intubation, as well as the potential risks of TEE and contraindications for the procedure.
- Performing a competent TEE study requires safe and skillful manipulation of the transducer; an understanding and interpretation of the information obtained; and accurate, comprehensive recording of the entire study. Trainees should be expected to acquire the skills necessary to perform a complete diagnostic evaluation of the heart, utilizing the various TEE probe manipulations and esophageal positions (5, 7). Obtaining a complete study necessitates the use of the methods common to all forms of echocardiography—2D imaging, color flow and spectral Doppler, and (when appropriate) M-mode imaging. In the intraoperative setting, the trainee should recognize the changing hemodynamic conditions following surgery, and their potential impact upon the echocardiographic findings.
- Trainees should be able to perform a diagnostic TEE study in patients with all forms of pediatric heart disease. This includes patients with complex CHD and cardiac malpositions, such as mesocardia and dextrocardia, in which evaluation of situs and careful segmental evaluation are paramount. Trainees should also be able to evaluate acquired forms of heart disease that might require TEE such as endocarditis and intracardiac thrombus.
- The most common environment for the performance of pediatric TEE is the intraoperative setting, in which both preoperative and postoperative studies are generally obtained. However, the training experience should not be limited to this venue; training should also be conducted in other locations for TEE such as the cardiac catheterization laboratory, intensive care unit, and outpatient setting.
- Trainees should understand the indications for the TEE procedure and the requisite information that must be obtained for any given patient, including informed consent. This includes prior

review of the patient's history and previous imaging studies (when available). Given the time constraints often accompanying a TEE study, particularly in the intraoperative setting, the trainee will need to prioritize the study such that the most relevant information is acquired first, and supplementary information obtained afterwards (time permitting).

- During surgical or cardiac catheterization procedures, it is essential that the echocardiographer communicates important TEE findings in a timely and clear manner to the surgeon or interventionalist, as well as to other members of the team such as the anesthesiologist. Pertinent positive and negative information must be articulated quickly, lucidly, and accurately. It is important for the trainee to understand the importance of team communication and to demonstrate the ability to do so.

4.1.3. Fetal Echocardiography

The goal of advanced fetal echocardiography training is to achieve competence with variable degree of supervision in the diagnosis, counseling, and perinatal management of the fetal diagnosis of congenital heart defects, arrhythmia, heart failure, and derangements in fetal physiology with cardiac and extracardiac fetal malformations (8-11). Recognizing that the percentage of fetal echocardiograms performed on those with CHD will vary from center to center, it is difficult to define a specific number of studies required to obtain competence that is generalizable to all programs. As a guideline, the advanced fetal echocardiography trainee should:

- Be involved in performance and interpretation and parental counseling of at least 50 fetal echocardiograms and additionally review and interpret another 50. Of these 100, at least 50 should have some form of CHD and/or abnormality of fetal circulation. This should ensure acquisition of knowledge and the technical skills required for assessment and recognition of normal and abnormal fetal cardiac anatomy, function and physiology. The advanced trainees should have exposure to normal screening exams and fetuses with a wide range of simple and complex heart defects, fetal arrhythmias, and derangements in fetal physiology.
- Be involved in fetal counseling as it pertains to diagnosis, associated syndromes, implications, and outcomes.
- Have the knowledge and skills needed to assess hemodynamic derangements and plan postnatal management of extracardiac conditions and in those with multiple gestations that can alter fetal hemodynamics.
- Actively participate in a multidisciplinary team approach involved in perinatal management of fetal CHD, arrhythmia, or heart failure.

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- Be aware of the utility, indications, and safety of other imaging modalities such as MRI in the management of a fetus with CHD, arrhythmia, and extra-cardiac defects.

4.2. Cardiac MRI

The goal of advanced cardiac MRI training is to achieve competence to perform and independently interpret cardiac MRI examinations in children and in adults with CHD. There is currently discussion within the Society of Cardiac Magnetic Resonance regarding development of specific advanced training credentialing guidelines for both pediatric and adult cardiac MRI. Until such specific guidelines have been approved, it is anticipated that advanced training in pediatric cardiac and congenital MRI should include at a minimum an additional 3 to 6 months of training beyond the standard core pediatric cardiology training experience, either as part of an advanced noninvasive cardiac imaging fellowship that also includes TTE, fetal, and TEE imaging, or as a separate advanced cardiac MRI training program.

In order to achieve this goal, the advanced cardiac MRI trainee should:

- Interpret at least 100 cardiac MRI examinations, including assessment of cardiac anatomy, function, and physiology; for at least 50 cardiac MRI examinations the advanced cardiac MRI trainee should be directly involved in the acquisition and interpretation of the study. The trainee should have adequate exposure to a broad range of simple and complex heart defects in children and adults with CHD, as well as exposure to the spectrum of acquired heart disease in children.
- Develop an understanding of MRI physics, instrumentation, nomenclature, and MRI safety.
- Participate in the training of MRI technologists and core cardiology trainees in cardiac MRI techniques, including image acquisition and interpretation.
- Participate in basic and/or clinical research project(s) in cardiac MRI, including the presentation of original data at 1 or more scientific meetings, together with original manuscript preparation.
- Participate in quality improvement initiatives within the cardiac MRI laboratory.

5. Evaluation and Documentation of Competence

All training programs should include written goals and objectives for each imaging rotation with performance goals set according to the fellow's level of training. These will serve as the basis for feedback. A copy of these goals and objectives should be supplied and explained to the trainee at the onset of fellowship training and reviewed at the beginning of each rotation. Evaluation of fellows should be performed midway through, and at the completion of, each rotation; evaluations should be directed towards whether the fellow met those pre-specified aims. The fellow evaluation should be performed by

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the echocardiographer/cardiac MRI lab director and/or senior echocardiographer/cardiac MRI physician chosen as director of noninvasive imaging training. The fellow evaluation should assess the fellow's performance in each of the 6 areas of core competencies, as appropriate for the level of training, and should be based on direct observation of the fellow. Evaluation of competency in preparation, performance, and interpretation of the results of a procedure should be given more consideration than a focus on the number of procedures performed. Evaluation of competency should be done in person with the trainee and documented in their fellowship record. If the trainee is not progressing as expected, remedial actions should be arranged and documented in accordance with institutional procedures. All fellows should maintain a log (preferably electronic) of all procedures performed.

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APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)—TASK FORCE 2: PEDIATRIC CARDIOLOGY FELLOWSHIP TRAINING IN NONINVASIVE CARDIAC IMAGING

Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional/ Organizational or Other Financial Benefit	Expert Witness
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Beth F. Printz (<i>Co-Chair</i>)	Rady Children's Hospital of San Diego—Associate Professor of Clinical Pediatrics and Associate Adjunct Professor of Radiology; University of California San Diego—Medical Director, Echocardiography and Non-Invasive Cardiac Imaging	None	None	None	None	None	None
Tal Geva	Harvard Medical School—Professor of Pediatrics; Boston Children's Hospital—Chief, Division of Noninvasive Cardiac Imaging, Department of Cardiology	None	None	None	None	None	None
Girish S. Shirali	Children's Mercy Hospital and Clinics—Melva and Randall L. O'Donnell, PhD, Chair in Pediatric Cardiology and Division Director, Cardiology; Ward Family Heart Center—Co-Director; University of Missouri—Professor of Pediatrics	None	None	None	None	None	None
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Pierre C. Wong	Children's Hospital of Los Angeles—Director, Echocardiography; Keck School of Medicine, University of Southern California—Associate	None	None	None	None	None	None

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional/ Organizational or Other Financial Benefit	Expert Witness
	Professor of Pediatrics						
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For the purpose of developing a general cardiology training statement, the ACC determined that no relationships with industry or other entities were relevant. This table reflects author's employment and reporting categories. To ensure complete transparency, authors' comprehensive healthcare-related disclosure information—including RWI not pertinent to this document—is available in an online data supplement (http://jaccjacc.acc.org/Clinical_Document/Ped_TS_TF2_Comprehensive_RWI_Supplement.pdf). Please refer to <http://www.acc.org/guidelines/about-guidelines-and-clinical-documents/relationships-with-industry-policy> for definitions of disclosure categories, relevance, or additional information about the ACC Disclosure Policy for Writing Committees.

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APPENDIX 2. PEER REVIEWER RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)—TASK FORCE 2: PEDIATRIC CARDIOLOGY FELLOWSHIP TRAINING IN NONINVASIVE CARDIAC IMAGING

Name	Employment	Representation	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional/ Organizational or Other Financial Benefit	Expert Witness
Craig Fleishman	The Heart Center at Arnold Palmer Hospital for Children—Director, Noninvasive Cardiac Imaging	SOPE	None	None	None	None	None	None
Regina Lantin-Hermoso	Texas Children's Hospital	ACC ACPC Council	None	None	None	None	None	None
Leo Lopez	Miami Children's Hospital—Medical Director of Noninvasive Cardiac Imaging	Content Expert; Chair, ASE Council on Pediatric and Congenital Heart Disease						
Swee Chye Quek	National University of Singapore, Department of Pediatrics	ACC ACPC Council	None	None	None	None	None	None
Geetha Raghuvver	Children's Mercy Hospital, Department of Cardiology	ACC BOG	None	None	None	None	None	None
Craig Sable	Children's National Medical Center—Training Director	AHA	None	None	None	None	None	None
Ritu Sachdeva	Sibley Heart Center—Medical Director,	AAP	None	None	None	None	None	None

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	Cardiovascular Imaging Research Core							
Timothy Slesnick	Emory University—Assistant Professor, Pediatric Cardiology	AHA	None	None	None	None	None	None
Carole Warnes	Mayo Clinic—Professor, Medicine	ACC BOT	None	None	None	None	None	None
Eric Williams	Indiana University School of Medicine—Professor (Cardiology) and Associate Dean; Indiana University Health, Cardiology Service Line Leader	ACC CMC Lead Reviewer	None	None	None	None	None	None
Luciana Young	Ann and Robert H. Lurie Children's Hospital of Chicago	ACC ACPC Council	None	None	None	None	None	None

For the purpose of developing a general cardiology training statement, the ACC determined that no relationships with industry or other entities were relevant. This table reflects peer reviewers' employment, representation in the review process, as well as reporting categories. Names are listed in alphabetical order within each category of review. Please refer to <http://www.acc.org/guidelines/about-guidelines-and-clinical-documents/relationships-with-industry-policy> for definitions of disclosure categories, relevance, or additional information about the ACC Disclosure Policy for Writing Committees.

AAP indicates American Academy of Pediatrics; ACC, American College of Cardiology; ACPC, Adult Congenital and Pediatric Cardiology; AHA, American Heart Association; BOG, Board of Governors; BOT, Board of Trustees; CMC, Competency Management Committee; and SOPE, Society of Pediatric Echocardiography.

Appendix 3. Core Curricular Competencies and Evaluation Tools for Noninvasive Imaging

Medical Knowledge

- Know the physical properties of ultrasound and Doppler principles.
- Know the principles of echocardiographic image construction and the factors that influence image composition.
- Know the ultrasound imaging devices, including ‘knobology’, appropriate transducer and settings to optimize images, and proper and safe use of the ultrasound equipment.
- Know the proper use of different echocardiographic techniques (2D, M-mode, 3D, color, and spectral Doppler) to thoroughly evaluate cardiac anatomy, physiology, and function.
- Know standard transthoracic imaging planes (subcostal, apical, parasternal, suprasternal).
- Know the effects of patient positioning on image acquisition and how to move them to optimize echocardiographic images.
- Know the indications for pediatric TTE.
- Know the hemodynamic and physiologic changes from fetus to adult.
- Know the full spectrum of pediatric cardiac surgical procedures, including the components of a complete pre- and postoperative echocardiographic assessment, as well as potential postoperative complications of each procedure.
- Know the techniques for imaging abnormal situs and dextrocardia, as well as the associated terminology of complex disease.
- Know basic TEE imaging views and indications, including the use of TEE for guidance of intraoperative and catheter-based interventions and be aware of limitations of TEE imaging.
- Know basic fetal imaging views and indications and limitations of fetal echocardiographic imaging.
- Know the basic principles used to generate MR images.
- Know the indications and contraindications for cardiac MR in patients with CHD, including children and adults.
- Know the indications and contraindications for cardiac MR in children with acquired heart disease.

Evaluation Tools: direct observation, conference participation and presentation, in-training exam

Patient Care or Procedural Skills

- Have the skills to do a clinical history, know the indications for study, review prior studies, and interim procedures.
- Have the skills to identify the goals of each study.
- Have the skills to consistently obtain adequate images from all planes on a standard TTE in a timely manner.
- Have the skills to identify cardiac structures displayed by echocardiography and how echocardiographic images correlate with cardiac anatomy.
- Have the skills to recognize imaging artifacts.
- Have the skills to obtain appropriate measurements of ventricular, valvar, and vascular dimensions.
- Have the skills to obtain appropriate measures of ventricular function.
- Have the skills to evaluate valvar stenosis and regurgitation with spectral (pulsed and continuous wave) and color Doppler.
- Have the skills to identify and describe common lesions: atrial septal defect, ventricular septal defect, patent ductus arteriosus, aortic stenosis, and pulmonary stenosis.
- Have the skills to complete a full examination of patients with simple congenital defects, including full Doppler assessment, along with a detailed, concise report.
- Have the skills to perform a comprehensive 2D and Doppler examination of a newborn with previously undiagnosed complex congenital heart disease and be able to assess need for prostaglandin without assistance. Complete description of complex anatomic details is encouraged but not required of a trainee completing core fellowship; accurate imaging/ interpretation of complex CHD may require advanced training and/or post-fellowship experience.
- Have the skills to identify and describe pericardial disease.

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- Have the skills to demonstrate familiarity with indications, use, and limitations of TEE.
- Have the skills to demonstrate familiarity with indications, use, and limitations of basic imaging skills for fetal echocardiography.
- Have the skills to read basic cardiac MR images acquired in infants, children, and young adults with either structurally normal or abnormal hearts.

Evaluation Tools: conference participation, direct observation, procedure logs

Appendix 4. Review of Current Practices

Prior to initiating a revision to the existing training guidelines a survey was sent out by our subcommittee via email to all pediatric cardiology fellowship program directors. The survey asked for details of the individual program's noninvasive imaging core fellowship training experience, including the numbers of echocardiograms required to be performed by the fellow to successfully complete their noninvasive imaging core fellowship training, how these studies are monitored, and metrics/methods for fellow training assessment. Programs were also asked for their total annual number of TTE, TEE, and fetal echocardiograms, as well as the number of cardiac MRIs and CTs performed the prior year at their institution, and for the number of core and advanced imaging fellows at that institution. Of the 54 programs contacted, responses were received from 33. The results of the survey were as follows.

Training Program Requirements of Fellows to Successfully Complete Core Training in Echocardiography

- All programs require that their fellows complete 300 echocardiographic procedures, and 8 required them to perform >300. Of these, 2 programs require 500 per year. Only 12 programs actually tracked echocardiograms performed by age and complexity.
- 13 programs require that their fellows graduating after 3 years of core training should be able to perform and interpret fetal echocardiograms based on fellow's participation in an average of 50 fetal studies.
- 20 programs reported all graduating fellows were expected to be able to perform TEEs with an average requirement of 36 procedures (range 10 to 100).
- 16 programs had a formal training program in MRI and only 1 in cardiac CT.
- 26 programs reported that all their graduating fellows who pursued a career in a nonacademic setting were able to perform and interpret fetal echocardiograms and complex TTEs independently.

Evaluation System

- All echocardiographic procedure logs were obtained from either the reporting system used (n = 10) or the digital archiving system (n = 23). Few programs required fellows to maintain their own logs.

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- Most programs assess performance of a fellow on direct observation of skills and 18 have an established separate questionnaire, OSCE (objective structured clinical examination) tool, or direct quizzing tool that they use during echocardiography conferences that are focused on assessment of knowledge.
- Eight programs reported use of a self-assessment tool.

The results of the survey suggested that in the current environment all fellows were being trained using current digital acquisition and storage platforms, and the requirement for number of echocardiograms performed per fellow are based on the existing RRC-ACGME requirements. Additionally, size of the echocardiographic volume per program did not impact the number of expected procedures to be logged by a fellow.

Appendix 5. Recommended Minimum Procedural Numbers for Competency Assessment

Procedure	Recommended Minimum Number
Core Training	
TTE perform and interpret	150
TTE review and interpret	100
Advanced Training	
TTE perform and interpret	100
TTE review and interpret	100
TEE perform and interpret	50
*Fetal echocardiogram perform and interpret	50
*Fetal echocardiogram review and interpret	50
Cardiac MRI perform and interpret	50
Cardiac MRI review and interpret	50

*Fetal echocardiogram: 50 should have congenital heart disease and/or abnormality of fetal circulation. MRI indicates magnetic resonance imaging; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

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