

Task Force 4: Recommendations for Training Guidelines in Pediatric Cardiac Electrophysiology

Endorsed by the Heart Rhythm Society

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INTRODUCTION

The field of clinical cardiac electrophysiology has rapidly expanded over the past 30 years. Advances in the diagnosis and treatment of pediatric cardiac rhythm disorders, and the increasing trend in medicine in general to develop criteria or guidelines for competence and training in specific fields, have led to the need to develop guidelines for training in pediatric clinical cardiac electrophysiology (CCEP).

The American College of Cardiology (ACC), American Heart Association (AHA), and Heart Rhythm Society (formerly NASPE) have addressed training guidelines in adult CCEP (1–3). The extensive body of literature regarding adult CCEP training and basic electrophysiology (EP) knowledge provides an important background and should be applied in an appropriately modified form to pediatric CCEP training (4–21). Recognizing the considerable differences in the pediatric and adult cardiology populations, guidelines that are unique to the pediatric and congenital heart disease population must be developed. Canadian recommendations for training in pediatric EP have been published (22). It should be recognized that pediatric patients are unique, as recognized by the separate training programs and board certification for pediatricians and internists, and for adult and pediatric cardiologists. In addition, the pediatric electrophysiologist will have experience and expertise in groups unique to pediatric cardiac electrophysiology, including the fetus with in utero arrhythmias, the child with a structurally normal heart and supraventricular tachycardia, ventricular tachycardia, or other arrhythmias, the child with preoperative or postoperative arrhythmias after surgery for congenital heart disease, and the adult with congenital heart disease, both in the pre- and postoperative states. This unique group of adults with congenital heart disease is best served by those with a combined knowledge of congenital heart disease and age-specific disease processes, whether this be provided by a combination of pediatric and adult cardiologists or single individuals with broad training or dual training in pediatric and adult cardiology.

FACILITIES AND ENVIRONMENT

Training should be obtained in an Accreditation Council for Graduate Medical Education (ACGME)-accredited pediatric cardiology training program. Recommendations

for catheter ablation facilities have been published (2,9). Pediatric catheterization laboratory facilities should be available with the appropriate EP equipment to perform EP studies and catheter ablation. These facilities should ensure a safe, sterile, and effective environment for invasive EP studies and implantation of pacemakers and arrhythmia control devices. In many settings, the operating room can be used for the pacing/arrhythmia control devices. Although experience at outside institutions, including adult programs, may be valuable, no more than two to four months of the one-year advanced training should be spent at other institutions. In particular, added experience in pacemaker and implantable cardioverter-defibrillator (ICD) implantation, as well as in ventricular tachycardia studies, may be acquired at a certified adult CCEP program, provided that it is within the previously noted time frame.

At least one board-certified pediatric cardiologist with advanced CCEP skills should be identified as the director of the core and advanced Electrophysiology Training Program. Because there is currently no pediatric EP examination, consideration should be given for one pediatric EP faculty member to take the NASPExAM, or its successor examination. For advanced training of fellows, at least one faculty member should be skilled in the implantation of pacemakers and ICDs.

LEVELS OF EXPERTISE

In this report we discuss *core* training for all fellows and *advanced* training for fellows desiring special expertise in pediatric CCEP. The *core* training is recommended for all clinical fellows during their core clinical experience. It is intended to be sufficient for fellows who do not plan a career in EP. The *advanced* training provides expertise in both diagnostic and therapeutic EP and it is intended to qualify a fellow to embark upon a career in pediatric CCEP. Within the *advanced* level are two tracks related to expertise in pacemaker/ICD care: track 1 physicians prescribe and follow patients who require pacemaker/ICD care; track 2 physicians will also be skilled in device implantation.

Core Training: Goals and Methods

Core EP training is required of all trainees to be a competent pediatric cardiologist. The goal is to enable all trainees to be skilled in electrocardiographic (ECG) interpretation, including standard, ambulatory (Holter), exercise ECGs, and transtelephonic ECGs.

Table 1. Core Competence Skills

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- Interpretation of ECGs, Holters, exercise testing, and event monitors with arrhythmia recognition
 - Recognition of developmental changes in cardiac rates and rhythm with age and of “normal” variants of rhythm
 - Management of arrhythmias in the acute care setting, including uses of pharmacologic agents, cardioversion with esophageal or intracardiac pacing, and direct current cardioversion
 - Management of common chronic arrhythmias such as infant supraventricular tachycardia
 - Evaluation of the patient with documented arrhythmia, symptoms of arrhythmia (palpitations, increased or decreased heart rate, irregular heart rhythm), and syncope or presyncope
 - Treatment of patients with all forms of syncope
 - Evaluation of patients with long QT syndrome or family history of sudden death and management of these patients
 - Knowledge of indications for use of noninvasive EP testing
 - Knowledge of indications for invasive EP studies and general understanding of information obtained from EPS, including interpretation of basic EP information
 - Knowledge of indications for catheter ablation, understanding of procedure and complications of procedure
 - Knowledge of indications for pacing, anti-tachycardia device, and ICD placement
 - Knowledge of pacing modes, basic pacemaker interrogation, reprogramming, and trouble-shooting for loss of capture, under or over sensing, battery end of life
 - Temporary transvenous and transcutaneous pacing
 - Evaluation of EP literature
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Additionally, the trainee should understand the indications for and the use of noninvasive diagnostic techniques including exercise testing, 24-h ambulatory and event monitors, and tilt table testing and should have a general understanding of their interpretation. All trainees should be able to properly interpret cardiac arrhythmias and manage arrhythmias in the acute care setting. There should be an understanding of the use of non-pharmacologic methods and pharmacologic agents to treat arrhythmias, including drug interactions and proarrhythmic potential. The trainee should understand the indications for the selection of patients for specialized electrophysiologic studies, including ablation. In addition, the trainee should obtain a basic understanding of the indications for, and the information obtained from, invasive EP studies. This should include an understanding of the use of information obtained from these testing modalities for the management of the patient’s clinical condition. The trainee should have skills in the interpretation of basic EP information obtained from electrophysiology study (EPS).

Participation in at least 10 EPS cases including catheter placement and analysis of electrophysiologic tracings are needed to acquire these skills. The trainee should understand the evaluation of patients with syncope, palpitations, chest pain, and irregular heart rhythms. All trainees should understand the indications for pacemaker placement, know the differences in pacing modes, understand and be able to perform basic pacemaker interrogation, reprogram and troubleshoot pacemakers, recognizing basic malfunctions such as capture failure, sensing malfunctions, and battery

end of service characteristics. Participation by the trainee in at least 20 pacemaker evaluations is recommended to develop these skills. The trainee should receive instruction in the insertion, management, and follow-up of temporary pacemakers, including measurement of pacing and sensing thresholds. He or she should understand the general indications for consideration of the use of arrhythmia control devices (ICDs and anti-tachycardia devices) and know when to refer these patients for more advanced EP evaluation. The trainee should understand the indications and techniques for elective and emergency cardioversion. Four elective direct current cardioversions are required.

The core training to obtain the previously described skills and knowledge should occur in the first three years of pediatric cardiology training and be equivalent to two to three months of concentrated study, but may be acquired throughout the three years as needed to obtain designated competence skills (Table 1).

***Advanced Training (Year 4 ± Year 5):
 Goals and Methods***

The goal of *advanced* training is to enable the pediatric electrophysiologist to perform, interpret, and train others to conduct and interpret specific procedures at a high skill level. Tables 2 and 3 describe the competence skills necessary for advanced-level training. The recommended minimum procedures are summarized in Table 4 for both core and advanced training.

Advanced-level skills involve understanding the evaluation and management of common arrhythmias, from the fetus to young adult. In addition, advanced understanding of complex arrhythmia management, especially in the post-

Table 2. Advanced EP Clinical Competence Skills

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- Advanced competence skills include core basic skills plus:
- Management of all types of cardiac arrhythmias in all ages from the fetus to young adult
 - Evaluation and management of patients with specific arrhythmia syndromes including long QT syndrome, Brugada syndrome, and right ventricular dysplasia
 - Evaluation of patients with family history of sudden cardiac death
 - Management of complex arrhythmias, especially in postoperative congenital heart disease patients
 - Evaluation of patient with syncope including, when appropriate, performance of tilt table testing with appropriate interpretation and management of patient
 - Performance of esophageal EPS
 - Knowledge of the indications, risks, and benefits of EPS/catheter ablation
 - Interpretation and use of EPS data
 - Technical and cognitive skills to perform EPS/catheter ablation, using current mapping technology and techniques
 - Advanced knowledge of selection of pacemaker type, programming, follow-up, and trouble-shooting
 - Advanced knowledge of pacemakers and implantable cardioverter-defibrillators
 - Intraoperative evaluation and programming of pacemakers and ICDs
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Table 3. Advanced EP Research Competence Skills

- Evaluation of EP literature
- Development of clinical research skills
- Completions of EP project which results in an abstract and/or manuscript
- Grant submission is encouraged

operative period after repair of congenital heart defects and in special groups such as long QT syndrome, Brugada syndrome, and right ventricular dysplasia, should be attained. Evaluation and management of the patient with all forms of syncope should be accomplished, including the performance of tilt table testing when appropriate. In those programs that employ tilt testing, participation in at least 10 procedures in a pediatric or adult laboratory is advisable. A thorough understanding of pathophysiology and therapy of syncope and tilt testing should be required of all trainees. Advanced-level trainees should develop the cognitive skills to evaluate the patient with a family history of sudden cardiac arrest or death. Skill and experience should be encouraged in pediatric EPS interpretation and use of the EP data to make management and therapeutic decisions. Experience with esophageal EPS should be obtained with participation in 10 procedures. The indications, risks, and benefits of these procedures should be known.

Advanced-level trainees will develop technical and cognitive skills and experience in the performance of invasive diagnostic and therapeutic CCEP. At least 75 diagnostic intracardiac EPS should be performed, of which at least 10 should be patients with ventricular tachycardia. At least 40 of these diagnostic procedures must be in patients who are 12 years of age or younger, and at least 10 should be in patients with repaired or palliated congenital heart disease. In addition, participation in at least 40 catheter ablation procedures is required. The diagnostic portion of a catheter ablation procedure may be used to satisfy the

requirement for participation in 75 diagnostic procedures. Participation should include scrubbing for the case, catheter manipulation, analysis, review of tracings, and generation of a report.

Advanced understanding of pacemaker indications, optimal pacemaker choices, and follow-up of pacemaker patients should be obtained. The Heart Rhythm Society has recommended two tracks for those caring for pacemaker patients. Track 1 involves electrophysiologists who will be involved in prescribing and following pacemaker and ICD patients. Track 2 individuals prescribe, implant, and follow patients with pacemakers and ICDs. In both tracks, advanced understanding of pacemaker and ICD indications, optimal pacemaker choices, and evaluation or follow-up of 75 pacemaker/ICD patients should be obtained. In addition, attendance—including intraoperative testing of 35 pacemaker or ICD implants (20 new, 10 revisions, 5 ICDs)—is required. To implant pacemakers and ICDs, direct participation in a total of at least 50 pacemaker and device implants is required, of which a reasonable number should be complex devices including ICDs. As new technology develops, the number of device implants necessary to achieve competence may change. Participation should include scrubbing for the surgery, catheter manipulation, participation in intraoperative testing, and generation of a report. As the skills for implanting devices in smaller children are specific to pediatric EP, at least 15 of these implantation procedures should be in children less than 12 years of age. Also, experience with implantation in patients with repaired congenital heart disease is essential.

Advanced-level pediatric electrophysiologists should have all the skills noted in the previous text, but they may or may not perform the implantation of pacemakers and ICDs. If the pediatric clinical cardiac electrophysiologist does not

Table 4. Core and Advanced Training: Recommended Minimum Experiences

Level of Training	Core Pediatric Cardiology Training	Advanced Pediatric EP Training
Training time	2 to 3 months equivalent	12 months or more post general PC training*
ECG interpretation	500†	1,500
Ambulatory ECG interpretation	50	200
Exercise ECG	10	40
Tilt table tests	2	10
Transesophageal EPS/temporary postoperative epicardial wire study	5	10
Intracardiac EPS	10	75‡
Intracardiac EPS 12 years of age or less		40
Intracardiac EPS in repaired congenital heart disease		10
Catheter ablation	5	40
Catheter ablation 12 years of age of age or less		20
Catheter ablation in repaired congenial heart disease		10
DC cardioversion	4	10
Pacemaker + ICD		
Evaluations/follow-up	20	50
Intraoperative evaluation pacemakers and devices		35 (20 new, 10 revisions, 5 ICDs)
Track 2: implant pacemaker and complex devices		50 (15 in ages 12 yrs or less)

*4 to 6 months of this training could be obtained during a regular 3-year pediatric cardiology training program if it did not interfere with other required training. †ECG reading may be performed throughout three-year fellowship. ‡The diagnostic portion of an ablation procedure may be used to satisfy this requirement.

actually perform these procedures, they should participate in the intraoperative evaluation and postoperative care. Advanced-level training is expected for any pediatric electrophysiologist who implants pacemakers and ICDs. An additional one to two years after the general cardiology training program is required to achieve advanced-level training. Supplementary training may be required to achieve track 2 implantation competence. Part of this experience with implantation may be gained in an outside program or an affiliated adult CCEP training program. Until specific pediatric pacemaker and ICD certification is available, consideration should be given for advanced trainees implanting pacemakers and ICDs to take the NASPE examination.

SPECIFIC PROGRAM CONTENT (CORE AND ADVANCED LEVELS)

Trainees will be expected to develop an appropriate level of knowledge and experience in the following areas:

- Basic cellular and whole organ EP related to normal physiology and cardiac arrhythmias in all pediatric and adult congenital patients.
 - Pharmacologic principles underlying the use of antiarrhythmic drugs and the effects of various conditions encountered in pediatrics on the use of those drugs (prematurity, developmental biologic changes, including those in volume of distribution, hepatic and renal clearance, drug interactions, and congestive heart failure).
 - Management of pediatric and adult patients with congenital heart disease and cardiac arrhythmias; knowledge of presentation and natural history of the variety of arrhythmias encountered in pediatric electrophysiology practice; understanding of the effects of various management strategies on the physiology and psychology of the pediatric and congenital heart patient.
 - Expertise in the use of the ECG and other noninvasive specialized testing, including ambulatory monitoring, transtelephonic monitoring, exercise stress testing, and tilt table testing to evaluate cardiac arrhythmias and symptoms.
 - An understanding of the indications, contraindications, and potential risks and benefits of intracardiac EPS and esophageal EPS. Core-level trainees should have a general understanding of the information provided by EPS and recognize basic information provided such as site of heart block, identification of mechanism of the arrhythmia, and location of accessory pathways or focal arrhythmia sites. Advanced-level trainees should have experience with esophageal EPS for the treatment and evaluation of arrhythmias. Advanced trainees should also develop an advanced understanding of intracardiac EPS interpretation and use of the data for management. In addition, advanced trainees should develop the advanced cognitive and technical skills to perform EPS.
- Proficiency in the use of esophageal, temporary postoperative epicardial wire, and intracardiac EPS for diagnosis and treatment should be achieved. This includes the ability to manipulate catheters, knowledge of EP equipment and catheters, and ability to perform the full spectrum of programmed electrical stimulation and intracardiac mapping and to interpret the results.
 - Advanced trainees should develop the full spectrum of cognitive and technical skills in all types of catheter ablation in children and young adults with congenital heart disease. Advanced trainees should develop skills in the indications for and potential complications of catheter ablation and should be prepared to treat any of these complications. During the four years of training, the advanced trainee should develop skills in transseptal perforation by participating in at least 10 transseptal procedures. Trainees should have exposure to and develop skills in manipulation of ablation catheters for antegrade ablation; retrograde (transaortic) ablation experience is also highly desirable.

Core-level trainees should have a basic knowledge and understanding of the use of pacemakers and ICDs in pediatric and congenital heart patients. In addition, the core trainee should develop an understanding of pacemakers and skills in evaluation of pacemaker problems that may occur. Advanced-level trainees should have advanced knowledge in the evaluation and management of pacemakers and ICDs. In addition, advanced trainees will participate in implantation (either intraoperative evaluation or actual implant depending on whether track 1 or 2 is chosen) of pacemakers and ICDs, and provide expert understanding and management of implanted pacemakers and ICDs. In addition, advanced-level trainees should have an understanding and experience in using pacemakers and ICDs for noninvasive EPS and internal cardioversion. All levels should have skills in introducing temporary transvenous pacemakers. All levels should have experience with transcutaneous pacing. Both levels should have the skill to use transthoracic temporary postoperative epicardial wires for the recording of electrograms. Advanced trainees should have knowledge and experience in using these wires to convert arrhythmias.

Core-level trainees should have a basic understanding of the indications for and use of cardiac surgery to treat arrhythmias. Advanced level trainees should provide expert mapping and other EP knowledge at the surgical procedure.

Specific formal instruction topics should be covered in a core lecture series and in a journal club format. There should be regularly scheduled conferences regarding EPS interpretation, application of the EPS to the patient's clinical management, and conferences on interpretation of standard and ambulatory ECGs.

This Task Force 6 Report is 1 of 13 COCATS 3 Task Force Reports, which encompass training recommendations for the fellowship programs in adult cardiovascular medicine and are published in their entirety in the January 22, 2008, issue of the Journal of the American College of Cardiology (J Am Coll 2008;51:374-80).
ACC policy statement: recommended guidelines for training in adult clinical cardiac electrophysiology: Electrophysiology/Electrocardiography Subcommittee, American College of Cardiology. J Am Coll Cardiol 1991;18: Zipes DP, DiMarco JP, Gillette PC, et al. Task Force 2: Pediatric Cardiology Fellowship Training in Noninvasive Cardiac Imaging Shubhika Srivastava, MBBS, FAAP, FACC, FASE, Co-Chair Beth F. Printz, MD, PHD, FAAP, FASE, Co-Chair Tal Geva, MD, FACC Girish S. Shirali, MBBS, FACC, FASE Paul M. Weinberg, MD Pierre C. Wong, MD Peter Lang, MD, FAAP, FACC.
ACCF/AHA/ AAP recommendations for training in pediatric cardiology: training guidelines for pediatric cardiology fellowship programs. J Am Coll Cardiol. 2005;46:1380-1381.
SECTION I Adult Electrocardiography Figure 1 Timing of cardiac action potentials recorded during inscription of an ECG complex. The action potentials responsible for the atrial and ventricular activation are designated manifest and those responsible for impulse initiation and propagation as concealed.
AEPC RECOMMENDATIONS FOR BASIC TRAINING IN PAEDIATRIC AND CONGENITAL CARDIOLOGY 2020 Association for European of Paediatric and Congenital Cardiology. Educational Committee.
Diagnosis and treatment of cardiac rhythm disorders 3.5.1 Clinical electrophysiology 3.5.2 Invasive electrophysiological studies and catheter ablation 3.5.3 Cardiac implantable electric devices (CIEDs) 3.5.4 Inherited arrhythmia syndromes 3.5.5 Arrhythmias in adults with congenital heart disease (ACHD).
The recommendations of the Association for European Paediatric and Congenital Cardiology (AEPC) for basic training in paediatric and congenital cardiology required to be recognized as a paediatric cardiologist by the AEPC are described below.
Task force 4: recommendations for training guidelines in pediatric cardiac electrophysiology endorsed by the Heart Rhythm Society.
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