

Recommendations for Advanced Fellowship Training in Clinical Pediatric and Congenital Electrophysiology

A Report from the Training and Credentialing Committee of the Pediatric and Congenital Electrophysiology Society

Endorsed by the Heart Rhythm Society

COMMITTEE MEMBERS

Edward P. Walsh, MD, FHRS, Chair
Yaniv Bar-Cohen, MD
Anjan S. Batra, MD, FHRS*
Macdonald Dick II, MD, FHRS
Christopher Erickson, MD
Frank Fish, MD
Robert M. Hamilton, MD[†]
Ronald J. Kanter, MD, FHRS[‡]
John H. Reed, MD, FHRS
George F. Van Hare, MD, FHRS
Victoria L. Vetter, MD, FHRS
Gregory Webster, MD

Writing Group Members

Edward P. Walsh, MD, FHRS
Yaniv Bar-Cohen, MD
Robert M. Hamilton, MD
John H. Reed, MD, FHRS
George F. Van Hare, MD, FHRS

*Research protocol participant, Medtronic; [†]Consultant, Boehringer Ingleheim; [‡]Fellowship Training Grants, Medtronic and St. Jude.

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1. Background

Pediatric electrophysiology (EP) first emerged as a distinct clinical discipline in the 1970s when it became apparent that rhythm management for young patients required a specific knowledge base focused on congenital heart defects and hereditary arrhythmia syndromes. Early practitioners acquired the requisite skills in diverse ways. Some were self-taught, others collaborated with electrophysiologists at affiliated adult hospitals, and some entered the field from a basic science background. As pediatric EP evolved to become more of an interventional subspecialty, this ad hoc approach to training proved inadequate and the need arose for formal fellowships at high-volume centers where trainees could be exposed to the full spectrum of relevant disease and begin to acquire the technical skills necessary for state-of-the-art practice. The complexity of this training curriculum has grown steadily. Not only must trainees now master all aspects of arrhythmia care in the fetus, infant, and children, but they must also be prepared to deal with arrhythmias in the rapidly expanding population of young adult survivors with congenital heart defects. In an effort to standardize the fellowship experience, guidelines for advanced training in pediatric and congenital EP were published in 2005 under the auspices of the American College of Cardiology, the American Heart Association, and the American Academy of Pediatrics, with endorsement from the Heart Rhythm Society (HRS). That document outlined the key topics for fellow education and offered estimates of the minimum procedural experience needed to perform EP studies, catheter ablation, and device implantation.¹ The guidelines were supplemented in 2008 by a consensus statement² from the Pediatric and Congenital Electrophysiology Society (PACES) and HRS that provided detailed recommendations for achieving clinical competency in more complex device procedures, including cardiac resynchronization therapy (CRT) and implantable cardioverter-defibrillators (ICDs).

The level of expertise needed to perform sophisticated procedures in children and young adults with congenital heart defects continues to rise, and the body of knowledge underlying arrhythmia treatment in this population continues to expand. In 2011, the executive committee of PACES launched a comprehensive review of advanced EP fellowships in an effort to ensure the highest possible standards for training programs and practitioners in the field. Among the

many motivations for this review was the absence of a third-tier certification examination in pediatric and congenital EP from the American Board of Pediatrics to parallel the rigorous certification process for EP graduates of internal medicine programs.³ A committee of PACES members was formed to 1) update the scientific curriculum for pediatric and congenital EP, 2) update the recommended procedure volume for trainees, 3) determine the level of procedural competence expected for the average graduate upon completion of training, 4) consider adoption of the examination offered by the International Board of Heart Rhythm Examiners (IBHRE) as a proxy for American Board of Pediatrics certification, and 5) establish criteria for patient volume, staffing, and infrastructure for institutions wishing to qualify as training centers in pediatric and congenital EP.

2. Overview of Training

All trainees must have successfully completed a core fellowship in pediatric cardiology at an accredited training program, or under special circumstances, an adult cardiology fellowship with concentration on congenital heart disease. The advanced fellowship in pediatric and congenital EP should involve a minimum of 12-month full-time clinical training beyond the core fellowship. The duration may be extended to a maximum of 24 months at the discretion of the training center if additional time is needed for a fellow to satisfy procedure quotas and/or pursue a block of protected research time. Occasional trainees may demonstrate the desire and the aptitude to pursue a more aggressive research agenda that causes them to deviate from the traditional clinical training path. If this occurs before the completion of 12 full months of basic EP training, any unmet clinical requirements would still have to be satisfied if the trainee subsequently elects to return to a clinical EP career.

Training should provide a combination of bedside teaching, didactic lectures, closely mentored procedural experience, and research exposure to give graduates a solid background in all aspects of the diagnosis and treatment of cardiac rhythm disturbances. A comprehensive curriculum for this purpose is outlined in Table 1. Although all items listed in the curriculum are considered vital to a well-rounded training experience, particular emphasis should be placed on topics specific to the younger population, including procedural and medication adjustments necessary for safe therapy in the pediatric age group, the effect of congenital heart disease, and hereditary channelopathies/myopathies.

3. Didactic Curriculum and Research Experience

Formal didactic lectures and a list of directed readings on clinical and basic science topics are essential to training. The lecture series should be designed so that the full list of topics will be covered at least once per trainee cycle. Trainees should also attend institutional conferences where multidisciplinary discussions are held in conjunction with cardiovascular surgeons regarding optimal device, antiarrhythmic, and ablation strategy for patients with congenital heart disease

undergoing repair. Quality assurance evaluation and morbidity/mortality conferences related to EP topics should also be held regularly.

Trainees should become involved in at least 1 EP research project over the course of their fellowship that ultimately results in a manuscript suitable for peer-reviewed publication. The training center is responsible for directing the fellow toward a worthy topic, ensuring that the study design is scientifically valid, assisting with production of an abstract that can be submitted to a national meeting, and supervising manuscript preparation. It is expected that such a project, especially if clinically based, will be completed during the 12-month fellowship or shortly thereafter.

4. Clinical Experience

Clinical training in pediatric and congenital EP must involve intense exposure to patient care with a focus on diagnostic and interventional procedures. Recognizing that the quality of the training experience can be as important as raw procedure numbers, recent medical education models have incorporated a competency-based measure that emphasizes the level of technical proficiency expected upon completion of training.^{4,5} A concept known as "Level of Entrustment" is included in this model, which is defined by 5 competency levels:

- Level 1: Trainee has basic knowledge
- Level 2: Trainee may act under full supervision
- Level 3: Trainee may act under moderate supervision
- Level 4: Trainee may act independently
- Level 5: Trainee may act as a supervisor or instructor

This ranking system has been adopted for these updated guidelines. Table 2 lists both the competency level and the minimal procedure volume for various diagnostic and therapeutic skills required by the end of fellowship training in pediatric and congenital EP. The use of this system implies dual responsibilities; the trainee must strive to reach the proper level of proficiency within the allotted time, and the training center must provide a learning environment and procedure volume that makes this possible. Absolute mastery of all aspects of EP is not expected based on the fellowship experience alone. For straightforward procedures, Level 5 mastery is required, but for very complex procedures, lower levels of proficiency are anticipated for new graduates. Realistically, full proficiency in advanced techniques may develop only after additional years of experience at the staff level.

Minimum procedure numbers adopted for this document were chosen by the consensus of the PACES committee members on the basis of personal experience with EP fellowship training and clinical practice, along with careful review of earlier guidelines. Trainees may satisfy their quotas with procedures performed during both their core fellowship and their clinical EP fellowship. It is anticipated that procedures during core fellowship will be largely

Table 1 Curriculum for Pediatric and Congenital Cardiac Electrophysiology

- I. Cellular and tissue electrophysiology
 - A. A Cardiac cell physiology and excitability
 - B. Impulse propagation
 - C. Repolarization and refractoriness
 - D. Effect of the central nervous system on cellular EP and impulse propagation
- II. Conduction tissues
 - A. Normal heart
 - B. Congenital heart disease
 - C. Accessory pathways
- III. Basic mechanisms of arrhythmias
 - A. Reentry, automaticity, and triggered activity
 - B. Bradyarrhythmias and block
- IV. Supraventricular tachycardias
 - A. Ectopic atrial tachycardia
 - B. Multifocal atrial tachycardia
 - C. Atrial flutter/intra-atrial reentrant tachycardia
 - D. Atrial fibrillation
 - E. Atrioventricular nodal reentrant tachycardia
 - F. Junctional ectopic tachycardia
 - G. Accessory pathway-mediated tachycardias
 - Wolff-Parkinson-White syndrome and concealed accessory pathways
 - Mahaim tachycardia and permanent junctional reciprocating tachycardia
 - H. Tachycardia-induced myopathy
- V. Ventricular tachycardias (VT)
 - A. Prevalence of VT in childhood and in adult congenital heart disease
 - B. Outflow tract and other focal VT
 - C. Left ventricular septal VT
 - D. Macroreentrant VT in patients with congenital heart disease
 - E. Myocarditis and VT
 - F. Cardiac tumors and VT
- VI. Channelopathies and hereditary cardiomyopathies
 - A. Long QT syndromes
 - B. Brugada syndrome
 - C. Catecholaminergic polymorphic VT
 - D. Short QT syndrome
 - E. Hypertrophic cardiomyopathy
 - F. Arrhythmogenic right ventricular cardiomyopathy
 - G. Genotyping and family counseling
- VII. Bradycardia and atrioventricular block
 - A. Autonomic-medicated bradycardia
 - B. Sinus node dysfunction after surgery for congenital heart disease
 - C. Atrioventricular block
 - D. Maternal antibody-mediated congenital heart block
 - E. Congenital heart block in congenital heart disease
 - F. Acquired heart block
- VIII. Specific clinical presentations
 - A. Fetal arrhythmias
 - B. Evaluation of recurrent palpitations
 - C. Evaluation of unexplained syncope

Table 1 (continued)

- D. Sudden cardiac death (see also point VI)
 - E. Evaluation for sports participation and other “screening” methods
 - F. Exercise and sports recommendations
 - G. Caring for the adult with congenital heart disease
- IX. Antiarrhythmic drug therapy
 - A. Classification schemes
 - B. Pharmacodynamics of antiarrhythmic drugs
 - C. Indications and contraindications of antiarrhythmic drugs
 - D. Side effects and toxicity of antiarrhythmic drugs
 - E. Anticoagulants used in arrhythmia management
 - F. Transplacental fetal therapy
 - G. Breast-feeding while mother taking antiarrhythmic drugs
 - X. Catheter ablation
 - A. Indications and published guidelines
 - B. Equipment
 - C. Radiation safety
 - D. Nonfluoroscopic mapping techniques
 - E. Catheter approaches
 - F. Ablation energy
 - G. Ablation of common arrhythmias
 - H. Ablation of complex/rare substrates
 - I. Ablation in infants and small children
 - J. Ablation in congenital heart disease
 - K. Sedation, anticoagulation, and other safety issues
 - L. Identification and management of potential complications
 - M. Outcomes data in pediatrics and congenital heart disease
 - XI. Pacemaker and implantable cardioverter-defibrillator therapy
 - A. Indications and published guidelines for devices in pediatrics and congenital heart disease
 - B. Pacemaker and implantable cardioverter-defibrillator generator and lead technology
 - C. Pacemaker and implantable cardioverter-defibrillator timing cycles and programming
 - D. Transvenous and epicardial implant techniques
 - E. Resynchronization pacing
 - F. Lead malfunction
 - G. Indications and techniques for lead extraction
 - H. Outcomes data in pediatrics and congenital heart disease
 - I. Contraindications to transvenous pacemaker or implantable cardioverter-defibrillator implant
 - J. Psychosocial and lifestyle issues
 - XII. Arrhythmia surgery and other perioperative issues
 - A. Intraoperative arrhythmia mapping and ablation
 - B. Right-atrial and biatrial “maze” procedure
 - C. Assisting with epicardial pacemaker or implantable cardioverter-defibrillator implant in operation room
 - D. Postoperative temporary wires (see also point IV)
 - E. Programming external temporary pacemakers
 - F. Sympathectomy
 - XIII. Adult electrophysiology data of importance
 - A. Landmark studies of risk-stratification for sudden cardiac death
 - B. Landmark outcomes data for antiarrhythmic drug therapy
 - C. Landmark outcomes data for implantable cardioverter-defibrillator therapy
 - D. Landmark outcomes data for resynchronization pacing
 - E. Outcomes data for the treatment of atrial fibrillation
 - F. Key consensus documents

Table 1 (continued)

XIV. Research

- A. Basic clinical study design and medical statistics
- B. Choosing research questions wisely (short-term and long-term studies)
- C. Presentation and publication
- D. Introduction to grant application and funding sources
- E. Regulations and research ethics

restricted to noninvasive tests (eg, electrocardiogram interpretation), while most invasive procedures (ablation and devices) will be performed during the advanced EP fellowship period.

It is imperative that fellows receive regular feedback on their performance throughout training to ensure they remain on target with procedural numbers and proficiencies. This should involve formal progress reviews by the fellowship director at least every 4 months.

4.1. Noninvasive Testing

All noninvasive categories listed in Table 2 are expected to be mastered (Level 5 competency) by the end of training. Accurate interpretation of the electrocardiogram and various forms of rhythm monitoring are essential skills for any clinician entering EP. As such, high-volume experience with careful staff supervision and feedback is critical during training. Exercise testing, especially as it relates to the evaluation of arrhythmia substrates (eg, Wolff-Parkinson-White syndrome, catecholaminergic polymorphic ventricular tachycardia, and long QT), requires generous exposure as well.

Familiarity with noninvasive atrial recordings and pacing (whether by temporary postoperative wires or esophageal catheter placement) is essential for both arrhythmia diagnosis and treatment. This is especially true in the postoperative setting, where evaluation of the atrial electrogram can facilitate diagnosis and guide optimal therapy. While most training programs are expected to provide a far greater exposure than the suggested procedure number (20 cases), proficiency in these techniques does not typically require a large number of cases. Similarly, a limited number of supervised DC cardioversions (10 cases) is generally considered sufficient to master this procedure.

The 2005 version of pediatric and congenital EP training guidelines recommended a number of tilt table tests for the evaluation of young patients with syncope. This requirement has been removed from the current guidelines. Although it remains crucial that trainees understand the mechanisms of syncope and the physiology behind tilt testing, exposure to this procedure is no longer considered mandatory.

4.2. EP Studies and Ablation

Diagnostic EP testing and transcatheter ablation account for the largest block of training time during EP fellowship.^{6,7} Clinical mastery (Level 5) is expected upon completion of

Table 2 Pediatric and Congenital Electrophysiology Training: Recommended Procedure Experience

Category	Competency level	Minimum no. of procedures
Noninvasive		
ECG interpretation	5	1500
Holter/event/other rhythm strips	5	400
Rhythm during exercise testing	5	20
Postop wires and/or esophageal EPS	5	20
DC cardioversion	5	10
Simple EPS and ablation		
Diagnostic studies	5	10
Ablation for APs and AVNRT	4	50
Complex EPS and ablation		
Small/young patients	4	5
3D mapping of complex substrates	3-4	10
Intraoperative EP		
Assist epicardial pacemaker	4	5
Assist epicardial ICD	4	3
Intraoperative ablation	3-4	3
Simple devices		
Test and program pacemaker and ICD	5	100
Transvenous pacemaker implant/revision	4	20
Transvenous ICD implant/revision	4	15
Complex devices		
Implant pacemaker/ ICD in young and CHD	4	10
Resynchronization pacing	3	5
Lead extraction	3	5

For the description of competency levels, see text.

3D = 3-dimensional; AP = accessory pathway; AVNRT = atrioventricular nodal reentry tachycardia; CHD = congenital heart disease; EP = electrophysiology; EPS = electrophysiological studies; ICD = implantable cardioverter-defibrillator.

training for all basic skills related to diagnostic testing, including vascular access, electrode positioning, programmed stimulation, electrogram analysis, and interpretation of common arrhythmias. These skills should be obtained through a process of mentored hands-on exposure to both diagnostic EP studies and ablation procedures.

For the purpose of these recommendations, ablation therapy is divided into *simple* and *complex*. By the end of training, graduating fellows are expected to have achieved Level 4 skills with *simple* catheter ablation and be able to independently perform procedures for accessory pathways and atrioventricular nodal reentrant tachycardia in otherwise healthy young patients. Data suggest that approximately 50 ablation procedures are a reasonable number of cases to obtain this Level 4 competency.⁸ Training centers are encouraged to expose their fellows to a variety of established techniques to accomplish a given task rather than focus on a single methodology. Instruction should include both the transeptal and retrograde approaches to left-heart substrates, the use of both radiofrequency current and cryoablation as an ablation energy source, and exposure to both fluoroscopic and nonfluoroscopic methods for catheter localization.

Complex ablation procedures are defined by 1) young patient age/small size (≤ 12 years; ≤ 35 kg), 2) the presence of congenital heart disease, and 3) complex arrhythmia substrates. The ability to perform catheter ablation in small children and patients with congenital heart defects are salient skills that define pediatric and congenital EP. Consequently, exposure to these complex procedures must be considered a vital part of the training experience. Fellows should receive detailed instruction in the modified techniques necessary for safe ablation in small patients,⁹ methods for navigating complex anatomy in congenital heart defects,^{10,11} mapping of unusual supraventricular and ventricular arrhythmias (including 3-dimensional localization), and advanced pacing maneuvers for rhythm analysis. Only Level 3-4 expertise can be expected for fellows upon completion of their training. Higher skill levels in *complex* ablation are typically obtained only after additional experience at the staff level.

4.3. Intraoperative Procedures

The practice of pediatric and congenital EP requires active participation in surgical procedures. These can include intraoperative arrhythmia mapping, surgical ablation of certain unusual atrial and ventricular substrates,¹² sympathectomy procedures for channelopathies,¹³ and epicardial device placement for patients who are not suitable for transvenous hardware.^{14,15} Trainees are expected to participate in these procedures to gain technical experience and to learn the importance of clear communication between the electrophysiologist and the surgeon. Most intraoperative procedures will involve device implants where the electrophysiologist assists the surgeon with hardware selection, lead testing (including defibrillation threshold for ICD implants), and programming. Trainees need to achieve Level 4 expertise with intraoperative device implants, and Level 3-4 expertise with intraoperative ablation, by the time their training is complete.

4.4. Cardiac Rhythm Management Devices

The 2005 version of these guidelines recognized 2 possible training paths in pediatric and congenital EP: 1 for physicians who would prescribe and follow patients with implantable devices but not perform the actual implants and 1 for those who would acquire the necessary skills for implantation. Given the increasing importance of resynchronization therapy and antitachycardia devices in modern cardiac care, implantation is now to be considered a mandatory part of the EP training experience for all fellows in these updated guidelines.

The scope of practice in pediatric and congenital device therapy includes the broad age range of infancy to young adulthood and structurally normal hearts as well as those with congenital anomalies (before and after surgical intervention). Trainees will be expected to acquire a full understanding of the indications and potential complications of device therapy in this population¹⁶ and become highly competent (Level 5) in all aspects of device programming, follow-up, and troubleshooting, including interpretation of

downloaded data from home monitoring of device function. The trainee should develop an in-depth understanding of generator and lead technology and apply this knowledge to optimal device selection and programming. The curriculum should include the available outcome data in pediatrics and adult congenital heart disease, as well as the landmark studies in older patients regarding ICD therapy and resynchronization pacing (Table 1).

Similar to the distinction made for ablation procedures, devices procedures can be separated into the categories of *simple* and *complex*. *Simple* procedures include pacemakers and ICDs in older children and teenagers with structurally normal (or only mildly abnormal) hearts. Training should include a minimum of 20 pacemaker procedures and 15 ICD procedures in this population, the majority of which should be new implants. Experience should include vascular access, pocket creation, lead manipulation and testing, device testing, closure, and generation of a report. The trainee should clearly understand indications for, and potential complications of, defibrillation testing. They should be knowledgeable regarding the various methodologies for estimating defibrillation energies and understand all the options for dealing with high thresholds. Fellows should be expected to reach Level 4 competency and function independently with *simple* implants by completion of their training.²

Complex device procedures include pacemakers and ICDs in smaller patients, those with major structural heart disease, and resynchronization pacing. Training should include pacemaker or ICD procedures in a minimum of 10 patients with small body size and/or complex anatomy, as well as a minimum of 5 procedures for CRT.¹⁷⁻¹⁹ Because full mastery of such implants usually requires more extensive experience, proficiency upon completion of fellowship training is expected only to reach Level 3, or perhaps Level 4 for certain trainees with exceptional aptitude.

Younger age at implant, increased patient longevity, and various lead problems have made lead extraction an increasingly important part of EP practice. The trainee should understand the indications for and, importantly, the complications of and safety precautions necessary for lead extraction in pediatrics and adult congenital heart disease.²⁰ Extraction experience during training is expected to be predominantly observational, but it is recommended that trainees be present and function as an assistant during 5 lead extractions to gain a full appreciation for tools and techniques. Only Level 3 competence is expected after this training. Individuals who choose to develop higher level skills in lead extraction are expected to seek further mentorship during their early years of staff practice.

5. Credentialing/Certification

In many subspecialties, credentialing of staff practitioners requires documentation of appropriate training, along with the passage of an examination demonstrating adequate knowledge of the field. But because of the relatively small number of practitioners in pediatric and congenital EP, there

is currently no third-tier board examination offered by the subboard of Pediatric Cardiology of the American Board of Pediatrics. This contrasts with the well-established certification process available for individuals who have trained in EP through the internal medicine route. Trainees with backgrounds in pediatrics and pediatric cardiology are not eligible for testing in Clinical Cardiac Electrophysiology under the American Board of Internal Medicine.

As an organization, PACES has explored ways to raise standards for pediatric and congenital EP practice, including a certification examination. In past years, the only available testing for this purpose was the NASPE_{AM} of Special Competency in Cardiac Pacing and Cardioversion Defibrillation. The 2005 version of these guidelines suggested that staff practitioners in the field (especially those at training centers) consider certification with the NASPE_{AM}. More recently, the IBHRE, the successor to NASPE_{AM}, has launched a modular examination of special competency in EP that addresses both adult and pediatric/congenital practice. As an affiliate, independent body of HRS, IBHRE is an internationally recognized certifying board that is accredited by the American National Standards Institute. Candidates take 2 of the 3 modules: general EP (in common for adult and pediatric candidates), plus a module in either adult or pediatric/congenital EP. Passage of the IBHRE examination with the pediatric/congenital module can be viewed as a valid measure of the specific knowledge underlying pediatric and congenital EP. Consequently, this committee strongly recommends that all graduating fellows, as well as all active clinicians in the field, take this examination. By way of enforcement, successful passage is now considered to be a criterion for pediatric and congenital practitioners to be appointed as Fellows of the Heart Rhythm Society. The committee believes that IBHRE certification is especially important for faculty who direct a training program in pediatric and congenital EP. The overarching goal of these guidelines in terms of credentialing is to move toward establishing the IBHRE examination as the equivalent of the American Board of Internal Medicine CCEP examination used in credentialing adult electrophysiologists.

6. Facilities and Requirements for a Pediatric and Congenital EP Training Center

Advanced training in pediatric and congenital EP should take place only at centers with an accredited core fellowship in pediatric cardiology and a robust cardiovascular surgical program. Centers must have on-site pediatric and congenital EP physician staff working on a full-time basis. Training centers must also have formal connection with a program of adult congenital heart disease, either on-site or at a closely affiliated institution.²¹

All training centers must have high-quality facilities and proper support staff^{22,23} for performing EP studies, catheter ablation, device implants, and intraoperative procedures in pediatric and young adult patients. The EP laboratory must be fully equipped for standard fluoroscopy and multichannel

electrogram registration, along with advanced equipment for 3-dimensional mapping. Ablation systems for radiofrequency current and cryoablation should be available. Equipment for intracardiac echo is considered highly desirable.

The procedure volume for diagnostic EP testing and catheter ablation at the training center must be sufficiently large to allow each clinical fellow to meet their recommended quotas within a 12-month training period. This requirement is usually easy to satisfy. In contrast, the procedure volume for device implants is a more complicated issue. Only a few pediatric and congenital EP training programs currently have adequate device volume to satisfy the recommended quotas over 1 year of training. This deficiency has been dealt with in several ways. Some centers have extended the duration of training, while others have made arrangements for trainees to spend time performing implants with an EP group at an affiliated adult hospital where device volume is higher. These arrangements are viewed by the committee as acceptable methods for trainees to gain necessary exposure to device procedures, including ICD and CRT. However, in an effort to keep the training experience focused primarily on young patients and adult congenital heart disease, it is recommended that the majority of the total device quota be satisfied within the primary training center. Under special circumstances, a trainee may be obligated to complete their formal fellowship training before reaching the recommended procedure quota and proficiency level for device implant. Such individuals would be expected to seek additional mentorship at the junior staff before being granted institutional privileges to perform these procedures independently.

Currently, there is no mechanism in place for reviewing advanced training programs in pediatric and congenital EP, nor is there a central database for tracking of training positions and graduates. The committee proposes that PACES assume an active role in the process, beginning with the registration of institutions that offer training and later expanding to formal appraisal of institutional qualifications to ensure compliance with these guidelines.

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