2021 PACES expert consensus statement on the indications and management of cardiovascular implantable electronic devices in pediatric patients: executive summary

Developed in collaboration with and endorsed by the Heart Rhythm Society (HRS), the American College of Cardiology (ACC), the American Heart Association (AHA), and the Association for European Paediatric and Congenital Cardiology (AEPC). Endorsed by the Asia Pacific Heart Rhythm Society (APHRS), the Indian Heart Rhythm Society (IHRS), and the Latin American Heart Rhythm Society (LAHRS).

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Preamble

Guidelines for the implantation of cardiac implantable electronic devices (CIEDs) have evolved since publication of the initial ACC/AHA pacemaker guidelines in 1984. CIEDs have evolved to include novel forms of cardiac pacing, the development of implantable cardioverter defibrillators (ICDs) and the introduction of devices for long term monitoring of heart rhythm and other physiologic parameters. In view of the increasing complexity of both devices and patients, practice guidelines, by necessity, have become increasingly specific. In 2018, the ACC/AHA/HRS published Guidelines on the Evaluation and Management of Patients with Bradycardia and Cardiac Conduction Delay, which were specific recommendations for patients >18 years of age. This age-specific threshold was established in view of the differing indications for CIEDs in young patients as well as size-specific technology factors. Therefore, the following document was developed to update and further delineate indications for the use and management of CIEDs in pediatric patients, defined as ≤21 years of age, with recognition that there is often overlap in the care of patients between 18 and 21 years of age.

This document is an abbreviated expert consensus statement (ECS) intended to focus primarily on the indications for CIEDs in the setting of specific disease/diagnostic categories. This document will also provide guidance regarding the management of lead systems and follow-up evaluation for pediatric patients with CIEDs. The recommendations are presented in an abbreviated modular format, with each section including the complete table of recommendations along with a brief synopsis of supportive text and select references to provide some context for the recommendations. This document is not

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intended to provide an exhaustive discussion of the basis for each of the recommendations, which are further addressed in the comprehensive PACES-CIED document,³ with further data easily accessible in electronic searches or textbooks.

Introduction

Methodology and evidence review

The principles in the development of this document are 1) new recommendations or changes to previous recommendations are based on data, when possible; 2) these recommendations are consistent with current ACC/AHA/HRS adult guidelines when reasonable; and 3) all recommendations have been critically reviewed, initially by the writing committee and editors, followed by the PACES executive committee, and subsequently by external HRS, ACCF, AHA, and AEPC representatives. Any revisions or additions to existing recommendations require approval of at least 80% by the members of the PACES writing committee.

These recommendations have been developed with standard guideline methodology, i.e., with both a class of recommendation (COR) and a level of evidence (LOE) (Table 1). The class of the recommendation indicates the strength of recommendation, based on the estimated magnitude or certainty of benefit in proportion to risk. The level of evidence rates the quality of evidence based on the type, quantity, and consistency of data from clinical trials and other sources. A recommendation with a Level of Evidence C-EO does not imply that the recommendation is weak. Many of the questions addressed in this (and other) documents either do not lend themselves to clinical trials or are rare disease entities. However, there may be unequivocal consensus that a particular intervention is either effective or necessary.

Organization of the writing committee

The writing committee consisted of members of PACES who were selected by the PACES executive committee. The writing committee members included junior and senior pediatric electrophysiologists as well as allied health professionals and represented diverse genders, countries, and cultures. The writing committee also included external representatives from the ACC, AHA, HRS, and AEPC. Prior to final publication, all committee members were required to verify their specific contributions to this document. Appendix 1 lists writing committee members’ relevant relationships with industry.

Document review and approval

Following internal review by the PACES executive committee, this document was then reviewed by the PACES writing committee. Following considerations of these comments and approval by an independent PACES reviewer, the recommendations were opened for public comment to PACES members. An official reviewer each nominated by HRS, ACC, AHA, and AEPC provided independent external review. This document was then approved for publication by the PACES executive committee and endorsed by all collaborators and the Asia Pacific Heart Rhythm Society (APHRS), the Indian Heart Rhythm Society (IHIRS), and the Latin American Heart Rhythm Society. Appendix 2 lists reviewers’ relevant relationships with industry.

Health policy objectives

The purpose of this document is to provide guidance to clinicians for the management of pediatric patients who may require a CIED, with a primary focus on the indications for device implantation. The document will be useful to pediatric cardiologists, cardiac surgeons, cardiac intensivists, anesthesiologists, and arrhythmia specialists. This document supersedes the pediatric CIED recommendations made in “ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities”⁴ and “2012 ACCF/AHA/HRS Focused Update of the 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities.”⁵

Top 10 take-home messages

1. In patients with isolated sinus node dysfunction (SND), there is no minimum heart rate or maximum pause duration where permanent pacing is absolutely recommended. Establishing a temporal correlation between symptoms and bradycardia is critical in the decision as to whether permanent pacing is indicated.

2. Young patients with impaired ventricular function or abnormal cardiovascular physiology may be symptomatic due to sinus bradycardia or the loss of atrioventricular (AV) synchrony at heart rates that do not produce symptoms in individuals with normal cardiovascular physiology.

3. Although the average ventricular rate in newborns and infants with congenital complete atrioventricular block (CCAVB) provides an objective measure regarding the decision for pacemaker implantation, additional factors may equally influence the decision/timing of pacemaker implant. These include birth
weight (size), congenital heart defects, ventricular function, and other comorbidities.

4. In patients with postoperative AV block, a period of observation for at least 7–10 days before pacemaker implantation remains advised; in select cases, earlier pacemaker implantation may be considered if AV block is not expected to resolve due to extensive injury to the cardiac conduction system.

5. Atrial pacing with antitachycardia pacing capabilities is reasonable for congenital heart disease (CHD) patients with recurrent intra-atrial reentrant tachycardia when medication and catheter ablation are not effective.

6. There is increased recognition of the need for pacemaker implantation in conditions such as Kearn-Sayre syndrome or certain neuromuscular disorders due to the unpredictable progression of conduction disease.

7. The cause of sudden cardiac arrest (SCA) remains undefined in nearly 50% of pediatric survivors. ICD implantation is recommended provided completely reversible causes have been excluded, other treatments that may be beneficial are considered, and meaningful survival is anticipated.

8. The decisions for implantation of an ICD for primary prevention in cardiac channelopathies or cardiomyopathies remain guided by limited and, at times, conflicting data. Consideration of patient-specific factors and shared decision-making are critically important.

9. In pediatric patients with nonischemic dilated cardiomyopathy (NIDCM), primary prevention ICD implantation for left ventricular ejection fraction (LVEF) ≤ 35%, in the absence of other risk factors, is not clearly supported by published data.

10. In patients with indications for implantation of a CIED, shared decision-making and patient/family-centered care are endorsed and emphasized. Treatment decisions are based on the best available evidence and patient’s preferences.

**Permanent pacemakers**

**Introduction**

The most common indications for permanent pacemaker implantation in children, adolescents, and patients with CHD are 1) symptomatic sinus bradycardia, 2) advanced second- or third-degree AV block, and 3) pacing for the prevention or termination of tachyarrhythmias. Many indications for pacemaker implantation in adolescents are similar to those in adults. However, in infants and young children, there are important differences. For example, criteria for normal heart rates are an age-dependent variable; whereas a heart rate of 45 bpm is normal in an adolescent, the same rate in a newborn or infant indicates profound bradycardia. In addition, young patients with impaired ventricular function or abnormal physiology may be symptomatic due to sinus bradycardia or loss of AV synchrony at heart rates that do not produce symptoms in individuals with normal cardiovascular physiology. Hence, the indications for pacemaker implantation in young patients need to be based on the correlation of symptoms with relative bradycardia rather than absolute heart rate criteria.

Significant technical challenges may complicate device and lead implantation in small patients or those with abnormalities of venous or intracardiac anatomy. Epicardial lead placement and innovative use of device technology may be needed to provide pacing or defibrillation in young patients. Furthermore, as device leads may need to be utilized for multiple decades, consideration of the potential consequences from lead failure plays a major role in implantation of pediatric devices.

### Isolated sinus node dysfunction

| COR | Recommendations | LOE | References |
|-----|----------------|-----|------------|
| I   | Permanent atrial or dual-chamber pacemaker implantation is indicated for SND when there is correlation of symptoms with age-inappropriate bradycardia. | C-EO |  |
| IIa | Permanent pacemaker implantation (with rate-responsive programming) is reasonable in patients with symptoms temporally associated with observed chronotropic incompetence. | C-LD | 19 |
| III No Benefit | Permanent pacemaker implantation is not indicated in patients with asymptomatic SND. | C-E0 |  |
| III Harm | Permanent pacemaker implantation is not indicated in patients with symptomatic SND due to a reversible cause. | C-E0 |  |

**Recommendation-specific supportive text**

Sinus node dysfunction (SND) refers to physiologically inappropriate atrial rates, either due to sustained bradycardia or abrupt pauses in the intrinsic cardiac rhythm. In patients with isolated sinus bradycardia without symptoms due to cerebral or systemic hypoperfusion, there is no minimum heart rate or maximum pause duration where permanent pacing is recommended. Establishing a temporal correlation between symptoms and age-related bradycardia is of paramount importance when determining whether permanent pacing is needed. In symptomatic patients with SND, atrial-based pacing is generally recommended over single chamber ventricular pacing.
Isolated congenital complete atrioventricular block

**Recommendations**

| COR | Isolated Congenital Complete Atrioventricular Block | LOE | References |
|-----|-----------------------------------------------------|-----|------------|
| I   | Permanent pacemaker implantation is indicated for patients with CCAVB with symptomatic bradycardia. | B-NR | 12,13 |
| I   | Permanent pacemaker implantation is indicated for patients with CCAVB with a wide QRS escape rhythm, complex ventricular ectopy, or ventricular dysfunction. | B-NR | 2,12 |
| I   | Permanent pacemaker implantation is indicated for CCAVB in asymptomatic neonates or infants when the mean ventricular rate is ≤50 bpm. Ventricular rate alone should not be used as implant criteria, as symptoms due to low cardiac output may occur at faster heart rates. | C-LD | 12,14 |
| IIa | Permanent pacemaker implantation is reasonable for asymptomatic CCAVB beyond the first year of life when the mean ventricular rate is <50 bpm or there are prolonged pauses in ventricular rate. | B-NR | 2,4,15 |
| IIa | Permanent pacemaker implantation is reasonable for CCAVB with left ventricular dilation (z score ≥3) associated with significant mitral insufficiency or systolic dysfunction. | C-LD | 16 |
| IIb | Permanent pacemaker implantation may be considered for CCAVB in asymptomatic adolescents with an acceptable ventricular rate, a narrow QRS complex, and normal ventricular function, based on an individualized consideration of the risk/benefit ratio. | C-LD | 2 |

**Atroventricular block: other considerations**

**Recommendations**

| COR | Atrioventricular Block: Other Considerations | LOE | References |
|-----|---------------------------------------------|-----|------------|
| I   | Permanent pacemaker implantation is indicated in patients with clinically significant ventricular tachycardia (VT) that is pause dependent or associated with severe bradycardia; ICD implantation may be considered as a reasonable alternative. | C-LD | 10 |
| I   | Permanent pacing is indicated in symptomatic patients with idiopathic advanced second- or third-degree AV block not attributable to reversible causes. | C-LD |
| IIa | Permanent pacemaker implantation is reasonable for any degree of AV block that progresses to advanced second- or third-degree with exercise in the absence of reversible causes. | C-LD |
| IIb | Permanent pacemaker implantation may be considered for patients with intermittent advanced second- or third-degree AV block not attributable to reversible causes and associated with minimal symptoms that are otherwise unexplained. | C-LD |
| III | Harm Permanent pacemaker implantation is not indicated for asymptomatic first-degree AV block or asymptomatic second-degree Mobitz type I. | C-LD | 2 |

**Recommendation-specific supportive text**

The average ventricular rate in neonates and infants with isolated CCAVB provides one objective parameter regarding the decision for pacemaker implantation. However, additional factors including birth weight (size), ventricular dysfunction, and other co-morbidities may equally influence the decision. Therefore, an average heart rate of ≤50 bpm is recommended for infant pacemaker implantation when overt symptoms related to low cardiac output are not present. Beyond the first year of life, permanent pacemaker implantation is generally indicated in symptomatic patients. Natural history studies have demonstrated progressive LV dysfunction and mitral insufficiency with cardiovascular mortality in the 4th or 5th decade in CCAVB patients who did not undergo pacemaker implantation.17

**Postoperative atrioventricular block**

**Recommendations**

| COR | Postoperative Atrioventricular Block | LOE | References |
|-----|-------------------------------------|-----|------------|
| I   | Permanent pacemaker implantation is indicated for postoperative advanced second- or third-degree AV block that persists for at least 7–10 days after cardiac surgery. | B-NR | 20,21 |
| I   | Permanent pacemaker implantation is indicated for late-onset advanced second- or third-degree AV block especially when there is a prior history of transient postoperative AV block. | C-LD | 22 |

(Continued)
Postoperative AV block complicates 3–8% of congenital heart surgeries, with 1–3% of patients requiring permanent pacemaker implantation for persistent postoperative AV block. A very poor prognosis has been established for CHD patients with permanent postoperative AV block who do not receive permanent pacemakers. Among patients who regain AV conduction following transient AV block, >85% have recovery of AV conduction by post-operative day 7 and ≥95% AV conduction by postoperative day 10,20,21. Although patients who regain AV conduction have a favorable prognosis, there is a small risk of late-onset complete AV block in transient postoperative AV block patients.22 Permanent pacemaker implantation may be considered for patients with restricted vascular access or evidence of conduction system. Extensive injury to the cardiac conduction system is associated with tachy-brady syndrome and symptoms attributable to pauses due to sudden-onset bradycardia. Patients with CHD often have important structural and functional lesions which influence both the indications for pacing as well as the type of pacing lead(s) utilized. Therefore, pacemaker implantation in these patients is not an isolated procedure. Bradycardia and scar related tachycardias are common following surgery, and in the absence of high-grade AV block, atrial pacing is preferred to avoid pacing-induced ventricular dysfunction. Permanent pacemaker and/or lead implantation may be considered at the time of surgery in patients with restricted vascular access or evidence of conduction disease in heart defects with a known natural progression to advanced heart block. Decisions regarding pacemaker implantation must also consider the complexity of the patient’s anatomy, surgical repair and hemodynamic status.

Conventional heart disease: specific considerations

Recommendations

| COR | Postoperative Atrioventricular Block | LOE | References |
|-----|-----------------------------------|-----|------------|
| IIb | Permanent pacemaker implantation may be considered for unexplained syncope in patients with a history of transient postoperative advanced second- or third-degree AV block. | C-LD | 23,24 |
| IIb | Permanent pacemaker implantation may be considered at <7 postoperative days when advanced second- or third-degree AV block is not expected to resolve due to extensive injury to the cardiac conduction system. | C-EO | |
| IIb | Permanent pacemaker implantation may be considered in select patients with transient postoperative advanced second- or third-degree AV block who are predisposed to progressive conduction abnormalities (see text). | C-EO | |

Recommendations

| COR | Congenital Heart Disease | LOE | References |
|-----|--------------------------|-----|------------|
| I   | Permanent pacemaker implantation is indicated for CCAVB in neonates or infants with complex CHD when bradycardia is associated with hemodynamic compromise or when the mean ventricular rate is <60-70 bpm. | C-LD | 25 |
| IIa | Permanent pacemaker implantation with atrial antitachycardia pacing is reasonable for patients with CHD and recurrent episodes of intra-atrial re-entrant tachycardia when catheter ablation or medication are ineffective or not acceptable treatments. | B-NR | 7,26 |

Recommendations

| COR | Post Cardiac Transplantation | LOE | References |
|-----|-----------------------------|-----|------------|
| I   | Permanent pacing is indicated for persistent symptomatic bradycardia that is not expected to resolve and for other class I indications for permanent pacing. | C-LD | 4,28 |

Recommendation-specific supportive text

Post cardiac transplantation

Recommendations

| COR | Congenital Heart Disease | LOE | References |
|-----|--------------------------|-----|------------|
| IIa | Permanent atrial or dual-chamber pacemaker implantation is reasonable for patients with CHD and impaired hemodynamics due to sinus bradycardia or loss of AV synchrony. | C-LD | 7 |
| IIa | Permanent atrial or dual-chamber pacing is reasonable for patients with tachy-brady syndrome and symptoms attributable to pauses due to sudden-onset bradycardia. | C-LD | |
| IIa | Permanent pacemaker implantation is reasonable for sinus or junctional bradycardia with complex CHD when the mean awake resting heart rate is <40 bpm or when there are prolonged pauses in the ventricular rate. | C-EO | |
| IIb | Permanent pacemaker implantation is reasonable for sinus or junctional bradycardia with simple or moderate CHD when the mean awake resting heart rate is <40 bpm or when there are prolonged pauses in the ventricular rate. | C-EO | |
| III | Endocardial leads should be avoided in patients with CHD and intracardiac shunt except in select cases, for whom there should be an individualized consideration of the risk/benefit ratio. In these exceptional cases anticoagulation is mandatory, but thromboembolism remains a risk. | B-NR | 27 |

Recommendation-specific supportive text

Patients with CHD often have important structural and functional lesions which influence both the indications for pacing as well as the type of pacing lead(s) utilized. Therefore, pacemaker implantation in these patients is not an isolated procedure. Bradycardia and scar related tachycardias are common following surgery, and in the absence of high-grade AV block, atrial pacing is preferred to avoid pacing-induced ventricular dysfunction. Permanent pacemaker and/or lead implantation may be considered at the time of surgery in patients with restricted vascular access or evidence of conduction disease in heart defects with a known natural progression to advanced heart block. Decisions regarding pacemaker implantation must also consider the complexity of the patient’s anatomy, surgical repair and hemodynamic status.
Recommendation-specific supportive text

Transient sinus bradycardia is common immediately after transplantation and typically resolves. In rare cases, symptomatic sinus bradycardia may persist, with at least one week allowed for recovery of sinus node function. Analysis of the United Network Organ Sharing database reported that 1% of heart transplant patients <18 years of age required a pacemaker in the acute post-transplant interval. Factors associated with need for pacing were bi-atrial anastomosis, older donor age and antiarrhythmic use.

Late onset conduction disorders (sinus node or AV node dysfunction) may be related to cardiac allograft vasculopathy or allograft rejection. Patients should be evaluated for the presence of transplant coronary artery disease, as late onset bradycardia may be the first manifestation. The role of prophylactic ICD implantation is not well established but may be considered in patients who require pacemakers.

Neuromuscular diseases and other progressive cardiac conduction diseases

| Recommendations | Neuromuscular Diseases and Other Progressive Cardiac Conduction Diseases | LOE | References |
|-----------------|------------------------------------------------------------------------|-----|------------|
| Ia | Permanent pacemaker implantation is indicated in patients with neuromuscular diseases with symptomatic bradycardia due to SND or any degree of AV block. | B-NR | 2,20 |
| I  | Permanent pacemaker implantation is indicated in Kearns-Sayre syndrome for any degree of AV block (including first-degree AV block) and/or conduction abnormality because of unpredictable progression of conduction disease. | C-LD | 31 |
| I  | Permanent pacemaker implantation is reasonable in patients with myotonic dystrophy type 1 for marked first-degree AV block (PR interval >240 ms) or intraventricular conduction delay (native QRS duration >120 ms). Additional defibrillator capability may be considered. | B-NR | 32 |

Conditions include Duchenne muscular dystrophy, Becker muscular dystrophy, myotonic dystrophy type 1, Friedreich ataxia, Emery-Dreifuss muscular dystrophies with a PR interval >240 ms and/or left bundle branch block. Additional defibrillator capability may be considered.

Progressive cardiac conduction diseases are genetic disorders with deterioration of the conduction system either in isolation or in conjunction with other diseases such as neuromuscular and mitochondrial diseases. Variable degrees of conduction abnormalities may occur, from first-degree AV block to complete AV block with an unpredictable progression. Laminopathies caused by mutations in the LMNA gene is a wide spectrum disorder with cardiac conduction abnormalities often observed before the onset of heart failure symptoms. Among the mitochondrial diseases, Kearns-Sayre syndrome, with progressive ophthalmoplegia and myopathy, has a high risk for AV block and sudden cardiac death (SCD).

Currently, an HRS expert consensus statement on the evaluation and management of arrhythmic risk in neuromuscular disorders is under development. Therefore, the above recommendations may be subject to modification as newer data become available.

Neurocardiogenic syncope

| Recommendations | Neurocardiogenic Syncope | LOE | References |
|-----------------|--------------------------|-----|------------|
| Ila | Permanent pacemaker implantation is reasonable with severe recurrent breath-holding spells with documentation of cardioinhibitory response on ECG monitoring and complicated by prolonged syncope, prolonged postanoxic convulsions, and other bradycardia-induced symptoms. | B-NR | 34,35 |
Recommendation-Specific Supportive text

In the vast majority of cases, neurocardiogenic syncope is a limited disease and pacemaker implantation is not required. However, in some patients, recurrent syncopal events may significantly impair quality of life and may result in traumatic injury, particularly when the dominant feature of reflex syncope is cardioinhibitory. Therefore, in a highly select group of patients who fail more conservative treatment options, pacemaker therapy may be useful by preventing profound bradycardia or prolonged asystole.36 Because the efficacy of pacing depends on the clinical setting, a clear relationship between symptoms and bradycardia or asystole should be established prior to pacemaker implantation.36,37

Cardiac channelopathies

Recommendation-Specific Supportive text

The utility of pacing as adjunctive therapy in the various channelopathies is not well defined. In patients with bradyarrhythmia-related or pause-related initiation of ventricular tachyarrhythmias, permanent pacemaker implantation may provide benefit. Also, pacing has been reported to improve outcomes in infants with prolonged QT-related functional 2:1 AV block.40 Limited data also suggest that atrial pacing faster than the intrinsic rate may decrease the arrhythmia burden or symptoms due to bradycardia.41

Inflammation/infection

Recommendation-Specific Supportive text

Permanent pacing is indicated in patients with high-grade or symptomatic AV block attributable to a known potentially reversible cause when AV block does not resolve despite treatment of the underlying cause.41 Pacemaker implantation is reasonable in Chagas disease and advanced second- or third-degree AV block, as spontaneous resolution is unlikely. ICD implantation may be a reasonable alternative.41 Permanent pacing should not be performed in patients who had acute AV block attributable to a known reversible cause, when there is recovery of normal AV conduction.41
Recommendation-specific supportive text
Systemic infections may cause myocardial inflammation or infiltration presenting with bradycardia or complete AV block. In most cases, there is recovery of AV conduction. However, in chronic Chagas disease, advanced heart block in Chagas is permanent and pacemaker implantation is indicated. Limited data suggest that children who develop AV block due to coronavirus 2019 (COVID-19)–related multisystem inflammatory syndrome will have recovery of normal AV conduction.

Implantable cardioverter defibrillators
Introduction
The following recommendations for ICD implantation are primarily based on contemporary adult guidelines, and with some modifications, applied to younger patients. Adult ICD guidelines have been established based on a specific diagnosis or presumed risk factor for a sudden cardiac event, such as ischemia, cardiomyopathy, or genetic cardiovascular disease. In contrast, studies of pediatric sudden cardiac arrest (SCA) survivors demonstrate that in approximately 50% of cases, the cause of the event remains undefined despite an extensive systematic evaluation.

Furthermore, in young patients with diagnoses such as catecholaminergic polymorphic ventricular tachycardia (CPVT) or Brugada syndrome (BrS), SCA is often the initial presentation of the disease. Therefore, while development of pediatric ICD recommendations based on specific cardiovascular diagnoses would be preferable, the following recommendations for ICD implantation will begin with general considerations for young patients, followed by more nuanced recommendations for ICD implantation when a specific cause or a defined risk factor for SCA has been identified. There remain extensive “gaps” in current ICD recommendations, irrespective of age, for many of the diseases associated with SCD in pediatrics. The recommendations that follow are largely based on limited clinical data or expert opinion and consensus and require the application of case-specific clinical judgment and a shared decision approach.

General recommendations for implantable cardioverter defibrillator therapy

| COR | Recommendations | LOE | References |
|-----|----------------|-----|------------|
| I   | ICD implantation is indicated for survivors of SCA due to VT/ventricular fibrillation (VF) if completely reversible causes have been excluded and an ICD is considered to be more beneficial than alternative treatments that may significantly reduce the risk of SCA. | B-NR | 4,45,46 |
| IIb | ICD implantation may be considered for patients with sustained VT that cannot be adequately controlled with medication and/or catheter ablation. | C-EO | |

ICD indications for cardiac channelopathies

Long QT syndrome

| COR | Recommendations | LOE | References |
|-----|----------------|-----|------------|
| I   | ICD implantation along with the use of beta-blockade is indicated for patients with a diagnosis of LQTS who are survivors of SCA. In select LQTS patients, medical therapy and/or cardiac sympathetic denervation may be considered as an alternative. | B-NR | 55,56 |

(Continued)
Both phenotypic and genotypic characteristics are used to guide risk stratification when patients with LQTS may require ICD therapy. Phenotypic risk factors include the onset of symptoms at age <10 years, patients with prior SCA or with recurrent syncope. Additional high-risk factors include a QTc ≥ 550 ms regardless of genotype, QTc ≥ 500 ms with LQT1, females with LQT2 and males with LQT3 genotype. Non-selective beta blockers are considered first line therapy and can significantly decrease subsequent cardiac events in patients, especially in those with KCNQ1 mutations. In addition, beta-blockers and cardiac sympathetic denervation without ICD may be appropriate in carefully selected patients. Conversely, ICD implantation in an asymptomatic low-risk patient with LQTS for a positive family history of LQTS related SCD is not clearly supported by published data and requires case-specific decision making.

Catecholaminergic polymorphic ventricular tachycardia

**Recommendation-specific supportive text**

SCA/SCD is reported in 3 to 13% of CPVT patients. High-risk factors include male gender, previous history of cardiac arrest, multiple genetic variants, and younger age at diagnosis. Complex ventricular ectopy on exercise testing despite optimal medical therapy is also associated with worse outcome. Treatment with nonselective beta blockers is associated with a significant reduction in adverse cardiac events, while the addition of flecainide to refractory patients may provide further benefit. In general, ICD implantation should be reserved for CPVT patients with prior SCA or with refractory ventricular arrhythmias on combination medical therapy. Inappropriate shocks are reported in 20–30% of CPVT patients with ICDs with cardiac sympathetic denervation recommended in patients who experience recurrent ICD shocks. In selected patients with aborted SCA as the initial presentation of CPVT, pharmacologic therapy and/or cardiac sympathetic denervation without ICD may be considered as an alternative.

**Brugada syndrome**

| COR | Recommendations | Long QT Syndrome | LOE | References |
|-----|-----------------|------------------|-----|------------|
| IIb | ICD implantation may be considered in CPVT patients with polymorphic/bidirectional VT despite optimal pharmacologic therapy with or without cardiac sympathetic denervation. | C-LD | 64 |
| III | ICD implantation is not indicated in asymptomatic patients with a diagnosis of CPVT. | C-EO |

**Recommendations**

| COR | Recommendations | Brugada Syndrome | LOE | References |
|-----|-----------------|------------------|-----|------------|
| I   | ICD implantation is indicated in patients with a diagnosis of CPVT who experience cardiac arrest or arrhythmic syncope despite maximally tolerated beta-blocker plus flecainide and/or cardiac sympathetic denervation. | B-NR | 65,66 |
| IIa | ICD implantation is reasonable for patients with BrS with a spontaneous type I Brugada ECG pattern and recent syncope presumed due to ventricular arrhythmias. | B-NR | 67,68 |
| IIb | ICD implantation may be considered in patients with syncope presumed due to ventricular arrhythmias with a type I Brugada ECG pattern only with provocative medications. | C-EO |
| III | ICD implantation is not indicated in asymptomatic BrS patients in the absence of risk factors. | C-EO |
Recommendation-specific supportive text

Although Brugada syndrome presents typically in the 4th to 5th decade, it may have onset during childhood, with rapid progression leading to life-threatening arrhythmias. The ICD remains the only therapy with proven efficacy for the management of ventricular arrhythmias or SCA in patients with Brugada syndrome. Adult recommendations for risk stratification including ventricular stimulation have been established, but have not been validated in pediatrics. Findings associated with high risk of ventricular arrhythmias and SCD in children include in order of relevance: the presence of symptoms (SCD or arrhythmogenic syncope), spontaneous coved type ST elevation (type I electrocardiogram [ECG] pattern), atrial arrhythmias and/or sinus node dysfunction and conduction abnormalities (AV block or intra-ventricular conduction delay). Conversely, implantation of an ICD is not indicated in asymptomatic patients in the absence of risk factors. Further studies are necessary to further characterize risk factors and primary prevention ICD indications for pediatric patients with Brugada syndrome.

ICD indications for cardiomyopathies

Hypertrophic cardiomyopathy

| COR | Recommendations | LOE | References |
|-----|----------------|-----|------------|
| I   | ICD implantation is indicated in patients with HCM who are survivors of SCA or who have spontaneous sustained VT. | B-NR | 45,69 |

IIa For children with HCM who have ≥1 primary risk factors, including unexplained syncope, massive left ventricular hypertrophy, nonsustained VT, or family history of early HCM-related SCD. ICD placement is reasonable after considering the potential complications of long-term ICD placement.

IIb ICD implantation may be considered in patients with HCM without the above risk factors but with secondary risk factors for SCA such extensive LGE on cardiac MRI or systolic dysfunction.

III Harm ICD implantation is not indicated in patients with an identified HCM genotype in the absence of known pediatric SCA risk factors.

Arrhythmogenic cardiomyopathies

| Recommendations | LOE | References |
|-----------------|-----|------------|
| I ICD implantation is indicated in patients with ACM who have been resuscitated from SCA or sustained VT that is not hemodynamically tolerated. | B-NR | 45,72 |

IIa ICD implantation is reasonable in patients with ACM with hemodynamically tolerated sustained VT, syncope presumed due to ventricular arrhythmia, or an LVEF ≤35%.

IIb ICD implantation may be considered in patients with inherited ACM associated with increased risk of SCD based on an assessment of additional risk factors.

Nonischemic dilated cardiomyopathy

| Recommendations | LOE | References |
|-----------------|-----|------------|
| I ICD implantation is indicated in patients with NIDCM who either survive SCA or experience sustained VT not due to completely reversible causes. | B-NR | 45,73 |

(Continued)
The annual incidence of SCD in pediatric patients with NIDCM is 1–5%, which is significantly less than in adult NIDCM patients. Although studies have shown ICD survival benefit for secondary prevention in pediatric NIDCM, the low incidence of events has made it difficult to establish risk factors to guide recommendations for primary prevention ICD implantation. However, in contrast to studies of adult patients with NIDCM and LVEF ≤35%, there is no clear evidence that ICDs implanted for primary prevention improve survival for pediatric patients with NIDCM. The phenotype of NIDCM may overlap with other cardiomyopathies resulting in variable risks of SCD. In the Sudden Death in Childhood Cardiomyopathy study, the cumulative incidence of SCD at 15 years was 5% for NIDCM compared to 23% for left ventricular noncompaction (LVNC). Myocardial dysfunction and/or a history of clinically significant arrhythmias were strongly associated with mortality in LVNC. Therefore, factors which influence implantation of a primary prevention ICD include the NIDCM etiology, the cardiomyopathy phenotype, the degree of ventricular dysfunction and the presence of cardiac arrhythmias.

**ICD indications for congenital heart disease**

| COR | Recommendations |
|-----|-----------------|
| IIb | ICD implantation may be considered in patients with NIDCM and syncope or an LVEF ≤35%, despite optimal medical therapy. |
| III | ICD implantation is NOT recommended in patients with medication-refractory advanced heart failure who are not cardiac transplantation or left ventricular assist device candidates. |
| III | ICD therapy is not indicated for patients with advanced heart failure who are urgently listed for cardiac transplantation and will remain in the hospital until transplantation, even if they meet ICD implantation criteria specified in the above recommendations. |

**Recommendation-specific supportive text**

The association between CHD and ventricular arrhythmias is well established. First demonstrated in repaired tetralogy of Fallot, studies have identified risk factors for VT and SCD including residual cardiac defects, abnormal hemodynamics, and scar from prior interventions/surgeries. While correction of residual abnormalities or ablation of arrhythmogenic substrate may improve ventricular function or reduce symptoms, these may be inadequate to prevent subsequent VT or SCA. ICD placement may therefore be appropriate in patients with, or at high risk of, potentially life-threatening arrhythmias. The role of programmed stimulation and presence and degree of ventricular dysfunction as risk factors for SCD in CHD continues to be debated. ICD implantation in patients with CHD must consider anatomy, intracardiac shunts and vascular access. This may require non-standard approaches such as epicardial leads or subcutaneous ICDs.

**Insertable cardiac monitors**

| COR | Recommendations |
|-----|-----------------|
| I | Noninvasive cardiac rhythm monitoring is indicated in all patients prior to placement of an ICM. |
Insertable cardiac monitors (ICMs) are subcutaneous devices which provide long term rhythm surveillance and provide documentation of rhythm during symptomatic events. Long-term monitoring using an ICM is recommended in highly symptomatic cases when non-invasive investigations are inconclusive, due to either infrequent events or the inability to complete a diagnostic protocol. For adults with syncope, ICM provides the most cost-effective method for establishing a diagnosis and are considered the method of choice when arrhythmogenic syncope is suspected but not proven. For bradyarrhythmias, ICM may be useful in both documenting the bradycardia and correlation with clinical symptoms. ICM may also be useful for patients at risk for intermittent AV block in conditions such as Kearns-Sayre syndrome. Finally, ICM may be useful for occult arrhythmia detection in asymptomatic patients with potentially lethal cardiac diseases (primary arrhythmia syndromes, cardiomyopathies) and identify events that warrant need for changes in management.

### CIED lead management

Lead management involves the decisions of whether or not to perform CIED lead extraction and assessment of the potential risks and benefits. Consensus statements regarding lead management and extraction were published in 2009 and updated in 2017. The following recommendations are complementary to the above guidelines with a perspective focused on pediatrics and patients with CHD. Although major complications during lead extraction are relatively rare (3–4%), significant potential for life-threatening events exists. Therefore, lead extraction should only be performed in centers with an institutional commitment to a comprehensive program. This includes facilities, equipment, personnel, and the ability to manage all complications. A multi-disciplinary team familiar with CHD is vital to maximizing procedural safety and efficacy. There are extensive gaps in knowledge regarding lead management in children and patients with CHD. This includes limited data in the very young and the impact of repeated extractions on vascular integrity and valvular function. There is also absence of data regarding prophylactic lead extractions, as long-term prospective studies on lead abandonment versus extraction in the young do not exist.

| Recommendations for CIED Lead Management* |
|------------------------------------------|
| COR | Thrombosis/Vascular Issues | LOE | References |
| I | Lead removal is recommended for patients with clinically significant thromboembolic events attributable to thrombus on a lead or a lead fragment that cannot be treated by other means. | C-LD | 85,86 |
| I | Lead removal is recommended for patients with superior vena cava stenosis, baffle stenosis, or venous occlusion that prevents implantation of a necessary lead, or when deployment of a stent is planned to avoid entrapment of the lead, or as a part of a comprehensive plan for maintaining patency. | C-LD | 86 |
| IIa | Lead removal can be useful for patients with ipsilateral venous occlusion to allow transvenous access to the heart for required placement of an additional or replacement lead. | C-LD |
| IIa | Lead removal can be useful for patients with an abandoned lead that interferes with the operation of a CIED system. | C-E0 |
| IIb | Lead removal may be considered for patients requiring CIED revision, taking into account the number of leads present, patient age, size, venous capacitance, and potential for vascular occlusion. | C-LD |
| IIb | Lead removal may be considered for isolated upper extremity venous stenosis or thrombosis without symptoms. | C-E0 |

*Continued*
CIED follow-up and ancillary testing

CIED follow-up includes both in-person evaluation (IPE) and remote interrogation and monitoring (RIM) of pacemakers, ICDs and ICMs. The benefits of routine monitoring are well established and include both prolongation of battery life as well as early detection of CIED malfunctions, arrhythmic issues, and adverse events. At present, there are no consensus guidelines for CIED follow up or ancillary testing in the pediatric population. Therefore, the following recommendations are based on Expert Consensus Statements on CIED monitoring90,91 with select pediatric-relevant modifications. Additional recommendations regarding ancillary testing in conjunction with IPE are also included.

| Recommendations for CIED Lead Management* | LOE | References |
|------------------------------------------|-----|------------|
| Infections Issues                        |     |            |
| I Lead removal is indicated for CIED-    | B-NR| 85,86      |
|  associated endocarditis, bacteremia     |     |            |
| with an alternative source (particularly  |     |            |
|  Staphylococcus aureus), or bacteremia    |     |            |
|  that persists or recurs despite         |     |            |
|  antimicrobial therapy.                  |     |            |
| I Pre-lead removal blood cultures and    | B-NR|            |
|  transesophageal echocardiography are     |     |            |
|  recommended for patients with          |     |            |
|  suspected systemic CIED infection to    |     |            |
|  guide antibiotic therapy and assess      |     |            |
|  the potential embolic risk of           |     |            |
|  identified vegetations.                 |     |            |
| I Lead removal may be considered for     | C-LD|            |
|  patients with an isolated superficial    |     |            |
|  CIED pocket infection with serial       |     |            |
|  negative blood cultures and no          |     |            |
|  evidence of endocarditis by              |     |            |
|  transesophageal echocardiography.       |     |            |
| Other Indications                        |     |            |
| I Lead removal is recommended for        | C-EO|            |
|  patients with life-threatening           |     |            |
|  arrhythmias secondary to retained leads.|     |            |
| IIa Device and/or lead removal can be    | C-EO|            |
|  useful for patients with severe chronic |     |            |
|  pain at the device or lead insertion    |     |            |
|  site or believed to be secondary to the |     |            |
|  device, for which there is no           |     |            |
|  acceptable alternative.                 |     |            |
| IIb Lead removal may be considered for   | C-LD|            |
|  patients with leads that, due to their  |     |            |
|  design or their failure, pose a          |     |            |
|  potential future threat to patients if  |     |            |
|  left in place.                          |     |            |
| Epicardial Leads                         |     |            |
| I Epicardial lead removal is             | C-LD| 89         |
|  recommended for patients where the lead |     |            |
|  is shown to be associated with           |     |            |
|  coronary artery compression and         |     |            |
|  evidence of myocardial injury.          |     |            |
| I Complete removal of epicardial lead(s) | C-EO|            |
|  and patches is recommended for all     |     |            |
|  patients with confirmed infection       |     |            |
|  surrounding the intrathoracic portion of |     |            |
|  the lead.                               |     |            |
| IIa Epicardial lead removal may be       | C-EO|            |
|  considered for patients with leads that|     |            |
|  are thought to be at risk for causing    |     |            |
|  coronary artery compression, valve      |     |            |
|  impingement, or cardiac strangulation.  |     |            |
| IIb Epicardial lead removal may be       | C-EO|            |
|  considered at the time of epicardial    |     |            |
|  lead replacement in the presence of a    |     |            |
|  damaged or nonfunctional lead, taking    |     |            |
|  into account the procedural risk and    |     |            |
|  benefit.                               |     |            |

*Recommendations based on adult lead management guidelines.85,86

CIED Ancillary Testing Recommendations

| Recommendations for CIED Follow-up Recommendations | LOE | References |
|----------------------------------------------------|-----|------------|
| I In-person evaluation (IPE) and the establishment | C-EO|            |
|  of remote interrogation and monitoring (RIM)       |     |            |
|  are recommended within 2–4 weeks post CIED        |     |            |
|  implantation.                                      |     |            |
| I At least one annual IPE of all CIEDs is          | C-EO|            |
|  recommended.                                      |     |            |
| I RIM is recommended for all patients with a       | C-EO|            |
|  CIED that has been recalled or has an advisory to  |     |            |
|  enable early detection of actionable events and    |     |            |
|  confirm proper device function.                    |     |            |
| I RIM of CIEDs is recommended every 3–12 months    | C-EO|            |
|  for pacemakers and 3–6 months for ICDs. Frequency |     |            |
|  should be increased (every 1–3 months) for        |     |            |
|  CIEDs approaching elective replacement indicators. |     |            |
| I It is recommended that allied health care         | C-EO|            |
|  professionals possess International Board of      |     |            |
|  Heart Rhythm Examiners certification or equivalent |     |            |
|  experience if they provide RIM and are involved in |     |            |
|  patient management decisions.                     |     |            |

(Continued)
CIEDs and magnetic resonance imaging

| COR | Recommendations | LOE | References |
|-----|----------------|----|------------|
| I   | MRI in all patients with conditional or nonconditional CIEDs should be performed in the context of a defined institutional protocol. | C-LD | 94 |
| IIa | MRI is reasonable in patients with nonconditional transvenous CIEDs if there are no fractured, epicardial, or abandoned leads. | B-NR | 94 |
| IIb | MRI may be considered in patients with epicardial or abandoned leads based on an individualized consideration of the risk/benefit ratio. | C-LD | 95,96 |

The 2017 MRI and Radiation Exposure in Patients with CIEDs Consensus Statement provides comprehensive recommendations for individuals with both conditional (Food and Drug Administration approved) and non-conditional transvenous devices. However, this document does not make specific recommendations for patients with either abandoned or epicardial CIED leads. For patients with epicardial CIED leads, as there are no MRI conditional epicardial leads, the system is considered non-conditional, even when used with a conditional device. Regarding abandoned leads, in vitro data suggest that epicardial leads generate more heat than transvenous leads; however, small studies of MRIs in patients with both epicardial and transvenous abandoned leads suggest that it can be done safely in the majority of cases. In summary, the data on MRI use in epicardial or abandoned leads are inadequate to provide specific recommendations or absolute contraindications. Acknowledging the sparsity of data, but also the importance of MRI, consideration of the risk/benefit ratio of MRI must be made on a “case by case basis.”

CIEDs and sports participation

| COR | Recommendations | LOE | References |
|-----|----------------|----|------------|
| I   | For patients with CIEDs, decisions regarding participation in sports or exercise are primarily based on considerations of the patient’s diagnosis and physiology rather than the presence of the device. | C-EO |  |

Shared decision-making

| COR | Recommendation | LOE | References |
|-----|----------------|----|------------|
| I   | Shared decision-making between the patient, their family, the provider, and other stakeholders is recommended prior to making care plans. This includes discussion of risks, benefits, alternatives, and expected outcomes for patients requiring CIEDs for their pre- and post-implant care. | B-NR | 2 |

Recommendation specific supportive text

The use of shared decision-making should occur prior to all CIED implantation procedures. Clinicians must estimate and clearly describe the potential benefits and risks for the patient and their family. Some decisions will be relatively straightforward; for example, the decision to implant a permanent pacemaker to treat postoperative surgical complete heart block in a patient who is...
pacemaker dependent will be largely uncontestable. However, other treatment decisions, such as implantation of an ICD for primary prevention of SCD, are more complex and nuanced and include choice of ICD system, device location, and personalized estimation of risk of life-threatening arrhythmia for the particular patient over time.

Knowledge gaps and future research

Critical knowledge gaps exist in several areas. One example is the use of ICDs for the primary prevention of SCD. With reduction in device size and the development of novel lead configurations for implantation in smaller patients, the accurate identification of patients at increased risk remains perplexing. Several other important knowledge gaps include but are not limited to the optimal timing of pacemaker implantation after postoperative AV block, contemporary outcomes of patients with isolated CCAVB who do not undergo pacing, risk factors for pacemaker-induced cardiomyopathy, optimal age and body size for transvenous lead implantation, and safety of MRI with abandoned or epicardial leads.

With continuing technological innovations, future research is needed to develop pediatric-specific criteria for application of these new technologies. These include subcutaneous ICDs, leadless pacemakers, and conduction system pacing. Multicenter prospective registries as well as high-quality retrospective data are necessary to provide real-world evidence for new and existing CIED technologies. Future research should be conducted in collaboration with PACES, other relevant scientific societies, the U.S. Food and Drug Administration, and industry partners for development of pediatric “appropriate” CIEDs and device algorithms to specifically benefit young patients and improve their long-term outcomes.

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## Appendix 1. Author relationships with industry

| Writing Group Member | Employment | Honoraria/ Speaking/ Consulting | Speakers’ Bureau | Research* | Fellowship Support* | Ownership/ Partnership/ Principal/ Majority Stockholder | Stock or Stock Options | Intellectual property/ Royalties | Other |
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| Mitchell I. Cohen | Inova Children’s Hospital | None | None | None | None | None | None | None | None |
| Aarti S. Dalal | Washington University in St. Louis, St. Louis Children’s Hospital | None | None | None | None | None | None | None | None |
| Brynn E. Dechert | University of Michigan, C.S. Mott Children’s Hospital | None | None | None | None | None | None | None | None |
| Anne Foster | Advocate Children’s Heart Institute | None | None | None | None | None | None | None | None |
| Roman Gebauer | Heart Centre Leipzig, University of Leipzig, Germany | None | None | None | None | None | None | None | None |
| M. Cecilia Gonzalez Corcia | Bristol Royal Hospital for Children | None | None | None | None | None | None | None | None |
| Prince J. Kannankeril | Vanderbilt University Medical Center | None | None | None | NIH grants | None | None | None | None |
| Writing Group Member | Employment                                                                 | Honoraria/Consulting | Speakers’ Bureau | Research* | Fellowship Support* | Ownership/Partnership | Stock or Stock Options | Intellectual property/ Royalties | Other |
|----------------------|----------------------------------------------------------------------------|----------------------|------------------|-----------|---------------------|-----------------------|------------------------|-----------------------------------|-------|
| Peter P. Karpawich   | The Children’s Hospital of Michigan, University Pediatricians PC          | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Jeffery J. Kim       | Baylor College of Medicine, Texas Children’s Hospital                    | None                 | None             | Cancer Prevention and Research Institute of Texas Grant | None                | None                  | None                    | None                              | None  |
| Mani Ram Krishna     | Amrita Institute of Medical Sciences                                      | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Peter Kubuš          | Children’s Heart Center, Charles University in Prague and Motol University Hospital | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Martin J. LaPage     | University of Michigan, C.S. Mott Children’s Hospital                    | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Douglas Y. Mah       | Harvard University, Boston Children’s Hospital                            | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Lindsey Malloy-Walton| Children’s Mercy Hospital                                                  | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Aya Miyazaki         | Mt. Fuji Shizuoka Children’s Hospital                                     | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Kara S. Motonaga     | Stanford University, Lucile Packard Children’s Hospital                  | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Mary C. Niu          | University of Utah Health Sciences Center/Primary Children’s Hospital    | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Melissa Olen         | Nicklaus Children’s Hospital                                              | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Thomas Paul          | Georg-August-University Medical Center                                    | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Eric Rosenthal       | Evelina London Children’s Hospital, Guy’s & St Thomas’ NHS Trust, St Thomas’ Hospital | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Elizabeth V. Saarel   | St. Luke’s Health System                                                  | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Massimo Stefano Silvetti | Bambino Gesu Children’s Hospital IRCCS                                   | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
| Elizabeth A. Stephenson | The Hospital for Sick Children                                           | None                 | None             | None      | None                | None                  | None                    | None                              | None  |
### Appendix 2. Reviewer relationships with industry

| Peer Reviewer       | Representation | Employment                                      | Honoraria/Speaking/Consulting | Speakers’ Bureau | Research* | Fellowship Support* | Ownership/Partnership/Principal/Majority Stockholder | Stock or Stock Options | Intellectual property/Royalties | Other |
|---------------------|----------------|-------------------------------------------------|-------------------------------|------------------|-----------|--------------------|-----------------------------------------------------|------------------------|-------------------------------|-------|
| Philip M. Chang     | ACC            | University of Florida Health/Shands Children’s Hospital | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| Fabrizio Drago      | AEPC           | Bambino Gesù Children’s Hospital IRCCS           | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| Anne M. Dubin       | PACES          | Stanford University, Lucile Packard Children’s Hospital | None                          | None             | None      | None               | None                                                | None                   | Uptodate royalties: 1          | None  |
| Susan P. Etheridge  | AHA            | University of Utah Health Sciences Center/Primary Children’s Hospital | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| Apichai Kongpattanaayothin | APHRS         | Bangkok General Hospital                         | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| Jose M. Moltedo     | LAHRS          | Sanatorio Finochietto                            | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| Ashish A. Nabar     | IHRS           | Lilavati Hospital, Jupiter Hospital              | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |
| George F. Van Hare  | HRS            | Washington University in St. Louis, St. Louis Children’s Hospital | None                          | None             | None      | None               | None                                                | None                   | None                          | None  |

Number value: 0 = $0; 1 = ≤ $10,000; 2 = > $10,000 to ≤ $25,000; 3 = > $25,000 to ≤ $50,000; 4 = > $50,000 to ≤ $100,000; 5 = > $100,000.

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