

# Cardiac rhythm devices in the pediatric population: Utilization and complications

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**BACKGROUND** Cardiac rhythm devices are important in the management of pediatric patients with rhythm abnormalities, although factors driving utilization are poorly understood.

**OBJECTIVE** This study sought to evaluate utilization trends, complication rates, and cost associated with device implantation in the pediatric population.

**METHODS** Device implantation was analyzed using the Kids' Inpatient Database from 1997 to 2006. The type of device implantation, patient demographics, hospital characteristics, acute in-hospital complications, cost, and length of stay (LOS) were analyzed.  $\chi^2$  tests were used to test association between categorical variables, and logistic regression analysis was performed to evaluate risk factors associated with complications.

**RESULTS** There were 5788 hospitalizations with device implantations. Although there was a significant increase in defibrillator implantation, there was no significant increase in the number of pacemaker implantations over this time period. Patient- and device-related complications were relatively common in all device cohorts (pacemaker 11.2%, 7.2%; defibrillator 5.9%, 11.5%; and biventricular device 19.4%, 26.7%). Type of complication was

dependent on device type. Increased risk of complication was evident in the pacemaker cohort, patients with congenital heart disease, cardiomyopathy, previous cardiac arrest, and other heart operations. Patient-related complications increased cost and LOS regardless of patient or procedural characteristics. Device implantation in patients <5 years old was associated with increased LOS and cost but was not associated with increased risk of complication.

**CONCLUSION** Device utilization in pediatrics is increasing due to escalating defibrillator implantation and biventricular pacing. Cost and LOS are significantly increased by patient complications. Reduction in these complications would improve patient care and lower medical costs.

**KEYWORDS** Pediatric; Electrophysiology; Cardiology; Pacemaker; Defibrillator; Complications; United States

**ABBREVIATIONS** BiV = biventricular pacing; CHD = congenital heart disease; CI = confidence interval; ICD = implantable cardioverter-defibrillator; LOS = length of stay; OR = odds ratio

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## Introduction

During the past 3 decades, implanted cardiac pacing and defibrillation devices have become mainstays in the treatment of pediatric patients with acquired and congenital heart disease (CHD). Specifically, patients with congenital complete heart block, those who have undergone Fontan or Senning/Mustard palliations, repair of tetralogy of Fallot, and patients with cardiac ion channel abnormalities and cardiomyopathies that carry an associated risk of sudden death contribute to the current demand for permanently implanted pacemakers and defibrillators.<sup>1–4</sup>

In addition to chronic pacing in patients with heart block, continually advancing technologies such as biventricular pacing (BiV) and miniaturization of implantable

cardioverter-defibrillators (ICD) have also impacted the landscape of pediatric device utilization.<sup>5</sup> Together with evolving device implant indications, improvements in device technology are likely to increase device demand in the pediatric population. Recently, Burns et al documented an increase in defibrillator utilization in pediatric patients; however, utilization and associated complications involved with pacing and biventricular systems were not evaluated.<sup>5</sup>

The increasing demand for cardiac pacing devices is associated with complications due to acute surgical implantation and postimplantation complications in younger individuals as well as increased cost and length of stay (LOS).<sup>6,7</sup> Although implant strategies continue to improve, pediatric device implantation remains an evolving field and continues to utilize equipment designed for adult populations. Whether these implant strategies impact hospital cost or LOS has not been evaluated.

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The ability to evaluate trends in the use of pediatric pacing devices faces a challenge similar to that limiting study in other fields of pediatric cardiology, namely the lack of patient cohort size. The Kids' Inpatient Database (KID) is a large national database designed to evaluate hospital outcomes and resource utilization of pediatric patients in the United States. The purpose of this study was to evaluate utilization trends and complications associated with pacemaker, defibrillator, and biventricular device implantation in the pediatric population. Additionally, we expand the recent literature by studying pacemakers and BiVs as well as defibrillators, and importantly, identify risk factors associated with acute complications and associated effects on hospital costs and LOS.

## Methods

### Study design and study period

A retrospective, observational analysis was performed at 4 annual time points over a 10-year period from 1997 to 2006 to study the use of implanted cardiac pacing devices in pediatric hospitalizations and to analyze acute complications and costs associated with device implantation. This study was performed in accordance with the institutional review board at Cincinnati Children's Hospital Medical Center. (IRB# 2010-0589).

### Data source

The 1997, 2000, 2003, and 2006 KID data were used to examine trends in implantation of cardiac pacing device-related pediatric hospitalizations. The KID, developed by the Healthcare Cost and Utilization Project (HCUP), which was sponsored by the Agency for Healthcare Research and Quality (AHRQ), was designed to analyze inpatient visits by children, age 20 years or less, in the United States. The KID includes a sample of discharges of children, extracted from over 2,500 hospitals. The hospitals were community-based nonrehabilitation hospitals and included stand-alone pediatric centers. Due to its large sample size, the KID is ideal for analyzing rare conditions, procedures, and subpopulations that cannot be studied at a single institution. The KID contains discharge weights or multipliers that, when multiplied for each visit, produce national estimates. The unit of analysis is the hospital visit.

### Visit selection

Visits during which cardiac pacing devices were implanted were identified in patients 20 years old or younger. All diseases were identified using primary and secondary International Classification of Diseases (ICD-9) procedure codes. This study evaluated new implantation-related hospitalizations in patients with pacemakers, biventricular pacing systems, and defibrillator systems. ICD-9 codes identified for device procedures were as follows: new implantation of a nonbiventricular pacemaker (37.80, 37.81, 37.82, and 37.83), new implantation of an ICD (37.94, 37.95, and 00.51), and new implantation of a biventricular pacemaker/defibrillator (00.50). There were no BiV-related hospitalizations in 1997 or 2000. Because of the small

number of BiV-related hospitalizations in 2003 and 2006, these frequencies were collapsed and not reported by year.

## Covariate description

### Patient and hospital characteristics

Patient-related variables were gender, age, comorbidities, and payer type. Age was categorized into 4 groups: 0 to <5 years; 5 to <12 years; 12 to <18 years, and 18 to 20 years. Because data on race were missing for a significant portion of records in the dataset, race was not used in the analysis. Comorbidities were categorized into 7 categories: CHD, cardiomyopathy, cardiac dysrhythmia, cardiac arrest, channelopathy, heart block, and other heart operations (refer to Appendix for ICD-9 codes). Patients identified as having cardiac arrest experienced a life-threatening event as a reason for hospitalization prior to device implantation. A patient could have more than 1 comorbidity. ICD-9 codes for cardiac ion channel abnormality were new in 2006 and did not exist in the 1997, 2000, and 2003 data years. Payer type was classified as private insurance, government insurance including Medicaid and Medicare, and other, which included self-pay, no charge, and charity.

Hospital-related variables included information such as hospital bed size, teaching versus nonteaching status, National Association of Children's Hospitals and Related Institutions type, location, and region. A small-bed-size hospital is defined as rural with 1 to 49 beds, urban and nonteaching with 1 to 99 beds, or urban and teaching with fewer than 300 beds; a medium-bed-size hospital is defined as rural with 50 to 99 beds, urban and nonteaching with 100 to 199 beds, or urban and teaching with 300 to 499 beds; a large-bed-size hospital is defined as rural with more than 99 beds, urban and nonteaching with more than 199 beds, or urban and teaching with more than 499 beds. National Association of Children's Hospitals and Related Institutions type identified if a hospital was defined as not a children's hospital, a children's general or specialty hospital, or a children's unit in a general hospital. Hospital region was defined as northeast, midwest, south, or west.

### Complications

Complications were categorized as device-related complications and patient-related complications. Device-related complications were defined as mechanical device issues for either a pacemaker or an ICD system and included issues with the system generator, lead body, or lead electrode. Patient-related complications included pneumothorax, pericardial effusion/tamponade, hematoma, endocarditis/pericarditis, surgical wound infection, and death (refer to Appendix for ICD-9 codes). Any complication included the number of patients with 1 or more complications during the hospitalization. All complications were acute, occurring during the same hospitalization as the implant procedure.

### Cost and LOS analysis

The KID database reports charges for each visit. Additionally, AHRQ provides a cost-to-charge multiplier that, when

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