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Characteristics of hospital admissions associated with implantable cardioverter defibrillator placement among adults with congenital heart disease☆

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ABSTRACT

Background: Characteristics of hospitalizations including healthcare utilization for adult patients with congenital heart disease (ACHD) at the time of implantable cardioverter defibrillator (ICD) placement has not been well studied.
Methods: We analyzed data from the 2002–2014 United States National Inpatient Sample (NIS). ICD implantation, CHD, complications, and indications for admissions were determined based on diagnostic codes among adults. Propensity score matching was performed, based on age, sex and in-hospital mortality index with a 10:1 ratio between adults without CHD and those with CHD, to determine relative healthcare utilization attributable to CHD.
Results: ACHD accounted for 136,509 ± 3488 admissions of which 1451 ± 121 admissions (1.1 ± 0.06%) were associated with an ICD placement. ICD placement occurred most frequently among patients with TOF, VSD, and transposition complexes usually in the context of a dysrhythmia. Compared to those without CHD, ACHD patients had higher adjusted total hospital charges ($147,002 ± 5516 vs $132,455 ± 2182; $p < 0.001$), length of stay (6.2 ± 0.5 vs 5.2 ± 0.1 days; $p < 0.001$), lower readmission score (5.5 ± 0.5 vs 9.7 ± 0.1; $p = 0.04$) and a higher complication rate (13.4% vs 8.3%; $p < 0.001$). Dysrhythmias were more frequently the primary diagnosis for admission in the ACHD cohort (63% vs 38%; $p < 0.001$).
Conclusion: Compared to a matched non-CHD population, ACHD patients had greater healthcare utilization and had more frequent complications. The reasons underlying this difference bear investigation to improve care quality.

1. Introduction

There are an estimated 1.4 million adults living in the United States with congenital heart disease (CHD), about 300,000 of whom have severe CHD [1]. This number of adults with CHD (ACHD) has surpassed the size of the pediatric CHD population and continues to increase. ACHD patients face ongoing morbidity and reduced long-term survival [2]. Over the past 15 years, there has been a dramatic rise in the number of hospital admissions and an even more dramatic increase in healthcare utilization during hospitalization in this unique population [3,4].

Sudden cardiac death (SCD) is one of the leading causes of mortality in ACHD and can be potentially prevented by the appropriate use of implantable cardioverter defibrillators [2,5]. However, characteristics of hospitalizations for ACHD patients at the time of ICD placement and the implications of these admissions for healthcare utilization has not been well studied.

We used a national database to study trends in ICD implantation and the associated hospital admission characteristics among ACHD patients. We also performed a matched analysis of these patients with those who did not have CHD, to determine relative healthcare utilization attributable to CHD among adults admitted for ICD implant in the US.

2. Methods

2.1. Data source

We analyzed data from the 2002–2014 National Inpatient Sample (NIS), a subset of the Healthcare Cost and Utilization Project (HCUP)

☆ All the authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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sponsored by the Agency for Healthcare Research and Quality. The NIS is the largest publicly available all-payer inpatient care database in the United States and is a complex stratified sample designed to sample 20% of U.S. community (nonfederal, short-term, general, and specialty) hospitals. A new design was implemented in 2012, changing to a 20% sample of discharges at each hospital. The study was reviewed by the Institutional Review Board of Cincinnati Children's Hospital and was determined that the study does not meet the regulatory criteria for research involving human subjects and ongoing oversight was not required.

2.2. Population

Adults (18 years of age or older) admitted to an acute care hospital with placement of an ICD during hospitalization were identified using the ICD-9 procedure code for implantation of an ICD (37.94). Patients with CHD were identified using corresponding ICD-9 codes (Appendix A). Patients undergoing concomitant cardiac surgery inclusive of heart transplant or ventricular assist device placement were excluded (ICD-9 and CPT codes included in the Appendix A). We also excluded patients with secundum atrial septal defects due to the difficulty in discerning patients with secundum defects from those with a patent foramen ovale.

2.3. Outcomes and variables

The annual number of admissions for ICD placement among ACHD patients along with patient characteristics, underlying CHD and complications (ICD-9 codes included in the Appendix A) were determined. The first diagnosis coded for the admission in this database is referred to as the "primary diagnosis" and was considered the primary reason for hospitalization. In cases where the first diagnosis was a congenital heart diagnosis, the second diagnosis was utilized to determine the primary reason for admission to the hospital. Hospital charges including inflation-adjusted charges (2014 Dollars) associated with the duration of hospitalization for the procedure were then assessed.

2.4. Statistical analysis

Analyses accounted for the complex survey sampling methodology used in the NIS and incorporated sampling weights to provide estimates for the total population of the NIS sampling space. Analyses were conducted with SAS® version 9.4 (SAS Institute Inc., Cary, North Carolina). Differences between ACHD and propensity-matched non-ACHD patients were compared for demographic and clinical variables using the chi-square test for categorical variables and *t*-tests or General Linear Models for continuous variables. Results are presented as estimate ± standard error. Trends in CHD and ICD placement hospitalization during the study period were estimated using logistic regression.

2.5. Propensity score matching

Propensity score matching was performed, based on age, sex and in-hospital mortality index with a 10:1 ratio between adults without CHD and those with CHD respectively, in order to compare the 2 subpopulations, using a sample of the non-ACHD group with a baseline risk similar to those in the ACHD group. Briefly, logistic regression was used, separately for men and women, to create a propensity score for each patient. Then ACHD and non ACHD patients were matched in a ratio of 1 to 10, using a maximum allowable absolute difference of 0.1, between propensity scores. The algorithm which was implemented gave priority to getting the closest possible matches [6]. Analyses of this matched subsample compared the length of stay, hospital charges, in-hospital complications and hospital re-admission index. Both the in-hospital mortality and hospital re-admission indices were created using software developed by an Agency for Healthcare Research and Quality (AHRQ) group to produce updated Elixhauser co-morbidity scores. The Elixhauser co-morbidity score includes 29 binary variables which are available through the HCUP – Elixhauser Comorbidity Software tool (Appendix A). The specific indices are developed by weighing the variables differently to predict in-hospital mortality or 30-day re-admissions. These scores have been validated to assess the risk of in-hospital mortality and readmission when using administrative data [7].

3. Results

3.1. Admission volume and trends

In the years 2002–2014, out of an estimated total 397,468,737 ± 5,598,524 hospital admissions, 680,118 ± 21,917 were associated with ICD placement. Patients with ACHD accounted for an estimated 136,509 ± 3488 admissions of which 1451 ± 121 admissions (1.1 ± 0.06%) were associated with an ICD placement. There was a trend toward decreased frequency of hospital admission associated with ICD placement in the total population over the study period ($p < 0.0001$) without an equivalent trend in those with ACHD ($p = 0.13$) (Fig. 1). On logistic regression analysis, ACHD patients who were hospitalized were more likely to have a hospitalization for an ICD placement compared to the overall population (OR: 6.5, 95% CI: 5.8–7.3).

3.2. Patient and admission characteristics

Tetralogy of Fallot (TOF) and ventricular septal defect (VSD) together accounted for nearly half of lesions in the ACHD group, while transposition complexes, inclusive of both complete transposition of great arteries (TGA) and congenitally corrected transposition of great arteries (CC-TGA), accounted for almost 25% (Supplemental Fig. 1). ACHD patients were predominantly young adults (41.1 ± 1.1 years) and had an average length of stay of 6.1 ± 0.5 days (Table 1). The inflation-adjusted total hospital charges for ACHD patients admitted for ICD implant averaged $147,002 ± 5516 (2014 dollars). The most common primary diagnosis at the time of hospitalization was dysrhythmia, noted in more than half of ACHD patients, among which ventricular tachycardia and ventricular fibrillation accounted for >70% (Fig. 2, Supplemental Fig. 2). The most common complication associated with ICD implant in the ACHD group was hematoma accounting for 3.7% (Table 2).

3.3. Comparison to matched non-CHD cohort

When compared to propensity-matched patients without CHD, ACHD patients had significantly higher adjusted total hospital charges ($147,002 ± 5516 vs $132,455 ± 2182; $p < 0.001$), length of stay (6.2 ± 0.5 vs 5.2 ± 0.1 days vs; $p < 0.001$) and a lower readmission score (5.5 ± 0.5 vs 9.7 ± 0.1; $p = 0.04$) (Table 1) (Appendix A). The total hospital charges were significantly higher in the ACHD cohort even after adjusting for length of stay ($142,253 ± 3977 vs 132,587 ± 1260; adjusted $p = 0.02$). ACHD patients were more likely to have complications associated with ICD implantation compared to non-ACHD patients (13.4% vs 8.3%, $p < 0.001$), specifically mechanical ($p = 0.02$) and infectious ($p = 0.04$) complications (Table 2). Dysrhythmias were more frequently the primary diagnosis for admission in the ACHD cohort (63% vs 38%, $p < 0.001$) while non-ACHD patients were more likely to have a diagnosis of heart failure, cardiomyopathy, and coronary artery disease (Fig. 2). Ventricular arrhythmias were the most frequent type of dysrhythmia in both cohorts ($p = 0.31$) (Supplemental Fig. 2).

4. Discussion

ICD placement associated with a hospital admission in the United States ACHD population between 2002 and 2014 occurred most frequently among patients with TOF, VSD, and transposition complexes

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