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Patient Characteristics, Outcomes and Trends of Hospitalization for Pediatric Cardiac Arrest and their Association with Underlying Heart Disease

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Abstract

Objective: There is limited information on hospitalization and outcomes for pediatric cardiac arrest, specifically among those with underlying heart disease. Hence, we aimed to study a nationally representative inpatient database to study patients who sustained in-hospital cardiac arrest or were hospitalized after an out-of-hospital cardiac arrest (OHCA).

Design: This was a retrospective database review.

Setting: The Kid's Inpatient Database (KID), a nationally representative in-patient database from 1994-2012 was used for this analysis.

Patients: All pediatric patients who were either hospitalized after a cardiac arrest or sustained a cardiac arrest during the admission were included.

Interventions: None. This was a retrospective database review.

Measurements and Main Results: We analyzed a total of 12,931,595 discharge records, of which 12,053 (0.1%) were associated with cardiac arrest. Among those who sustained cardiac arrest, congenital heart disease (CHD) was noted in 2,163 (18%) patients, non-hypertrophic cardiomyopathy (non-HCM) in 413 (3.4%) and hypertrophic cardiomyopathy in 22 (0.2%) patients. On multivariable regression analysis CHD (OR: 4.3, 95% CI: 3.9 - 4.7) and cardiomyopathies (HCM OR: 7.3, 95% CI: 3.2 - 16.5; non-HCM OR: 5.4, 95% CI: 4.3 - 6.7) were strongly associated with cardiac arrest. Among all patients, mortality remains high after cardiac arrest (56.8%) especially after OHCA (79.7%). However, there is a decreasing temporal trend in the mortality of patients with CHD admitted with cardiac arrest ($p < 0.01$).

Conclusion: CHD and cardiomyopathies are significantly associated with cardiac arrest in the pediatric population. However, there is a decreasing trend of mortality following cardiac arrest among those with CHD.

Keywords: *Cardiac Arrest; Congenital Heart Disease; Critical Care; Out of Hospital Cardiac Arrest; Database Research; In Hospital Cardiac Arrest*

Introduction

Cardiac arrest occurs in approximately 16,000 children every year in the United States, with an estimated incidence of 8 - 20 per 100,000 children per year [1]. Out of hospital cardiac arrest (OHCA) has been estimated to occur in 7.3 per 100,000 children per year in the United States [2]. There have been variable reports of in-hospital cardiac arrest (IHCA), with a reported estimate of cardiac arrest occurring in 2 - 6% among those admitted to the pediatric intensive care unit. While the rate of survival of OHCA has been dismal at 6-8%, the survival after IHCA is significantly higher at 27% [3-5]. Although underlying heart disease accounts for approximately 8% of children with OHCA, a significant proportion (30 - 50%) sustaining IHCA have underlying heart disease [6-8]. There are limited large-scale studies

characterizing the heart disease profile, trends, outcome and healthcare utilization among children with underlying heart disease who sustain cardiac arrest. Most of the studies have been limited to IHCA after cardiac surgery or as an investigation of sudden unexplained death [9-13]. There is a paucity of data regarding pediatric OHCA in those with congenital heart disease although such studies could be helpful in assessing the magnitude of the problem, identifying high-risk subgroups, and allocating healthcare resources to target specific high-risk populations.

The Kid's inpatient database (KID), is the largest publicly-available pediatric inpatient care database in the United States, with data from approximately 3 million pediatric discharges every year. KID has been previously used to evaluate cardiopulmonary resuscitation (CPR) among patients with underlying heart disease in one prior study [11]. Analysis of CPR instead of cardiac arrest excludes OHCA and might not include patients with a do-not-resuscitate status. Furthermore, the prior study did not evaluate healthcare utilization or associations with specific congenital heart disease and was limited until the year 2006. Hence, we aimed to identify patients who sustained a cardiac arrest during hospitalization or OHCA from 1994 - 2012 by using an appropriate ICD-9 code (427.5) and further characterize the population based on the presence of underlying heart disease. This methodology has been previously used in the adult population to study both ICHA and OCHA, but has not been previously used to study OHCA in the pediatric population [14,15].

Methods

Institutional review board approval was waived as this study utilizes de-identified data from a national database. Consent was not obtained for this study as the data was derived from a national database. This cross-sectional study is in compliance with the Helsinki declaration.

Kids' inpatient sample

KID, made available through the Healthcare Cost Utilization Project (HCUP) by the Agency for Healthcare Research and Quality (AHRQ) is a large database designed to capture data from community, non-rehabilitation hospital admissions in the United States. Community hospitals are defined differently by the database when compared to the definition used by some healthcare providers. The definition of a community hospital used by the database is as follows: "all non-federal, short-term, general, and other specialty hospitals". Freestanding and non-freestanding children's hospitals are both included, as are teaching and non-teaching hospitals. Discharges of patients less than 20 years of age are included in the database. Rehabilitation and long-term acute care hospitals are excluded from this database. Patients from all regions of the United States with a variety of payer types are captured in this database. Data from a total of 44 states is captured.

Patient identification

Data regarding hospital admissions was obtained from 6 available iterations of the database, spanning from 1994 to 2012. Only patients under 18 years of age were included in this analysis. Patients with cardiac arrest were identified using ICD-9 code 427.5 coded either as the primary or secondary diagnosis. Patients who were coded with the ICD-9 code 427.5 as the primary diagnosis were identified as to have OHCA, a methodology validated in adult studies utilizing the adult corollary database [14,15]. The determination of congenital heart disease, acquired pediatric heart disease and cardiac surgery were made based using respective ICD-9 codes.

Data collection

Demographic information including gender and race were collected for each admission. Admission characteristics such as admission month, length of stay, and cost of stay were collected as well. Information regarding comorbid conditions was also collected.

Statistical analysis

A cross-sectional study was conducted. Continuous variables are reported using median and range deviation while categorical variables are reported using absolute frequency and percentages. Continuous variables were analyzed using a student t-test or Mann-Whitney-U test as appropriate with categorical variables being analyzed using chi-square analysis. Baseline characteristics, cardiac morphology, cardiac surgery, and other comorbidities were compared between those with and without cardiac arrest.

A logistic regression was then to determine factors associated cardiac arrest with cardiac arrest as the dependent variable. Next, logistic regression analysis was conducted to determine risk factors for increased length of hospitalization, cost of hospitalization, need for extracorporeal membrane oxygenation, and inpatient mortality. Cost of stay used represents the total charges recorded for the admission.

These analyses were repeated twice. The first set of analyses was done using a cohort in which cardiac arrest was coded for in any of the diagnosis fields, primary or secondary, while the second set of analyses was done using a cohort in which cardiac arrest was coded for only in the primary diagnosis field, the later indicating OHCA. All statistical analysis was done utilizing SPSS Version 20.0 (Chicago, IL).

Results

Characteristics of admissions with and without cardiac arrest in all patients (Table 1 and 2)

	No cardiac arrest (n= 12,919,542)	Cardiac arrest (n= 12,053)	Odds ratio (95% confidence interval)	p-value
Age (years)	0.1 (0 to 17)	1 (0 to 17)	--	< 0.01
Race			--	< 0.01
White	5,305,159 (50.9)	4,574 (46.6)		
Black	1,782,979 (17.1)	2,064 (21.0)		
Hispanic	2,349.290 (22.5)	2,053 (20.9)		
Asian or Pacific Islander	345,004 (3.3)	357 (3.6)		
Native American	77,951 (0.7)	85 (0.9)		
Other	470,423 (5.5)	679 (6.9)		
Heart failure	40,203 (0.3)	1,057 (8.8)	30.7 (28.8 to 32.8)	< 0.01
Tachyarrhythmia	8,389 (0.1)	839 (7.0)	115.1 (10.6.9 to 123.8)	< 0.01
Atrioventricular block	5,123 (0.1)	68 (0.6)	14.3 (11.2 to 18.1)	< 0.01
Congenital heart disease	359,378 (2.8)	2,163 (17.9)	7.6 (7.2 to 8.0)	< 0.01
Hypertrophic cardiomyopathy	828 (0.1)	22 (0.2)	28.5 (18.6 to 43.5)	< 0.01
Cardiomyopathy other than hypertrophic	12,751 (0.1)	413 (3.4)	35.9 (32.5 to 39.6)	< 0.01
Acute myocarditis	115 (0.1)	*** (***)	46.6 (19.0 to 114.1)	< 0.01
Long QT syndrome	1,739 (0.1)	66 (0.5)	40.8 (31.9 to 52.3)	< 0.01
Length of hospital stay (days)	2.0 (0.0 to 206.0)	6.0 (0.0 to 359.0)	--	< 0.01
Cost of hospitalization (US dollars)	6,472	68,740	--	< 0.01
Need for extracorporeal membrane oxygenation	4,999 (0.1)	789 (6.8)	100.4 (92.9 to 108.4)	< 0.01
Inpatient mortality	81,229 (0.6)	6,841 (56.8)	207.4 (199.9 to 214.2)	< 0.01

Table 1: *Characteristics of admissions with and without cardiac arrest in those with and without congenital heart disease.*
**** Represents an absolute frequency less than 10 which per database policies cannot be explicitly reported.*
Continuous variables reported as median and range.

Factor	Odds ratio and 95% CI, p-value
• Increased age	1.1 (1.1 to 1.1), < 0.01
• Heart failure	4.6 (4.0 to 5.3), < 0.01
• Hypertension	3.1 (2.6 to 3.7), < 0.01
• Arrhythmia	29.4 (25.2 to 34.2), < 0.01
• Atrioventricular block	1.7 (1.1 to 2.6), p= .01
• Acute kidney injury	18.8 (16.8 to 21.2), p< 0.01
• Congenital heart disease	4.3 (3.9 to 4.7), p< 0.01
• Hypertrophic cardiomyopathy	7.3 (3.2 to 16.5), p< 0.01
• Non-hypertrophic cardiomyopathy	5.4 (4.3 to 6.7), p< 0.01
• Long QT syndrome	12.6 (7.3 to 21.8), p< 0.01

Table 2: *Factors associated with increased risk of cardiac arrest after regression analysis.*

Out of a total of 12,931,595 admissions, cardiac arrest was noted in 12,053 admissions (0.1%). Those with cardiac arrest tended to be older with a median age of 1 year compared to 0.1 years in the no cardiac arrest group (p < 0.01). The racial breakdown was also different between the two groups with a higher proportion of African Americans, Asian or Pacific Islanders, and Native Americans in the cardiac arrest group (p < 0.01).

Congenital heart disease was present in 17.9% of those with cardiac arrest compared to 2.8% of those without cardiac arrest (OR 7.6, 95%CI 7.2 to 8.0, p < 0.01). Hypertrophic cardiomyopathy (OR 28.5, 95%CI 18.6 to 43.5, p < 0.01) and non-hypertrophic cardiomyopathy

(OR 35.9, 95%CI 32.5 to 39.6, p < 0.01) were more prevalent in the cardiac arrest group. Acute myocarditis (OR 46.6, 95%CI 19.0 to 114.1) and long QT syndrome (OR 40.8, 95%I 31.8 to 52.3, p < 0.01) were also more prevalent in the cardiac arrest group.

Length of admission was longer in the cardiac arrest group with a median of 6.0 days compared to a median of 2.0 days in the no cardiac arrest group (p < 0.01). Cost of admission was also greater in the cardiac arrest group with a median cost of 68,470 compared to 6,472 (p < 0.01). Need for extracorporeal membrane oxygenation was also more prevalence in the cardiac arrest group (OR 100.4, 95%CI 92.9 to 108.4, p < 0.01). Inpatient mortality was noted in 56.8% of those in the cardiac arrest group compared to 0.6% of those in the no cardiac arrest group (0R 207.4, 95%CI 199.9 to 214.2, p < 0.01).

Regression analysis identified patients with congenital heart disease (OR: 4.3), hypertrophic cardiomyopathy (OR: 7.3, 95% CI: 3.2, 16.5) and non-hypertrophic cardiomyopathy (OR 5.4, 95% CI: 4.3 - 6.7) to be associated with an increased odds of cardiac arrest.

Characteristics of admissions with and without cardiac arrest among patients with underlying heart disease (Table 3 and 4)

	No cardiac arrest (n= 359,314)	Cardiac arrest (n= 2,163)	Odds ratio (95% confidence interval)	p-value
Age (years)	0.1 (0 to 17)	0.15 (0 to 17)	--	< 0.01
Race			--	< 0.01
White	144,555 (48.4)	823 (46.2)		
Black	43,441 (15.2)	312 (17.5)		
Hispanic	75,830 (25.4)	443 (24.9)		
Asian or Pacific Islander	10,940 (3.7)	56 (3.1)		
Native American	2,415 (0.8)	*** (***)		
Other	19,304 (6.5)	138 (7.7)		
Heart failure	23,714 (6.6)	532 (24.6)	4.6 (4.1 to 5.0)	< 0.01
Tachyarrhythmia	2,610 (0.7)	189 (8.7)	13.0 (11.2 to 15.2)	< 0.01
Atrioventricular block	1,761 (0.5)	29 (1.3)	2.7 (1.9 to 3.9)	< 0.01
Cardiac lesion				
Double outlet right ventricle	10,403 (2.9)	211 (9.8)	3.6 (3.1 to 4.1)	< 0.01
Atrioventricular septal defect	16,443 (4.6)	242 (11.2)	2.6 (2.2 to 3.0)	< 0.01
Partial anomalous pulmonary venous connection	2,177 (0.6)	15 (0.7)	1.1 (0.6 to 1.9)	0.61
Total anomalous pulmonary venous connection	3,818 (1.1)	81 (3.7)	3.6 (2.8 to 4.5)	< 0.01
Coronary artery anomaly	3,880 (1.1)	86 (4.0)	3.7 (3.0 to 4.7)	< 0.01
Atrial septal defect	218,204 (60.7)	753 (34.8)	0.3 (0.3 to 0.3)	< 0.01
Tetralogy of Fallot	23,315 (6.5)	257 (11.9)	1.9 (1.7 to 2.2)	< 0.01
Ventricular septal defect	119,287 (33.2)	648 (30.0)	0.8 (0.7 to 0.9)	< 0.01
Pulmonary atresia	5,545 (1.5)	109 (5.0)	3.3 (2.7 to 4.1)	< 0.01
Tricuspid atresia	6,492 (1.8)	86 (4.0)	2.2 (1.8 to 2.7)	< 0.01
Ebstein anomaly	3,197 (0.9)	41 (1.9)	2.1 (1.5 to 2.9)	< 0.01
Hypoplastic left heart syndrome	15,160 (4.2)	401 (18.5)	5.1 (4.6 to 5.7)	< 0.01
Transposition	6,414 (1.8)	93 (4.3)	2.4 (2.0 to 3.0)	< 0.01
Congenitally corrected transposition	1,896 (0.5)	36 (1.7)	3.1 (2.2 to 4.4)	< 0.01
Common arterial trunk	3,409 (0.9)	67 (3.1)	3.3 (2.6 to 4.2)	< 0.01
Cardiac surgery				
Valvuloplasty, no valve replacement	5,619 (2.1)	111 (5.2)	2.5 (2.1 to 3.1)	< 0.01
Valvuloplasty with valve replacement	2,207 (0.8)	51 (2.4)	2.9 (2.2 to 3.9)	< 0.01
Septal defect repair	33,689 (12.5)	393 (18.5)	1.5 (1.4 to 1.7)	< 0.01
Tetralogy of Fallot repair	5,683 (2.1)	82 (3.9)	1.8 (1.4 to 2.3)	< 0.01
Total anomalous pulmonary venous connection repair	2,171 (0.8)	38 (1.8)	2.2 (1.6 to 3.1)	< 0.01
Common arterial trunk repair	783 (0.3)	34 (1.6)	5.5 (3.9 to 7.8)	< 0.01
Arterial switch	2,661 (1.0)	58 (2.7)	2.8 (2.1 to 3.6)	< 0.01
Atrial switch	891 (0.3)	19 (0.8)	2.5 (1.6 to 4.1)	< 0.01
Right ventricle to pulmonary artery conduit	3,065 (1.1)	78 (3.7)	3.3 (2.6 to 4.1)	< 0.01
Blalock-Tausig shunt	46 (0.1)	*** (***)	5.5 (13 to 22.7)	< 0.01
Glenn	4,537 (1.7)	97 (4.6)	2.7 (2.2 to 3.4)	< 0.01
Fontan	3,952 (1.5)	61 (2.9)	1.9 (1.5 to 2.5)	< 0.01
Heart transplant	248 (0.1)	32 (1.5)	16.6 (11.4 to 24.0)	< 0.01
Hypertrophic cardiomyopathy	102 (0.1)	*** (***)	6.5 (2.4 to 17.7)	< 0.01
Non-hypertrophic cardiomyopathy	1,404 (0.4)	69 (3.2)	8.4 (6.5 to 10.7)	< 0.01
Acute myocarditis	*** (***)	*** (***)	83.1 (7.5 to 919.9)	< 0.01
Long QT syndrome	124 (0.1)	*** (***)	5.3 (1.9 to 14.5)	< 0.01
Length of hospital stay (days)	5 (0 to 876)	20 (0 to 351)	--	< 0.01
Cost of hospitalization (US dollars)	28,073	190,369	--	< 0.01
Need for extracorporeal membrane oxygenation	2,074 (0.8)	390 (18.4)	29.0 (25.7 to 32.6)	< 0.01
Inpatient mortality	8,981 (2.5)	946 (43.8)	30.3 (27.8 to 33.1)	< 0.01

Table 3: *Characteristics of admissions with congenital heart disease, with and without cardiac arrest.*
**** Represents an absolute frequency less than 10 which per database policies cannot be explicitly reported.*

Factor	Odds ratio with 95% confidence interval, p-value
• Decreased age	0.9 (0.9 to 0.9), 0.04
• Heart failure	2.1 (1.8 to 2.6), < 0.01
• Tachyarrhythmia	5.3 (3.9 to 7.2), < 0.01)
• Double outlet right ventricle	2.1 (1.6 to 2.7), < 0.01
• Atrioventricular septal defect	1.5 (1.1 to 2.0), < 0.01
• Coronary artery anomaly	1.8 (1.1 to 2.8), < 0.01
• Congenitally corrected transposition	2.9 (1.6 to 5.2), < 0.01
• Pulmonary atresia	1.8 (1.2 to 2.7), < 0.01
• Tricuspid atresia	2.0 (1.3 to 2.9), < 0.01
• Ebstein anomaly	3.0 (1.8 to 4.9), < 0.01
• Hypoplastic left heart syndrome	4.2 (3.3 to 5.4), < 0.01
• Common arterial trunk	2.7 (1.5 to 4.9), < 0.01
• Tetralogy of Fallot	1.8 (1.3to 2.5), < 0.01
• Septal defect repair	1.4 (1.1 to 1.7), < 0.01
• Arterial switch	1.8 (1.1 to 3.2), 0.04
• Acute kidney injury	6.0 (4.7 to 7.7), < 0.01
• Hypertrophic cardiomyopathy	11.3 (3.2 to 40.2), < 0.01
• Non-hypertrophic cardiomyopathy	4.5 (2.8 to 7.2), <0.01
• Myocarditis	130.2 (4.7 to 3557.1), < 0.01
• Long QT syndrome	9.9 (2.2 to 42.9), < 0.01

Table 4: *Factors associated with increased risk of cardiac arrest in those with congenital heart disease.*

A total of 361,541 admissions with congenital heart disease were identified. Of these 2,163 (0.6%) had cardiac arrest. Those in the cardiac arrest group tended to have a greater median age (0.15 years versus 0.1 years, $p < 0.01$). Those in the cardiac arrest group were more likely to be African American.

Atrial septal defect (OR 0.3, 95%CI 0.2 to 0.4, $p < 0.01$) and ventricular septal defect (OR 0.8, 95%CI 0.7 to 0.9, $p < 0.01$) were noted to be less frequent in those with cardiac arrest. The remainder of cardiac lesions were more prevalent in the cardiac arrest group with odds ratios ranging from 1.9 for Tetralogy of Fallot to 5.1 for hypoplastic left heart syndrome.

Median length of admission in those with congenital heart disease was greater in the cardiac arrest group (20 days versus 5 days, $p < 0.01$) as was median cost of admission ($190,369 versus $28,073, $p < 0.01$). Extracorporeal membrane oxygenation was required with greater frequency in those with cardiac arrest (OR 29.0, 95%CI 25.7 to 32.6, $p < 0.01$). The prevalence of inpatient mortality was 43.8% in the cardiac arrest group versus 2.5% in the no cardiac arrest group (OR 30.2, 95%CI 27.8 to 33.1, $p < 0.01$).

Regression analysis demonstrated myocarditis (OR: 130.2, 95% CI: 4.7, 3557, $p < 0.01$), hypertrophic cardiomyopathy (OR: 11.3, 95% CI: 3.2, 40.2, $p < 0.01$), non-hypertrophic cardiomyopathy (OR: 4.5, 95% CI: 2.8, 7.2, $p < 0.01$), hypoplastic left heart syndrome (OR: 4.2, 95% CI: 3.3, 5.4, $p < 0.01$) and congenitally corrected transposition (OR: 2.9, 95% CI: 1.6, 5.2, $p < 0.01$) to be strongly associated with cardiac arrest.

In those with congenital heart disease, cardiac arrest (as a primary or secondary diagnosis) was independently associated with an increase in length of admission (+16.7 days, $p < 0.01$), increase in cost of admission (+$172,139, $p < 0.01$), and increase in inpatient mortality (OR 14.9, 95%CI 12.5 to 17.8, $p < 0.01$).

Temporal trends in cardiac arrest as a primary or secondary diagnosis (OHCA and IHCA) in those with congenital heart disease

When admissions with congenital heart disease were analyzed, the proportion of admissions with cardiac arrest showed a small statistically significant decrease from 0.8% in the period spanning from 1994 to 1997 to 0.7% in the period spanning from 2010 to 2012 ($p < 0.01$). Inpatient mortality in admissions with congenital heart disease and cardiac arrest decreased from 58.0% in the period spanning from 1994 to 1997 to 28.9% in the period spanning from 2010 to 2012 ($p < 0.01$) (Figure 1).

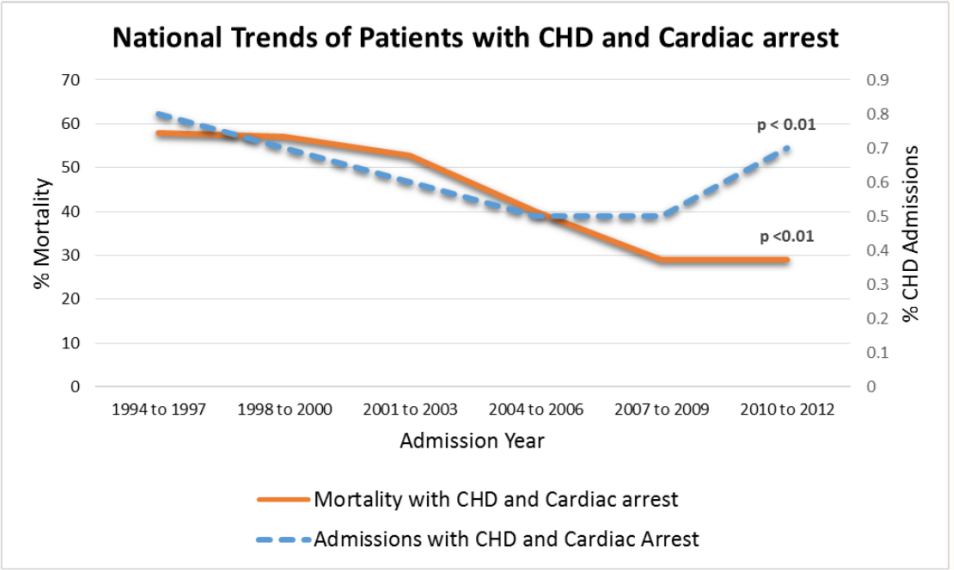

Figure 1: *National trends of patients with congenital heart disease and cardiac arrest.*
CHD: Congenital Heart Disease.
Figure Legend: National trend demonstrates a small statistically significant decrease in the admissions of patients with CHD and cardiac arrest with a significant decrease in in-patient mortality.

Characteristics of admissions with and without OHCA as primary diagnosis in all patients, univariate analyses

A total of 8,277,150 admissions were included in these analyses. Of these, 979 (0.01%) had cardiac arrest as a primary diagnosis (OHCA). Those with OHCA tended to have a lower median age (1 year versus 5 years, $p < 0.01$) and were more likely to be African American or Asian or Pacific Islander ($p < 0.01$)

In regards to comorbidities, those with OHCA were more likely to have heart failure (OR 3.3, 95%CI 1.9 to 5.5, $p < 0.01$) acute kidney injury (OR 28.2, 95%CI 22.9 to 34.7, $p < 0.01$), and tachyarrhythmia (OR 61.7, 95%CI 47.1 to 81.0, $p < 0.01$). Congenital heart disease was also more prevalent in those with OHCA (OR 3.2, 95%CI 2.5 to 4.1, $p < 0.01$). Hypertrophic cardiomyopathy (OR 10.5, 95%CI 1.4 to 75.2, $p < 0.01$), non-hypertrophic cardiomyopathy (OR 14.1, 95%CI 9.0 to 22.0, $p < 0.01$), and long QT syndrome (OR 27.2, 95%CI 11.2 to 65.6, $p < 0.01$) were also more prevalent in those with OHCA.

Median length of admission was decreased in those with cardiac arrest (1 day versus 2 days, $p < 0.01$). Median cost of admission, however, was greater ($29,941 versus 8,277, $p < 0.01$). Approximately 1.6% of those in the OHCA group required extracorporeal membrane oxygenation compared to 0.1% in the no OHCA group (OR 13.1, 95%CI 7.9 to 21.9, $p < 0.01$). Inpatient mortality occurred in 79.7% of those in the OHCA group compared to 0.5% of the no OHCA group (OR 801.6, 95%CI 686.1 to 937.2, p 0.01).

Comparison of characteristics of admissions with and without OHCA as primary diagnosis in all patients, regression analysis

The following were found to be independently associated with increased odds of OHCA: younger age, arrhythmia, acute kidney injury, and non-hypertrophic cardiomyopathy. It should be noted that congenital heart disease was not independently associated with OHCA.

Comparison of characteristics of admissions with and without OHCA as primary diagnosis in patients with congenital heart disease, univariate analyses

A total of 197,953 patients were included in this analysis of admissions with congenital heart disease. Of these, 72 (0.03%) had OHCA. There were no significant differences between those with and without OHCA in regards to age or race. Those with OHCA were more likely to have acute kidney injury (OR 4.4, 95%CI 1.7 to 10.9, $p < 0.01$) and tachyarrhythmia (OR 3.4, 95%CI 1.1 to 10.9, $p= 0.02$).

The only cardiac lesions found to be more prevalent in the OHCA group were hypoplastic left heart syndrome (OR 2.5, 95%CI 1.3 to 4.9, $p < 0.01$) and congenitally corrected transposition (OR 4.6, 95%CI 1.4 to 14.9, $p < 0.01$). Non-hypertrophic cardiomyopathy was more prevalent in those with OHCA (OR 6.6, 95%CI 2.0 to 21.1, $p < 0.01$).

Median length of admission was lower in those with OHCA (2 days versus 5 days, $p < 0.01$) with no significant difference in median cost of admission. Those in the OHCA group were also more likely to need extracorporeal membrane oxygenation (OR 7.7, 95%CI 3.5 to 16.9 $p < 0.01$). Inpatient mortality was 72.2% in the OHCA group compared to 3.2% in the no OHCA group (OR 47.3, 95%CI 47.3 to 132.9, $p < 0.01$).

OHCA independently decreased length of admission (-8.5 days, $p = 0.09$) but had no statistically significant independent effect on cost of admission in those with congenital heart disease. OHCA did independently increased inpatient mortality (OR 56.4, 95%CI 19.5 to 163.3, $p < 0.01$).

Discussion

We have studied a large national database of pediatric patients and report on the characteristics of patients who sustain cardiac arrest. The main findings of the study was that the incidence of cardiac arrest is increased among those with heart disease when compared to those without heart disease but still remained relatively low. While HCM, non-hypertrophic cardiomyopathy and long QT syndrome were associated with cardiac arrest in the overall population, congenitally corrected transposition of great arteries and HLHS were the specific cardiac lesions most associated with cardiac arrest.

Our database review demonstrates that in a nationally representative hospital records, 0.1% (1 per 1000) of the patients were admitted for cardiac arrest. OHCA accounted for a small but considerable proportion of this group (11.7%; ~ 1 per 10,000). These findings are in accordance with a prior study done in Australia which demonstrated an IHCA of 1 per 1000 [16]. The frequency of OHCA is in accordance with the United States national statistics based on EMS assessed OHCA of 1.1 per 10,000 [2]. Among those with heart disease, cardiac arrest was noted in 6 per 1000 patients, which is similar but lower to a prior study that assessed use of CPR in KID and found an incidence of 7 per 1000 admitted patients [11]. The use of different ICD-9 codes could be responsible for the difference. There is an overall improvement in inpatient mortality for those with CHD who are admitted or cardiac arrest. This is likely related to improvement in earlier diagnosis, operative techniques, post-operative management and strategies for effective follow up [17].

CHD, HCM and non-HCM were significantly associated underlying etiologies with cardiac arrest among the overall population. This reflects a combination of SCA, pre-operative, intra-operative and post-operative CA. It is also possible that these reflect CA post-heart transplant or while on mechanical support. Other associations such as long QT syndrome, heart failure, tachyarrhythmia, atrioventricular block, and acute kidney injury could reflect consequences rather than etiological contributions to the cardiac arrest. When looking specifically into those with CHD, the highest risk was among those with concomitant cardiomyopathy or myocarditis. This combination of etiology for CA has not been systematically studied to the best of our knowledge and has been limited to case reports [18]. Among specific CHD, those with HLHS, Ebsteins, common arterial trunk and CC-TGA appeared to be at particular risk for CA. Although we are unable to determine if these patients had prior surgeries it is possible that those with HLHS likely reflects interstage mortality between their Norwood and Glenn procedure [19]. Common arterial trunk is particularly difficult to manage pre-operatively with a high mortality without surgery, while CC-TGA is associated with spontaneous high grade AV block that could result in CA [20]. Recent studies demonstrate the high risk for SCA among those with Ebsteins [21]. As expected CA was associated with increased length of stay, cost and inpatient mortality.

OHCA accounted for a small but sizable population of those with CA (1422 patients, 11.7%). These numbers reflect those patients who survived until admission to the hospital and does not represent patients who sustained SCA and were unable to be resuscitated at the scene or in the ER. The mortality was higher in this group than the overall mortality rate (72.2% vs 43.8%) and likely reflects the delay in initiation of CPR or advanced resuscitation techniques that leads to worse outcome. Given the absence of significant associated between SCA in the community and CHD before the second post-operative decade, it is not surprising to find the absence of association between OHCA and CHD [22]. Furthermore this renders further support to the notion that patients with CHD are more likely to have IHCA. Prior studies have noted only a small incidence of sudden death in children with HCM (1:150,000) [23]. Hence although considered to be a risk factor for SCA in the community, HCM in children might not be a frequently associated cause. Non-HCM which would include dilated cardiomyopathy appeared to be associated with OHCA. It is possible that that the ambiguous diagnostic code of Non-HCM resulted in accruement of multiple cardiac disorders including potentially ischemic cardiomyopathy associated with abnormal coronary arteries which are strongly associated with SCA/SCD in the young. The other cardiomyopathies that are associated with CA include left ventricular non-compaction and restrictive cardiomyopathy. Although these non-HCM patients are at risk for malignancy ventricular arrhythmias that can result in CA, they could have also sustained CA after heart transplant. When specifically looking into those with cardiac disease, OHCA was associated with those who had CC-TGA and HLHS. As previously stated this likely reflects SCA associated with high grade heart block and inter-stage cardiac arrest.

Limitations of the Study

Large databases such as the KID are limited by the absence of center specific data and the absence of temporal associations which makes determining causation difficult. Furthermore the use ICD-9 codes has not been rigorously evaluated in patients with CHD and errors associated with coding is possible. Finally, it is important to note that this study does not include patients who did not survive before being hospitalized such as in the emergency room or in the community.

Conclusion

We have studied a large national database to characterize CA in children, including OHCA with a specific focus on those with CHD. Overall the database demonstrates decrease in admissions and mortality of those with CHD. Specific CHD and non-HCM are associated with CA that require further characterization and strategies to prevent CA and improve mortality in prospective studies.

Authors Contribution

SB: Concept/Design, Data Interpretation, Drafting Article

RL: Concept/Design, Data Analysis, Critical Revision of Article, Statistics

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