Resource Use Among Adult Congenital Heart Surgery Admissions in Pediatric Hospitals

Risk Factors for High Resource Utilization and Association With Inpatient Death

Yuli Y. Kim, MD; Kimberlee Gauvreau, ScD; Emile A. Bacha, MD; Michael J. Landzberg, MD; Oscar J. Benavidez, MD, MPP

Background—Pediatric hospitals frequently perform congenital heart surgery in adults with congenital heart disease. The impact of these admissions on pediatric hospital resources is unknown. Our goals were to examine resource use by adults undergoing congenital heart surgery in pediatric hospitals, explore the association between high resource use (HRU) and inpatient death, and identify HRU risk factors.

Methods and Results—We obtained inpatient data from 42 pediatric hospitals from 2000 to 2008 and selected adult congenital heart (ACH) surgery admissions. We defined HRU admissions as those exceeding the 90th percentile for total hospital charges. We performed multivariable analyses using generalized estimating equations to identify risk factors for HRU. Of 97,563 congenital heart surgery admissions to pediatric hospitals, 3,061 (3.1%) were adults, accounting for 2.2% of total hospital charges. The threshold for HRU was total hospital charges ≥$213,803. Although HRU admissions comprised 10% of admissions, they accounted for 34% of charges for all ACH surgery admissions. Mortality rate was 16% for HRU admissions and 0.7% for others (P<0.001). Multivariable analysis demonstrated higher case complexity: risk category 2 (adjusted odds ratio [AOR], 3.6; P=0.02), risk category 3 (AOR, 13.7; P<0.001), and risk category 4+ (AOR, 30.7; P<0.001) as compared with risk category 1; DiGeorge syndrome (AOR, 4.2; P=0.006); depression (AOR, 3.1; P<0.001); weekend admission (AOR, 2.6; P<0.001); and government insurance (AOR, 2.0; P<0.001) as risk factors for HRU.

Conclusions—High resource use ACH surgery admissions are associated with significantly greater mortality rates. ACH admissions with greater surgical complexity, government insurance, DiGeorge syndrome, weekend admission, and depression were more likely to result in HRU. (Circ Cardiovasc Qual Outcomes. 2011;4:634-639.)

Key Words: heart defects ■ congenital ■ surgery ■ risk factors ■ resource utilization

Adults with congenital heart disease now outnumber the pediatric congenital heart population.1 Hospitalizations for these adult patients have doubled over the past 20 years, with congenital heart surgery accounting for nearly 20% of these admissions.2 Pediatric hospitals frequently perform congenital heart surgery in these adult patients. Adults with congenital heart disease are complex and have greater comorbidities and higher admission rates compared with the general patient population.3–7 This complexity often contributes to the increased utilization of health care resources. Despite the important role that pediatric hospitals play in the care of patients with congenital heart disease, resource utilization of adult patients who undergo congenital heart surgery in pediatric hospitals is understudied.

The impact of adult congenital heart (ACH) surgery admissions on pediatric hospital resources is unknown and may be substantial. Understanding patterns and determinants of resource use of ACH surgery admissions may assist pediatric hospitals in predicting resource needs to care for this growing patient population.8 Identification of potentially modifiable patient characteristics of high resource use (HRU) may provide pediatric hospitals with an opportunity to develop care strategies to reduce this risk and improve the care of these patients.
The purpose of this study was to (1) examine the pattern and proportion of resources consumed by adults who undergo congenital heart surgery in free-standing pediatric hospitals; (2) explore the association of HRU with in-hospital death and length of stay during ACH surgery admissions; and (3) identify risk factors for HRU among ACH surgery admissions in pediatric hospitals.

WHAT IS KNOWN
- Pediatric hospitals have historically played an important role in the care of all patients with congenital heart disease, including a growing population of adults.
- The annual adjusted hospital charge for adults who receive care in pediatric hospitals is estimated to be greater than $1 billion.
- Resource utilization and risk factors for high resource use among adults who undergo congenital heart surgery in pediatric hospital have not been explored.

WHAT THE STUDY ADDS
- Adults who undergo congenital heart surgery in pediatric hospitals do not consume a disproportionate amount of resources compared with the pediatric congenital heart surgical population.
- Risk factors for high resource use include higher surgical complexity, government-sponsored insurance, depression, and weekend admissions and is associated with inpatient mortality.

Methods
The study methods were reviewed and approved by the Institutional Review Board of Children’s Hospital Boston.

Data Source
We analyzed data from the Pediatric Health Information System (PHIS) from January 2000 through December 2008. PHIS is an administrative database containing comprehensive inpatient data from 42 not-for-profit children’s hospitals belonging to an alliance of free-standing pediatric hospitals, the Child Health Corporation of America (Shawnee Mission, KS), which has been previously used to study clinical outcomes.7–11 PHIS contains admission data including age, sex, race, International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes, insurance type, length of stay, and discharge status (discharged to home, rehabilitation facility, nursing facility, or inpatient death). Data are deidentified and undergo quality and validity checks before inclusion in the database.

ACH Surgery Case Selection
To identify ACH surgery admissions, we selected admissions ages 18 to 49 years with ICD-9-CM codes indicating surgical repair of a congenital heart defect (ICD-9-CM) diagnosis and procedure codes, whereby category 1 has the lowest risk of death and category 6 the highest. In this study, we combined surgical risk categories 4 through 6 due to the paucity of category 5 and 6 cases; we labeled this category as category 4+. Cases with combinations of cardiac surgical procedures were placed in the category corresponding to the single highest risk procedure.

Surgical Complexity
To attempt to adjust for case mix, we categorized surgical complexity according to the risk categories of the Risk Adjustment for Congenital Heart Surgery-1 (RACHS-1) method, a consensus-based risk-adjustment tool developed to compare in-hospital mortality of pediatric patients undergoing congenital heart surgery12 that has been previously applied to an ACH surgical population.14 This method assigns congenital heart surgical cases to 1 of 6 risk categories, based on the presence or absence of specific diagnosis and procedure codes, whereby category 1 has the lowest risk of death and category 6 the highest. In this study, we combined surgical risk categories 4 through 6 due to the paucity of category 5 and 6 cases; we labeled this category as category 4+. Cases with combinations of cardiac surgical procedures were placed in the category corresponding to the single highest risk procedure.

Resource Use
We used hospital charges as a surrogate for resource utilization. Inpatient charges were categorized as follows: pharmacy, supply, laboratory, imaging, clinical, and other service charges. Supply charges include all medical, surgical, and nursing supplies including cardiovascular devices and prostheses. Imaging charges include diagnostic services such as radiography, angiography, echocardiography, computed tomography, MRI, and nuclear medicine but excludes cardiac catheterization and coronary angioplasty, which are considered clinical charges. Clinical charges reflect all clinical services rendered by health care provider by subspecialty. Other charges include charges for room, board, and nursing as well as other ancillary services such as discharge planning and social services.

Definition of High Resource Use
We examined the distribution of total hospital charges for ACH surgery admissions in these pediatric hospitals. We defined admissions with total charges above the 90th percentile as HRU admissions.

Statistical Analysis
We examined the distribution of baseline admission characteristics for ACH surgery admissions and calculated the proportion of ACH surgery admissions to total (adult + pediatric) congenital heart surgery admissions. We analyzed the total hospital charges and charges by category for HRU admissions compared with non-HRU admissions. We examined the relationship between inpatient mortality and HRU using Fisher exact test and the relationship between length of stay and HRU using the Wilcoxon rank sum test. We estimated the unadjusted association with high resource use to patient-level characteristics (age, sex, race, genetic syndromes, comorbidities, surgical risk category, and insurance status) and admission characteristics (weekend admission, use of emergency department) using generalized estimating equations (GEE) models, which account for the correlation among different admissions within the same hospital. Characteristics with probability value <0.1 in univariate analysis were considered for inclusion into a multivariable model for HRU. A probability value <0.05 was required for retention in the
final model. Odds ratios (OR) and 95% confidence intervals (CI) for HRU were estimated.

**Results**

**ACH Surgery Admissions**

Of the 42 hospitals in the PHIS database, 39 performed ACH surgery between 2000 and 2008. There were 97,563 total (adult and pediatric) congenital cardiac surgical admissions, of which 3,061 (3.1%) were adults. The proportion of ACH surgery admissions steadily increased from 2.5% of all congenital heart surgical admissions in 2000 to 3.6% in 2008 (Figure 1).

**ACH Surgery Admission Characteristics**

Admission characteristics are summarized in Table 1. Thirty-nine percent of these ACH surgical admissions were 25 years of age or greater. Three-quarters of ACH surgery admissions were assigned to surgical risk categories 2 and 3. Most common surgical procedures by RACHS-1 risk category are risk category 1, secundum atrial septal defect repair; risk category 2, pulmonary valve replacement; risk category 3, aortic valve replacement; and risk category 4, repair of hypoplastic aortic arch.

**Length of Stay, Discharge Services, and Inpatient Mortality**

Median length of stay was 5 days (range, 1–149 days). More than 90% of admissions were discharged to home. More than 90% of admissions were discharged to home. There were 124 admissions (4.1%) that ended with a discharge to a short-term rehabilitation facility, and approximately 1% was discharged with home health services. There were 67 adult inpatient deaths among these pediatric hospitals or an unadjusted mortality rate of 2.2%.

**ACH Surgery Resource Utilization**

Whereas adults comprised 3.1% of all congenital heart surgery admissions, they used 2.2% of the total hospital charges. Median hospital charges for ACH surgery admissions was $88,759 (interquartile range, $63,339 to $134,482) compared with $92,529 (interquartile range, $56,191 to $188,748) for pediatric congenital heart surgery admissions.

Median total charges were examined by RACHS-1 risk category for adult and pediatric congenital heart surgical admissions (Figure 2). Total charges increased with higher surgical complexity for both age groups. Though median total charges for risk categories 1 through 3 procedures were comparable between adult and pediatric admissions, there was a trend for adult admissions to incur higher charges for surgical categories 1 and 2. In contrast, the median total charges for risk category 4+ were higher for the pediatric population than for adults but did not reach statistical significance.

**High Resource Use Admissions**

The 90th percentile threshold for total hospital charges defining HRU admissions was $213,803. Although high

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**Figure 1. Adult congenital heart (ACH) surgical admissions from 2000 to 2008 in pediatric hospitals as a proportion of total congenital heart surgery admissions. The proportion of ACH surgical admissions has increased from 2.5% in 2000 to 3.6% in 2008.**

**Table 1. Adult Congenital Heart Surgery Admission Characteristics (n=3,061)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, y</strong></td>
<td></td>
</tr>
<tr>
<td>18–19</td>
<td>924 (30.2)</td>
</tr>
<tr>
<td>20–24</td>
<td>957 (31.3)</td>
</tr>
<tr>
<td>25–34</td>
<td>734 (24.0)</td>
</tr>
<tr>
<td>35–49</td>
<td>446 (14.6)</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>1595 (52.1)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>2452 (80.1)</td>
</tr>
<tr>
<td>Black</td>
<td>263 (8.6)</td>
</tr>
<tr>
<td>Asian</td>
<td>66 (2.2)</td>
</tr>
<tr>
<td>Other</td>
<td>163 (5.3)</td>
</tr>
<tr>
<td>Not reported</td>
<td>117 (3.8)</td>
</tr>
<tr>
<td><strong>Genetic syndrome</strong></td>
<td></td>
</tr>
<tr>
<td>Down</td>
<td>126 (4.1)</td>
</tr>
<tr>
<td>DiGeorge</td>
<td>24 (0.8)</td>
</tr>
<tr>
<td><strong>Comorbidity</strong></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>295 (9.6)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>145 (4.7)</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>130 (4.2)</td>
</tr>
<tr>
<td>Depression</td>
<td>65 (2.1)</td>
</tr>
<tr>
<td><strong>RACHS-1 risk category</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>284 (9.3)</td>
</tr>
<tr>
<td>2</td>
<td>939 (30.7)</td>
</tr>
<tr>
<td>3</td>
<td>1375 (44.9)</td>
</tr>
<tr>
<td>4+</td>
<td>121 (4.0)</td>
</tr>
<tr>
<td>Unassigned</td>
<td>342 (11.2)</td>
</tr>
<tr>
<td><strong>Payer status</strong></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>1426 (46.5)</td>
</tr>
<tr>
<td>Government</td>
<td>820 (26.9)</td>
</tr>
<tr>
<td>Self-pay</td>
<td>99 (3.2)</td>
</tr>
<tr>
<td>Other</td>
<td>716 (23.4)</td>
</tr>
<tr>
<td><strong>Weekend admission</strong></td>
<td>92 (3.0)</td>
</tr>
<tr>
<td><strong>Emergency department services</strong></td>
<td>88 (2.9)</td>
</tr>
</tbody>
</table>

RACHS-1 indicates Risk Adjustment for Congenital Heart Surgery.
resource admissions (307 admissions) represented 10% of all ACH surgery admissions, they accounted for 34% of total charges of ACH surgery admissions (Figure 3). Median length of stay for HRU admissions was 19 days versus 5 days for non-HRU admissions ($P < 0.001$). Inpatient mortality rate was 16% for HRU admissions versus 0.7% for non-HRU admissions ($P < 0.001$).

**Categories of Resource Use Among HRU Admissions**

The median total hospital charges for HRU admissions was $299,901, compared with $82,738 for non-HRU admissions. Total charges were examined by category: pharmacy, laboratory, imaging, clinical, supply, and other charges. HRU admissions consistently but not uniformly accrued higher charges across each category (Figure 4). The two most costly categories for HRU admissions were other (room and nursing), with median charge $99,963 versus $30,161 for non-HRU admissions.

**Risk Factors for High Resource Use**

On multivariable analysis, we found that HRU was associated with DiGeorge syndrome, higher surgical risk category, depression, government-sponsored insurance, and weekend admission (Table 2). Admissions with a diagnosis of depression had 3-fold greater adjusted odds for HRU; additionally the higher surgical risk category, the higher the odds for HRU.

**Discussion**

**Impact of ACH Surgery in Pediatric Hospitals**

The annual adjusted hospital charges for adults with conditions of childhood onset who receive care in pediatric hospitals are estimated to exceed $1 billion. As the adult congenital cardiology population progressively grows, the resources required by hospitals to care for this population will increase.

**Table 2. Multivariable Analysis of Risk Factors for High Resource Utilization**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DiGeorge syndrome</td>
<td>4.2</td>
<td>(1.5, 11.6)</td>
<td>0.006</td>
</tr>
<tr>
<td>Depression</td>
<td>3.1</td>
<td>(1.7, 5.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RACHS-1 risk category</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>3.6</td>
<td>(1.2, 11.2)</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>13.7</td>
<td>(4.1, 45.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4+</td>
<td>30.7</td>
<td>(10.6, 88.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unassigned</td>
<td>18.2</td>
<td>(5.8, 56.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Government payer status</td>
<td>2.0</td>
<td>(1.5, 2.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weekend admission</td>
<td>2.6</td>
<td>(1.6, 4.1)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

RACHS-1 indicates Risk Adjustment for Congenital Heart Surgery. c Statistic = 0.731.
We demonstrated that although the number and proportion of congenital heart surgery admissions in pediatric hospitals is increasing, presently these adult admissions do not consume a disproportionate amount of resources among these hospitals. This finding contrasts with another study in which adult survivors of pediatric illness accounted for 4.9% of all pediatric hospital discharges but accrued 6.3% of total inpatient charges.9 However, our study population is surgical, and our results may be explained by the fact that pediatric patients undergo highly complex surgical procedures such as the Norwood operation that require an enormous amount of resources to provide adequate care. This is supported by the breakdown of total charges by surgical risk category in Figure 2 that demonstrates higher median total charges for risk category 4+ procedures in the pediatric population versus adults.

High Resource Use, Length of Stay, and In-Hospital Mortality
Our exploratory analysis demonstrated that HRU admissions of adults undergoing congenital heart surgery in pediatric hospitals were associated with inpatient mortality. This finding is consistent with a recent federal report analyzing the cost of inpatient death in the United States. In the year 2007, admissions resulting in death accounted for 1.9% of all hospital admissions but cost 5.2% of all spending for inpatient care by all payers. The average cost for an admission that ended in inpatient death was $26,035 compared with $9447 for those who were discharged alive.15

Risk Factors for High Resource Use
We identified surgical complexity as a risk factor for HRU and demonstrate an incremental increase in odds for HRU with higher risk category. This is consistent with the congenital heart surgery literature16,17 and other studies that have investigated clinical risk factors associated with higher hospital charges for congenital heart surgery in children.18,19 It is of interest that Down syndrome in adults was not associated with higher resource utilization, in contrast to findings by Ungerleider in the pediatric population.19 Instead, we identified DiGeorge syndrome as an independent clinical risk factor associated with HRU. DiGeorge syndrome has a wide spectrum of disease severity with multi-organ involvement. Admissions coded with DiGeorge syndrome probably belong to patients whose clinical manifestations are severe enough to warrant genetic testing and to confirm the diagnosis. It is possible that these admissions may have incurred higher cost from management of comorbidities associated with DiGeorge syndrome such as immune deficiency, electrolyte disarray, developmental delay, and neuropsychiatric disorders.

Interestingly and potentially modifiable, depression was associated with more than 3-fold odds of being a high resource admission. In the adult cardiology literature, depression is a clinical risk factor for morbidity and mortality after coronary artery bypass surgery,20,21 including increased length of stay22 and readmission.23,24 Approximately one-third of adults with congenital heart disease have mood disorders, and depression may be unrecognized and/or undertreated in this population.25,26 Though the nature of the association between depression and HRU in adult congenital heart disease patients is not well understood, heightened awareness, screening, and treatment could potentially mitigate HRU during congenital heart surgery admissions.

We show that government-sponsored health insurance and weekend admissions had an increased likelihood of being a high resource admission. These findings are consistent with Connor et al, who also showed that weekend admissions or admissions with Medicaid were more likely to result in high resource use in the pediatric congenital heart surgery population.16 The association between government-sponsored insurance status and weekend admissions with high resource use suggests these variables may be surrogates for barriers to appropriate care for a subset of adults with congenital heart disease.

Limitations
Despite the strengths of our methodology and the consistency of our findings, our study also has limitations. Administrative data provide limited clinical information and may not have captured other important risk factors for increased resource use. However our findings using these data are consistent with prior studies; for example, our case mix is consistent with descriptive studies characterizing the frequency of adult congenital cardiac surgery case mix, and our reported mortality rate was also consistent with prior reports.14,27–31

It is also important to note this was a study of pediatric hospitals and outcomes of ACH surgery admissions in these pediatric hospitals cannot be generalized outside of this hospital setting. Adults who undergo congenital heart surgery in a pediatric hospital may have a different clinical profile from those who undergo congenital heart surgery in an adult hospital, which can account for differences in outcomes.

Different authors have used various strategies to examine case complexity including the RACHS-1 method used in this report.14,32–40 Though the RACHS-1 risk categories performed well in its discriminatory ability with regard to identifying high resource use admissions, these categories were not specifically designed for ACH surgery admissions. At present, however, there is no universally agreed-on method of risk adjustment for surgical case complexity in the ACH surgery population. Although this method was useful, a specific risk adjustment tool for ACH surgery is needed.

Conclusion
The number of adults who undergo congenital heart surgery in pediatric hospitals is increasing annually. Adult congenital heart surgery admissions with higher surgical complexity, government insurance, DiGeorge syndrome, depression, and weekend admissions were more likely to result in high resource use in pediatric hospitals. High resource use admissions were associated with higher death rates. The relationship between high resource utilization and potentially modifiable risk factors such as depression merits further study to identify the ability of care strategies to reduce resource use among these patients and improve the overall quality of care.

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Disclosures

None.

References


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