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ORIGINAL ARTICLE

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Readmissions after adult congenital heart surgery: Frequency and risk factors

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Abstract

Objective: Despite their clinical importance, 30-day readmission after adult congenital heart surgery has been understudied. They sought to determine the frequency of unplanned readmissions after adult congenital heart surgery and to identify any potential associated risk factors.

Design: Retrospective cohort study using State Inpatient Databases for Washington, New York, Florida, and California from 2009 to 2011.

Setting: Federal and nonfederal acute care hospitals.

Patients: Admissions of patients age 18–49 years with *International Classification of Diseases, Ninth Revision, Clinical Modification* codes indicating adult congenital heart surgery.

Outcome Measures: Readmission was defined as any nonelective hospitalization for a given patient ≤30 days of discharge from the index congenital heart surgery admission.

Results: Of 9863 admissions, there were 8912 patients discharged home, of which 1419 were readmitted (14.2%). Unadjusted mortality rate was 2.6%. Most common indications for readmission were cardiac (pericardial disease, atrial fibrillation, heart failure) and infectious (postoperative infection, endocarditis). On multivariable analysis, female gender (adjusted odds ratio [AOR] 1.1; $P = .05$), black race (AOR 1.2; $P = .05$), median income <$40,000 (AOR 1.3; $P = .01$), government-sponsored insurance (AOR 1.4; $P < .001$), renal insufficiency (AOR 2.1; $p < .001$), Risk Adjustment for Congenital Heart Surgery-1 (RACHS-1) 3 complexity (AOR 1.3; $P = .04$), and emergent admissions (AOR 1.5 $P < .001$) were risk factors for readmission.

Conclusions: One out of seven adult congenital heart surgery hospitalizations results in unplanned readmission. Female gender, lower income status, black race, government-sponsored insurance, renal failure, unscheduled index admission, and RACHS-1 three surgical procedures are risk factors for subsequent unplanned 30-day readmission. These risk factors may serve as potential quality improvement targets to reduce readmissions.

KEYWORDS
heart defects, congenital, surgery, risk factors, readmission

1 | INTRODUCTION

Adults with congenital heart disease are a high resource use population compared with their age-matched peers and have higher hospitalization rates compared with that of the general population.[1–3]. Approximately 15%–20% of these hospitalizations are admissions for congenital cardiac surgery[4] and comprise a significant proportion of health services utilization and cost. Unplanned readmissions after discharge add to cost[5] and are increasingly being scrutinized as a marker of quality of care. The full impact of such a growing, resource-intense patient population is not known and patterns of resource utilization are incompletely defined.

Numerous studies examining rehospitalization after coronary artery bypass and/or valve surgery show readmissions occur frequently with a 30-day readmission rate ranging between 13% and 18.7%.[6–10] There are few studies on congenital heart surgery[7] with existing data limited to CHS outcomes in the pediatric population, mostly from single-center studies. The 30-day readmission rates for pediatric heart surgery range from 6.4% to 11% depending on study design and population.[11–15] The 30-day readmission rate after adult CHS is not well-described.

The purpose of this study was to determine 30-day unadjusted readmission rate for adult CHS and to examine potential risk factors associated with readmission. We hypothesized that identifiable risk factors are present during the index admission that are associated with unplanned readmission.

2 | METHODS

The study methods were reviewed and approved by the Institutional Review Board of the Massachusetts General Hospital.

2.1 | Data source

We analyzed data from the 2009 to 2011 State Inpatient Databases for Washington, New York, Florida, and California.[16] The State Inpatient Databases are part of the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality. Data from the Healthcare Cost and Utilization Project has been previously utilized to examine outcomes for adult and pediatric CHS.[17–19]

2.2 | Study population

Index admissions were identified of patients ages 18–49 years with *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes indicating at least one congenital heart surgery procedure as previously described.[20–22] We excluded transcatheter interventions, extracorporeal membrane oxygenation, ventricular assist device or pacemaker placements if it was the sole surgical procedure coded. The upper age limit was set to less than 50 years to minimize inclusion of acquired heart disease.

2.3 | Readmissions

Each admission correlated to a unique patient. We defined readmission as any nonelective hospitalization for a given patient $\leq$30 days of discharge from the index CHS admission. Transfers to another facility from the index admission were excluded from the readmission analyses.

2.4 | Patient and admission characteristics

Patient and admission-level characteristics examined included demographics (age, gender, race), median annual income by zip code, genetic syndrome (Down syndrome and DiGeorge syndrome), comorbidities (hypertension, heart failure, chronic renal insufficiency, complicated diabetes mellitus, peripheral vascular disease, chronic lung disease, liver disease, stroke, obesity, and depression), admission day of the week (weekend or weekday), and whether the admission was scheduled. Payer status was categorized into government-sponsored (Medicare, Medicaid, Title V, other government), private, or other insurance.

2.4.1 | Case mix adjustment

We utilized the surgical risk categories of the Risk Adjustment for Congenital Heart Surgery-1 (RACHS-1) method to adjust for surgical case complexity. RACHS-1 is a consensus-based risk-adjustment tool developed to compare in-hospital mortality of pediatric patients undergoing congenital heart surgery[21] that has been previously applied to an adult congenital cardiac population.[22,23] This method assigns congenital heart surgical cases to one of six 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. We combined surgical risk categories 4 through 6 due to the paucity of category 5 and 6 cases and labeled this category 4+. Cases with combinations or multiple cardiac surgical procedures were placed in the category corresponding to the single highest risk procedure.

2.5 | Resource utilization

Total hospital charges were used as a surrogate for resource utilization and we examined the distribution of total hospital charges across all admissions. A high resource use (HRU) admission was defined as an admission that exceeded the 90th percentile for total hospital charges for all adult CHS admissions.

2.6 | Complications

Adult CHS admissions were characterized as having had a complication as defined by the Society for Thoracic Surgery (STS) complication short list for CHS operations.[24] Compiled by an international multidisciplinary working group, this catalogue defined a complication as an unwanted clinical event and defined a set of ICD-9-CM codes as a means to identify complications during CHS admissions.[25]

2.7 | Main exposures

Our main exposures were (1) clinical and demographic patient characteristics and (2) index admissions characteristics such as case complexity, HRU, or those with a complication.

2.8 | Main outcomes

The main outcome of interest was readmission within 30 days of discharge after an adult CHS admission.

2.9 | Statistical analysis

Continuous variables are presented as median and interquartile range (IQR) and categorical variables are summarized as frequencies and percentages. We examined the potential predictors of 30-day readmission after index adult CHD surgery admissions. To account for the

TABLE 1 Adult congenital heart surgery admission characteristics ($n = 9863$)

	Number (%)
Age (years)	
18–24	942 (9.6)
25–34	1835 (18.6)
35–49	7086 (71.8)
Male	5893 (59.7)
Ethnicity	
White	5733 (58.1)
Hispanic	1547 (15.7)
Black	1167 (11.8)
Other	1022 (10.4)
Not reported	394 (4.0)
Median annual income by zip code	
< \$40,000	2369 (24.0)
\$40,000–\$49,999	2376 (24.1)
\$50,000–\$65,999	2408 (24.4)
> \$66,000	2449 (24.8)
Unknown	261 (2.6)
Genetic syndrome	40 (0.4)
Down	19 (0.2)
DiGeorge	
Comorbidity	
Hypertension	3758 (38.1)
Congestive heart failure	215 (2.2)
Peripheral vascular disease	1165 (11.8)
Diabetes-complicated	193 (2.0)
Chronic lung disease	1250 (12.7)
Renal insufficiency	884 (9.0)
Liver disease	324 (3.3)
Stroke	321 (3.3)
Obesity	1223 (12.4)
Depression	649 (6.6)
Alcohol abuse	401 (4.1)
Substance abuse	786 (8.0)
RACHS-1 risk category	
1	614 (6.2)
2	938 (9.5)
3	6993 (70.9)
4+	54 (0.5)
Unassigned	1264 (12.8)
Payer status	
Government-sponsored	2976 (30.2)
Private	5767 (58.5)
Other	1120 (11.4)
Unscheduled admission	3713 (37.6)
Weekend admission	878 (8.9)
Complications	4828 (49.0)

*RACHS-1, Risk Adjustment for Congenital Heart Surgery.

correlation among different admissions from the same hospital, we used the generalized estimating equations approach with logistic regression analysis for both univariate and multivariable models. We estimated the unadjusted association of patient-level characteristics (age, sex, race, household income, insurance status, genetic syndromes, comorbidities, RACHS-1 surgical risk category, and complication) and admission characteristics (weekend admission, urgent/emergent admission, and HRU) to 30-day readmission. The multivariable model included pre-specified risk factors and characteristics with *P* value $<.1$ in the univariate analysis.

3 | RESULTS

3.1 | Admission characteristics

Between 2009 and 2011, there were 9,863 adult CHS admissions (Table 1). Median age was 42 (IQR 33-46) years with 71.8% between ages 35 and 49. Hypertension was the most common comorbidity found in over a third of all admissions. The most frequently performed surgical procedures were predominantly related to valve disease: aortic valve replacement or repair (38.4%), mitral valve replacement (25.4%), pulmonary valve replacement (4.5%), annuloplasty (4.4%), and atrial septal defect repair (4.9%). The majority of the surgeries (70.9%) were RACHS-1 category three procedures. Examples of the most common surgeries according to RACHS-1 surgical risk categories are risk category 1: secundum atrial septal defect repair; risk category 2: pulmonary valve replacement; risk category 3: mitral valve replacement; and risk category 4: Konno operation. Half of the admissions had a complication as defined above. Median length of stay was 7 (IQR 5–13) days. There were 255 deaths during the index admission or 2.6% unadjusted mortality.

3.2 | Incidence and cause of readmissions

Of 9,608 patients who survived to discharge from adult CHS admission, 8912 were discharged to home. Of these, there were there were 1264 readmissions (14.2%) within 30 days (Figure 1). Index hospitalizations that resulted in readmission were compared with those that did not (Table 2).

The most frequent causes of readmissions were cardiac (pericardial disease, atrial fibrillation, heart failure), infectious (post-operative

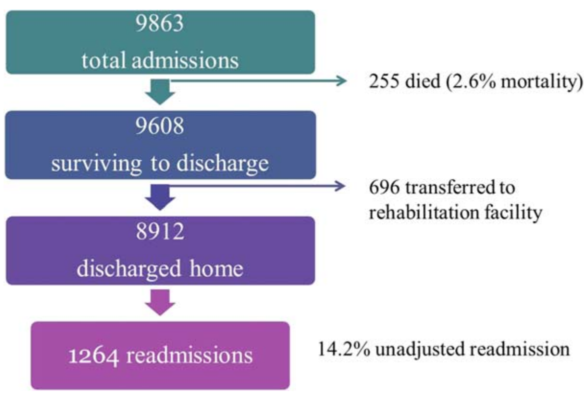

FIGURE 1 Disposition of patients and unadjusted 30-day readmission rate for adult congenital heart surgery. After excluding patients who died during the index hospitalization and those who were transferred to a rehabilitation facility, there was a 14.2% unadjusted readmission rate.

TABLE 2 Index hospitalization characteristics by readmission or nonreadmission status

	Discharged home N = 8912	Non-readmitted N = 7648	Readmitted N = 1264	P value
Median total adjusted hospital charges, $K (IQR)	163 (103,261)	158 (101,252)	193 (121,307)	<.001
Median length of stay, days (IQR)	7 (5,12)	7 (5,11)	9 (6,15)	<.001
Complication, *N* (%)	4150 (46.6)	3474 (45.4)	676 (53.5)	<.001
High resource use, *N* (%)	611 (6.9)	483 (6.3)	128 (10.1)	<.001

*IQR, Interquartile range.

infection), and respiratory (cough, pneumonia) and are summarized in Figure 2.

3.3 | Readmission characteristics

Median length of stay for readmission was 4 (IQR 2–7) days. Median total charges of these readmissions were $33 002 (IQR 16 813-60 805). There were 20 deaths out of 1264 readmissions or an unadjusted mortality of 1.6%. There were less than 10 CHS procedures (most frequently aortic valve replacement and mitral valve replacement or repair) indicating an additional CHS procedure performed during a subsequent readmission.

3.4 | Risk factors associated with readmission

Independent risk factors associated with readmission within 30 days after discharge after adult CHS are summarized in Table 3. Patient-level characteristics associated with readmission were female gender (adjusted odds ratio [AOR] 1.1; $P = .05$), black race (AOR 1.2; $P = .05$), median income <$40 000 (AOR 1.3; $P = .01$), government-sponsored insurance (AOR 1.4; $P < .001$), and renal insufficiency (AOR 2.1; $P < .001$). Admission-level characteristics associated with readmission were index admissions that were unscheduled (AOR 1.5 $P < .001$) and RACHS-1 3 complexity (AOR 1.3; $P = .04$). Older age, HRU, or complications were not associated with readmission.

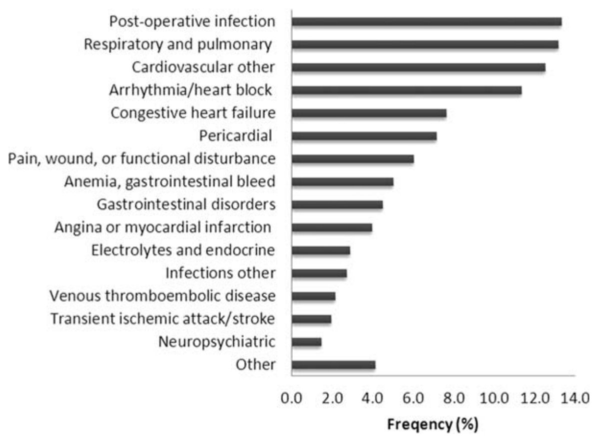

FIGURE 2 Principle diagnosis for readmission within 30 days of discharge after adult congenital heart surgery. The most common principle diagnosis associated with readmission was post-operative infection. Overall, cardiovascular diagnoses accounted for the majority of readmission at 42.5%.

4 | DISCUSSION

This is the first study, to our knowledge, to examine 30-day readmission after adult CHS. We found that the rate of unplanned readmissions after adult CHS is 14.2%. We also found that identifiable risk factors including female gender, black race, low median annual income, government-sponsored insurance, renal insufficiency, emergent admissions and those of RACHS-1 3 complexity to be independently associated with 30-day readmission after adult CHS.

Our findings are consistent with and comparable to the adult cardiac surgery literature on readmissions. The 30-day readmission rate and readmission diagnoses of infection, heart failure, and arrhythmia are similar to those for adult cardiac surgery.[7,10,26] Our results recapitulate findings from prior studies which show that women, blacks as well as those with elevated creatinine are more likely to experience readmission after coronary bypass graft surgery and/or valve surgery.[6,7,10,27,28]

Studies on gender differences in congenital heart disease have shown that females are more likely to have milder forms of congenital heart disease and less likely to undergo high-risk CHS in infancy but when they do are at higher risk of death.[29–31] Why female gender is an independent risk factor for worse surgical and postoperative outcomes such as readmission is incompletely understood and warrants further investigations.

Racial disparities have been well-documented in cardiovascular disease for both congenital and noncongenital heart disease populations with worse outcomes in non-Hispanic blacks.[32,33] Black race and poverty are independent but related risk factors for surgical readmission.[34] These patient characteristics may represent an at-risk population lacking social support or access to care that would otherwise prevent a “bounce back” to the hospital system[35] or represent a vulnerable group for whom effective communication regarding education and discharge planning is crucial. Though we were unable to assess education level, patients' knowledge about their congenital heart disease is variable and may affect this outcome.

Though gender, race, income, and insurance status were associated with readmissions, the odds ratios were relatively low suggesting that these factors are not the primary drivers for unplanned readmission after CHS surgery. Furthermore, these are nonmodifiable risk

TABLE 3 Multivariable analysis of risk factors for readmission after adult congenital heart surgery

Value	Adjusted odd ratio	95% confidence interval	P
Female	1.1	(1.0, 1.3)	.05
Black	1.2	(1.0, 1.5)	.05
Median annual income <$40 000	1.3	(1.1, 1.5)	.01
Government payer status	1.4	(1.2, 1.6)	<.001
Renal insufficiency	2.1	(1.6, 2.6)	<.001
Obesity	1.2	(1.0, 1.5)	.07
RACHS-1 risk category			
1	1.0	–	–
2	0.9	(0.6, 1.2)	.42
3	1.3	(1.0, 1.8)	.04
4+	1.7	(0.7, 4.1)	.21
Unassigned	0.9	(0.6, 1.3)	.65
Unscheduled admission	1.5	(1.2, 1.7)	<.001

*RACHS-1, Risk Adjustment for Congenital Heart Surgery.

factors that may represent the complex interplay between race, gender, socioeconomic status and untoward health outcomes that disadvantage these at-risk populations.

Our finding supports renal insufficiency as a powerful predictor of outcome in adult congenital heart disease with two-fold increased odds of readmission after adult CHS compared with those without. Renal insufficiency is prognostic in adult congenital heart disease and is associated with increased mortality.[36,37] Renal dysfunction is also associated with perioperative mortality and its relationship to death and surgical readmission is not well-understood.[38,39]

We did not identify older age as an independent predictor of readmission after CHS. Our study capped the upper age limit to 50, similar to prior studies to minimize the inclusion of non-CHS admissions.[22] The mean age in our study was 42 years, significantly lower than the average age of 64 years from a recent multicenter study on readmissions after cardiac surgery.[10] It is known that older age (particularly the elderly age group) is a risk factor for readmission[7,27] and it is possible that the age cap in this study blunted this effect of older age. The comparable readmission rate of this younger cohort to that of adult cardiac surgery patients suggests there may be other factors intrinsic to this population which place them at increased risk.

4.1 | Limitations

A limitation of our study revolves around the use of administrative databases and the issues related to coding accuracy with ICD-9 diagnostic and procedural codes. Specificity for congenital heart surgery admissions may be limited due to this lack of clinical insight. Specifically, the case mix in this study using the State Inpatient Database is distinct from those examining adult CHS in the Pediatric Health Information System[22] or the Society of Thoracic Surgeons Congenital Heart Surgery Database.[40] Currently, there is no universally agreed-upon method of risk adjustment for adult CHS. We adjusted for case complexity using the RACHS-1 method which is not specifically designed for adult congenital heart surgery. Using state databases, we are not able to account for readmissions for patients who may have traveled across state lines for surgery and local readmissions would therefore not have been captured.

5 | CONCLUSIONS

One out of seven adult CHS hospitalizations results in unplanned readmission within 30 days of discharge. Risk factors include female gender, lower income status, black race, government-sponsored insurance, renal failure, unscheduled index admission, and RACHS-1 3 surgical procedures. Knowing patient-level and admissions-level characteristics associated with readmissions can help providers develop measures to prevent subsequent readmissions by targeting at-risk patients and examine efficacy of such strategies.

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DISCLOSURE

There is no relationship with industry to disclose.

AUTHOR CONTRIBUTIONS

Concept/design: Kim, Benavidez
Data analysis and interpretation: Kim, He, Benavidez
Drafting article: Kim
Critical revision of article: Kim, He, MacGillivray, Benavidez
Statistics: He
Approval of article: He, MacGillivray, Benavidez

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