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Clinical predictors of length of stay in adults with congenital heart disease

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Abstract

Objective—Length of Stay (LOS) is a major driver of inpatient care costs. To date, few studies have investigated risk factors associated with increased LOS in adult congenital heart disease (ACHD) patients. In the present work, we sought to address this knowledge gap.

Methods—We conducted an analysis of the State Inpatient Databases from Arkansas, California, Florida, Hawaii, Nebraska, and New York. We analyzed data on admissions in ACHD patients and constructed a series of hierarchical regression models to identify the clinical factors having the greatest effects on LOS.

Results—We identified 99,103 inpatient hospitalizations meeting criteria for inclusion. Diagnoses associated with the longest LOS were septicemia (LOS = 14.2 days in ASD patients, and 11.7 days among all other ACHD) and peri-, endo-, and myocarditis (LOS = 13.6 days and 10.0 days respectively). When separated by underlying anatomy, the variables most consistently associated with longer LOS were bacterial infection, complications of surgeries or medical care, acute renal disease, and anemia.

Conclusions—In the present study, we identified risk factors associated with longer LOS in ACHD. These data may be used to identify at risk patients for targeted intervention to decrease LOS and thereby cost.

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INTRODUCTION

Congenital heart disease is the most common form of birth defect in the U.S. and the world [1]. Advanced surgical and clinical management has allowed an ever-increasing number of these patients, who previously would have perished in childhood, to survive into adulthood [2]. This growing population of adult survivors with congenital heart disease is projected to continue to grow in the coming years, with an accompanying growth in healthcare utilization [3–6]. Furthermore, the deterioration of surgical repairs performed in early childhood combined with the inevitable onset of acquired heart disease promises continued increases in healthcare utilization in this population as they age [7,8].

In particular, inpatient hospitalization represents a significant cost burden for adult congenital heart disease (ACHD) patients and the healthcare infrastructure alike [8,9]. To our knowledge, however, there has yet to be an in depth lesion-specific investigation of what risk factors are associated with increased inpatient LOS and which of these factors, if any, may be modifiable. These data are important to provide guidance for the development of treatment algorithms designed to minimize LOS without compromising health outcomes and quality of life in the ACHD population. The purpose of the current study was therefore to identify predictors of increased LOS in ACHD patients.

METHODS

For this analysis, State Inpatient Databases (SID) were used which are part of the Healthcare Cost and Utilization Project (HCUP)[10]. We specifically used the SIDs for Arkansas (2008–2010), California (2003–2012), Florida (2005–2012), Hawaii (2006–2010), Nebraska (2003–2011), and New York (2005–2012). We selected these SIDs because they uniquely track hospitalizations in individual patients longitudinally, whereas data from other states track hospitalizations without tracking patients risking repeated sampling of the same patient. The dates used were the most complete and up to date available at the time of analysis in April 2015. The primary outcome was length of stay for hospitalizations among ACHD patients in the states investigated. The present study was approved by the Institutional Review Board at Washington University School of Medicine.

As a first step, we identified patients in the databases with ACHD by selecting patients in the SIDs with an age of greater than 18, and with a 3-digit ICD-9 diagnosis code of 745, 746, or 747, the administrative codes that identify congenital cardiovascular anomalies. To this group of patients we applied a validated hierarchical algorithm described by Broberg et al to categorize patients based on anatomy [11]. Patients categorized as having a shunt according to this algorithm who had only the ICD-9 code for atrial septal defect (ASD, 745.5) were analyzed separately from the rest of the group of patients categorized as having shunts due to the inclusion of patent foramen ovale (PFO) in this coding group and the desire to prevent contaminating the analysis of shunt lesions with what is generally considered to be a variant

of normal atrial septal anatomy. Any patients who failed to be classified according to this algorithm were excluded to increase the probability that all the patients included for analysis in fact had ACHD. We next identified all hospitalizations during the study period among patients meeting inclusion criteria. We included only initial hospitalizations during the study period for any individual patient to avoid repeated sampling of the same patient. We also omitted hospitalizations with missing LOS data and trimmed the upper 1% to exclude extreme outliers.

Next, we constructed a series of hierarchical (patient, hospital, state) multivariable regression models to examine our primary outcome of interest: LOS. All models treat site of hospitalization and US state as random effects. A different model for each congenital heart lesion group as defined by the hierarchical algorithm was constructed using pre-identified variables based on anticipated clinical significance. In addition, we constructed separate models for admissions during which an operative procedure took place and those without in recognition of the potential impact of operative procedures on LOS and on the clinical variables effecting LOS. From these overall models, patients categorized as having an isolated ASD based on the hierarchical algorithm were excluded to avoid contaminating the sample with patients having only a PFO, as explained above. Each model included the same set of independent variables, which can be found in the supplemental materials. As the purpose of these models was descriptive not predictive, variables were not excluded for the sake of parsimony and given large sample size, over-fitting was not a concern. The sample size of each model changed, due to the varying number of subjects in each diagnosis group. The reference value is zero (“no”) for each dichotomous variable included in the models. The estimated contribution to LOS in days, 95% confidence intervals, and p-values were reported from these models and all significance tests were two-sided with type I error set to 5%, i.e. $\alpha = 0.05$.

All analyses were conducted using SAS v9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Patient Characteristics

We identified 99,103 unique index hospitalizations from our dataset meeting criteria for inclusion in this study (Figure 1). Average age in our population was 57.1 ± 18.5 years and 50.0% were female. The majority were white (69.7%) and from urban locations (67.3%). Further demographic information can be found in Table 1.

Most Common Admission Diagnoses

Tables 2 and 3 list the 15 most common admitting diagnoses among patients with an ASD, and among other ACHD patients respectively with associated mean LOS. These diagnoses represent 72% of the total number of admissions in ASD patients, and 69% of admissions among other ACHD patients. When the admission diagnosis of cardiac and circulatory congenital anomalies is omitted, the most common admitting diagnoses among patients with an ASD were for acute cerebrovascular disease (n=10,698) and heart valve disorders (n=4,046) while the most common admitting diagnoses among ACHD patients without an

ASD were heart valve disorders (5,003) and coronary atherosclerosis (3823). Of the top 15 admitting diagnoses, those that were associated with the longest LOS among patients with an ASD (in days) were septicemia (mean LOS = 14.2) and peri-, endo-, and myocarditis (mean LOS = 13.6). Similarly, among ACHD patients without an ASD they were septicemia (mean LOS = 11.7), and peri-, endo- and myocarditis (mean LOS = 10.0).

LOS by type of ACHD

When separated by type of ACHD, the longest average LOS was seen in patients with subaortic stenosis (7.4 ± 7.7 days), and isolated ASD (7.3 ± 8.2 days), while the shortest average LOS was seen among patients with anomalous coronary arteries (4.6 ± 5.5 days) and pulmonary stenosis (5.5 ± 6.5 days) (Figure 2).

Predictors of increased LOS

Among all ACHD admissions having an operative procedure during their hospitalization, excluding patients with an ASD, the variables associated with the greatest increase in LOS were bacterial infection (6.2 days longer 95% CI 5.9–6.6, $p < 0.0001$), acute kidney disease (3.3 days longer 95% CI 2.8–3.8, $p < 0.0001$), having “no charge” as the primary payer (2.4 days longer 95% CI 0.8–4.1, $p = 0.0036$), pulmonary heart disease (2.1 days longer 95% CI 1.6–2.5, $p < 0.0001$), congestive heart failure (CHF) (2.0 days longer 95% CI 1.7–2.4, $p < 0.0001$), complications of surgeries or medical care (1.9 days longer 95% CI 1.6–2.2, $p < 0.0001$), and anemia (1.8 days longer 95% CI 1.5–2.1, $p < 0.0001$). Among all ACHD admissions without an operative procedure, excluding patients with an ASD, the variables associated with the greatest increase in LOS were having had an aortic valve operation (16.1 days longer 95% CI 15.0–17.4, $p < 0.0001$), complications of surgeries or medical care (4.0 days longer 95% CI 3.4–4.7, $p < 0.0001$), acute kidney disease (2.9 days longer 95% CI 2.5–3.4, $p < 0.0001$), bacterial infection (2.9 days longer 95% CI 2.6–3.2, $p < 0.0001$), coagulopathy (2.4 days longer 95% CI 1.9–2.9, $p < 0.0001$) and having subaortic stenosis (2.1 days longer 95% CI 0.8–3.5, $p = 0.0016$). All variables having a significant impact on LOS for admissions with and without operative procedures are listed in supplemental tables 1 and 2 respectively.

Due to the heterogeneity of ACHD, we next sought to identify lesion-specific variables associated with increased LOS. Included in this analysis was an assessment of variables affecting LOS specifically in the population of patients with an isolated ASD which had been excluded from the above models. All variables having a significant impact on LOS separated by lesion type, are listed in supplemental table 3. Although we found significant heterogeneity among lesions, the variables most consistently associated with increased LOS across ACHD categories were bacterial infection, complications of surgeries or medical care, acute renal disease, and anemia.

DISCUSSION

In the present study, we investigated clinical variables associated with increased LOS among hospitalized patients with ACHD. We found that overall, the variables most strongly

associated with increased LOS, regardless of underlying anatomy, were acute kidney failure, bacterial infection, complications from medical or surgical procedures and anemia.

In the present analysis, we analyzed ACHD patients with an isolated ASD separately from the rest of the ACHD group. We did so due to the well-described limitation in the ICD-9 coding system whereby there is no mechanism for differentiation between ASD and PFO. A large proportion of patients falling into this category in the present analysis likely had PFOs (which are very common) as opposed to ASDs (which are far less common). As such, extrapolation of the present data to the ASD population may be limited. Importantly, however, the fact that over 50% of the total ACHD population identified by ICD9 codes alone fall into this category, suggests that research based on administrative data which fail to analyze lesions separately may arrive at conclusions relevant predominantly to the population of patients with PFOs. This limitation has not been addressed in the new ICD-10 coding system and will therefore continue to be a limitation to ACHD research into the future.

Most of the hospitalizations in the present dataset were for cardiac conditions. This is expected, and largely reproduces other reports on the most common reasons for hospitalization in ACHD patients [12] (also reviewed in [9]). Interestingly, we found that one of the most common reasons for admission in ASD patients specifically was cerebrovascular disease. We suspect that this is attributable to the fact that ICD9 does not differentiate between ASD and patent foramen ovale (PFO), both of which are coded as 745.5. As up to 20% of the general population have a PFO, the high incidence of hospitalization for cerebrovascular disease among the ASD group is likely due to incidentally noted PFOs among patients presenting to the hospital for stroke when imaging studies were obtained to identify the etiology of the event. We also found that complications of device implants or grafts, infections involving the heart, and septicemia are among the most common reasons for hospitalization in ACHD patients both with and without ASDs. Given their condition, ACHD patients undergo medical procedures more frequently than age matched patients without ACHD. The frequency with which ACHD patients are admitted with these diagnoses suggests periprocedural care as a high-yield area for potential quality improvement.

The LOS reported in the present study is similar to that which has been previously reported. Compared to data from the Dutch CONCOR database of ACHD patients hospitalized from 2001 to 2006[12] our study found a slightly longer mean LOS for all lesions. This slight difference in LOS may be explained by differences in clinical practices between the U.S. and the Netherlands. In support of this conclusion, in a study using the National Inpatient Sample (NIS) to investigate trends in ACHD hospitalization, Opatowsky et al found an overall average length of stay of 5.6 ± 0.1 days, comparable to the findings of the present study[4]. Although this study investigated the frequency of hospitalization among various types of ACHD, they did not report lesion specific differences in LOS.

In the present study we found that across groups, many of the variables strongly associated with increased LOS were both acute, and potentially modifiable. These included bacterial infections, complications of surgeries or medical care, acute renal disease and anemia. There

is the potential that rates of medical or surgical complications and bacterial infection may be minimized through protocols to optimize pre and post-operative care, intra-operative technique, and prophylactic antibiotic use respectively. Similarly protocols can be implemented to increase vigilance for and prevention of acute kidney injury during and between hospitalizations. These potentially modifiable risk factors are clear and actionable targets for hospital based treatment algorithms to minimize LOS in ACHD patients and, in turn, improve care quality in this patient population.

It is interesting that chronic comorbidities such as hypertension and CKD were not strongly associated with increased LOS in ACHD. This finding seems to conflict with existing data. Using the Charlson comorbidity score in a Canadian population, Mackie et al. demonstrated that ACHD patients with a greater comorbid burden utilize more healthcare services though they did not report specifically on LOS[5]. In the US, Opatowsky et al. studied the effects of comorbidity on LOS in ACHD[4] and found that increasing numbers of medical comorbidities correlated with increased LOS. The lack of correlation between these comorbid risk factors and LOS in our current study may have multiple explanations. The present population differs from that in Canada, and from the population investigated by Opatowsky et al., the latter both in the years and the states investigated. More importantly, however, coding for comorbidities in these two studies was very different from that in the present study. Whereas we investigated specific variables we believed would be associated with increased LOS, in these two works the authors used a composite score (the Charlson comorbidity index and Elixhauser's list of comorbidities respectively). We did not exhaustively include all comorbidities included in either of these scoring systems, and as such may have missed the variables responsible for the effects of comorbidities seen in these two works. Alternatively, although the composite of all comorbidities included in these indices may have achieved statistical significance in these studies, each individual comorbidity taken in isolation may not have been found to be significant, which would have been necessary for detection in the present analysis.

Limitations

There are multiple limitations to the present study due to the use of administrative data. The accuracy and completeness of the data depends on the care with which data was entered, which is likely variable from institution to institution. Although we made every effort to include all ACHD patients, to exclude patients not having ACHD, and to correctly characterize patients based on underlying anatomy, no algorithm is perfect, and it is almost certain that some patients in the present study were mischaracterized. Although geography including state of hospitalization may influence cost and outcomes, the states represented in the present analysis are limited, and this may have biased our results.

Conclusions

In the present study, we identified potentially modifiable risk factors associated with increased LOS in ACHD. We anticipate that these data may be used to design targeted interventions to decrease LOS and potentially cost in ACHD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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KEY MESSAGES**What is already known about this subject?**

We recently demonstrated that LOS was among the primary drivers of inpatient care cost in ACHD regardless of lesion, however to our knowledge there has been no analysis of the clinical variables correlated with increased LOS in this group of patients.

What does this study add?

By analyzing data from a large administrative database, we present novel information on lesion-specific clinical variables associated with the greatest effects on inpatient LOS in ACHD.

How might this impact on clinical practice?

The present analysis is hypothesis forming, and identifies potentially high-yield areas for intervention to decrease LOS and thereby decrease inpatient care costs and improve care quality in ACHD.

Figure 1. Inclusion and Exclusion Diagram

Graphical representation of the patients included in the present analysis. 155,297 index admissions were found. Admission data were then excluded if patients failed to be categorized by the algorithm to identify ACHD lesion and if records were missing LOS information required for analysis yielding 109,450 total admissions. Repeated admissions or records were then removed resulting in 100,067 index admissions for individual patients. After trimming the top 1% to remove outliers, this resulted in a final tally of 99,103 admissions which were used for analysis.

Figure 2.

Average length of stay by ACHD lesion type in days. Error bars depict standard deviation. TGA: transposition of the great arteries; AVCD: atrioventricular canal defect; PS: pulmonary valve stenosis; PVC: pulmonary venous connection; CoA: coarctation of the aorta; ASD: atrial septal defect; AS/BAV: aortic stenosis/bicuspid aortic valve; CHD: congenital heart disease.

Table 1

Demographic information

Demographic Characteristics		Number of Hospitalizations	
Age		57.1±18.5	
Sex (Female)		49459	50.0%
Race/Ethnicity	White	64978	69.7%
	Black	8257	8.9%
	Hispanic	12244	13.1%
	Asian/Pacific Islander	3700	4.0%
	Native American	195	0.2%
	Other	3850	4.1%
Payer	Medicare	40868	41.2%
	Medicaid	11521	11.6%
	Private Insurance	39382	39.7%
	Self-pay	3303	3.3%
	No charge	601	0.6%
	Other	3405	3.4%
Population of City where Hospitalized	Top quartile	66698	67.3%
	Second quartile	24792	25.0%
	Third quartile	5020	5.1%
	Bottom quartile	2555	2.6%
Eisenmengers		256	0.3%
Single Ventricle		1663	1.7%
TGA		1294	1.3%
Conotruncal abnormalities		454	0.5%
AVCD		674	0.7%
Ebstein's		679	0.7%
PS		2095	2.1%
Anomalous PVC		64	0.1%
CoA		1375	1.4%
Shunts	ASD	55,208	55.7%
	Non-ASD	10,171	10.3%
Subaortic stenosis		615	0.6%
Congenital AS/BAV		16728	16.9%
Anomalous coronary artery		8766	8.8%
Other CHD		6175	6.2%

TGA: transposition of the great arteries; AVCD: atrioventricular canal defect; PS: pulmonary valve stenosis; PVC: pulmonary venous connection; CoA: coarctation of the aorta; ASD: atrial septal defect; AS/BAV: aortic stenosis/bicuspid aortic valve; CHD: congenital heart disease.

Table 2

LOS in the Most Common Admission Diagnoses among patients with an ASD

Diagnosis	Number of Admissions	Mean LOS (Days)	Median LOS	StdDev
Acute cerebrovascular disease	10698	8.5	5	8.9
Cardiac and circulatory congenital anomalies	6912	3.2	1	4.3
Heart Valve Disorder	4046	9.8	7.5	7.2
Cardiac arrhythmias	3956	4.5	3	4.9
TIA	2714	3.6	3	3.2
Congestive Heart Failure	2675	9.1	6	8.9
Coronary atherosclerosis	2036	8.6	7	8.1
Acute MI	1233	10.6	8	9.2
Septicemia	1063	14.2	11	11.0
Non-specific chest pain	903	2.8	2	3.2
Pulmonary heart disease	889	9.9	7	8.7
Complication of device implant or graft	831	12.3	8	11.3
Pneumonia	819	8.7	6	8.4
Syncope	681	3.4	3	3.3
Peri/endo/myocarditis	568	13.7	10	11.5

StdDev: standard deviation; TIA: transient ischemic attack; MI: myocardial infarction

Table 3

LOS in the Most Common Admission Diagnoses among ACHD patients without an ASD

LOS in ACHD Excluding ASD				
Diagnosis	Number of Admissions	Mean LOS (Days)	Median LOS	StdDev
Cardiac and circulatory congenital anomalies	6098	5.8	5	5.0
Heart Valve Disorders	5003	8.1	6	6.0
Coronary Atherosclerosis	3823	4.4	3	5.0
Acute MI	2454	6.5	4	7.2
Cardiac Dysrhythmias	2373	4.0	3	4.6
Nonspecific chest pain	2362	2.3	2	2.3
CHF	1857	7.9	5	8.0
Aortic peripheral and visceral artery aneurysms	1306	7.8	6	6.3
Peri/endo/myocarditis	952	10.0	6	10.1
Complication of device implant or graft	879	6.9	4	7.9
Pneumonia	799	7.4	5	7.9
Other complications of pregnancy	723	3.3	3	4.0
Septicemia	599	11.7	8	10.6
Acute cerebrovascular disease	582	9.4	5	10.1
Syncope	475	3.2	2	3.0

StdDev: standard deviation; MI: myocardial infarction