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Current Trends in Racial, Ethnic, and Healthcare Disparities Associated with Pediatric Cardiac Surgery Outcomes

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Abstract

Objective—Despite overall improvements in congenital heart disease outcomes, racial and ethnic disparities have continued. The purpose of this study is to examine the effect of race and ethnicity, as well as other risk factors on congenital heart surgery length of stay and in-hospital mortality.

Design—From the 2012 Healthcare Cost and Utilization Project Kids Inpatient Database (KID), we identified 13,130 records with Risk Adjustment in Congenital Heart Surgery complexity score-eligible procedures. Multivariate logistic and linear regression modeling with survey weights, stratification and clustering was used to examine the relationships between predictor variables and length of stay as well as in-hospital mortality.

Results—No significant mortality differences were found among all race and ethnicity groups across each age group. Black neonates and black infants had a longer length of stay (neonatal Estimate = 8.73 days, p = .0034; infant Estimate 1.10 days, p = 0.0253), relative to whites. Government-sponsored insurance was associated with increased odds of neonatal mortality (odds ratio = 1.51, p = .0055), increased length of stay in neonates (Estimate = 4.26 days, p = .0009) and infants (Estimate = 1.52 days, p = .0181), relative to private insurance. Government-sponsored insurance was associated with increased number of chronic conditions, which were also associated with increased LOS (estimate 8.39 days, $p < 0.001$ in neonates; estimate 3.60 days, $p < 0.001$ in infants; estimate 1.87 days, $p < 0.001$ children).

Conclusions—Racial/ethnic disparities in congenital heart surgical outcomes may be changing compared to previous studies using the KID database. Increased length of stay in children with government-sponsored insurance may reflect expansion of individual states government-sponsored

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insurance eligibility criteria for children with complex chronic medical conditions. These findings warrant cautious optimism regarding racial and ethnic disparities in congenital heart surgery outcomes.

Keywords

congenital heart disease; database; outcomes research

Introduction

Congenital heart disease (CHD) outcomes have improved dramatically in the recent era due to improvements in CHD recognition, surgical techniques, and perioperative management, yet racial and ethnic disparities in congenital heart outcomes continue to exist. Benavidez and colleagues utilized the Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Database (KID) from 2000 and reported that race/ethnicity and insurance type predicted perioperative complications, and complications were associated with mortality.[1] Chan, et al used the KID to examine “failure to rescue” (FTR, or death following a hospital complication) as a more sensitive marker of hospital care disparities than mortality alone, and found that Hispanic race was associated with increased complications, while black and “Other” race was associated with FTR.[2] Longer length of stay (LOS) following congenital heart surgery has been reported in black and Hispanic children compared to white children.[3,4]

Increased congenital heart surgical mortality has been reported in patients with Medicaid insurance compared to private insurance, and in non-white children compared to white children, although this finding varies across geographic regions and by specific types of CHD.[5–8] Other studies have reported increased CHD and congenital heart surgery mortality for black and Hispanic children compared to white children.[3,4,9–12]

The purpose of this study is to describe the effect of race and ethnicity on congenital heart surgery LOS and mortality, after adjusting for known confounding variables, using the most recent edition of the KID. Although several previous studies, some using the KID, have reported that black and Hispanic race is associated with increased mortality, LOS and/or complications, it is important to evaluate whether or not these disparities continue using the most recent data available. This could help support development of strategies to improve care for at-risk populations and optimize health care delivery.

Methods

Data Source

This retrospective cohort analysis was approved by the MemorialCare Health System Institutional Review Board. Data was obtained from the 2012 KID, under a Data Use Agreement. The KID is published triennially from a stratified random sample of pediatric hospital discharges, including 10% of normal hospital births and 80% of complicated births and other pediatric discharges.[13] The KID 2012 includes administrative data from 4179 acute care hospitals in 44 states (see http://www.hcup-us.ahrq.gov/db/hcupdatapartners.jsp)

with approximately 3,195,000 pediatric hospital discharges for patients aged 20 years and less.[14] Congenital cardiac surgical discharges in patients less than 18 years of age were identified within the 2012 KID by International Classification of Diseases, 9th edition, Clinical Modification (ICD-9-CM) diagnoses and procedure codes, and were assigned Risk-Adjustment for Congenital Heart Surgery, version 1 (RACHS-1) complexity scores.[15,16] RACHS-1 is a validated risk stratification system with six levels of expected short-term mortality, and has been used with ICD-9-CM diagnoses and procedure codes.[15,17] Procedures in patients ≥ 18 years of age, cardiac transplant, and patent ductus arteriosus closure in premature infants and infants ≤ 30 days old as the only cardiac procedure were ineligible for RACHS-1 risk category. We chose RACHS-1 as a measure of surgical complexity because it can be applied to ICD-9-CM codes, which are the procedural data available within the KID. Other well-validated measures of congenital heart surgical complexity, such as the Society of Thoracic Surgeons/European Association for Cardiothoracic Surgery Congenital Heart Surgery Mortality (STAT) categories, are assigned from clinical information not accessible in this administrative database.

Outcomes

We examined in-hospital mortality and LOS for neonates, infants, and children undergoing RACHS-1 complexity level-eligible congenital heart surgery. The cohort was divided into 3 groups based on age at admission: neonates (younger than 30 days), infants (30 days to 1 year), and children (1 to 17 years of age). Because LOS was highly age-dependent, reflecting the overall increased complexity of neonates who require cardiac surgery, these three cohorts were analyzed separately for LOS. For in-hospital mortality, the infant cohort was combined with the children cohort because the low mortality rate and similar distributions of in-hospital mortality across race/ethnicity categories in these two age groups.

Variables

The primary exposure variable was race/ethnicity (“race”) with mutually exclusive categories of white, black, Hispanic, Asian/Pacific Islander and Other (including Native American and multiracial). To examine in-hospital mortality, Asians were merged with the “Other” group due to the limited number of outcome events and KID DUA reporting requirements for small cell sizes. For LOS, the Asian/Pacific Islander group was analyzed as a separate group. Primary insurance payer, as identified by the KID, included Medicare, Medicaid, private insurance, self-pay, no charge, and other. Due to small sample size of the Medicare group (N = 28), Medicare was combined with Medicaid (N = 6151), as a category of government sponsored payer, and three groups (self-pay [N = 211], no charge [N = 32], and other [N = 948]) were combined into “Other”. Thus, insurance payer categories included government-sponsored, private insurance, and “Other”. Other variables included gender, primary insurance payer, elective admission status, whether any Emergency Department (ED) codes are associated with the admission, income quartiles by ZIP code, presence of major non-cardiac structural defect, number of chronic conditions, presence of any genetic abnormality, presence of any hospital-acquired or medical injury, volume of RACHS-1 eligible major congenital heart surgeries for each hospital (<150, 150 to 250, 250 to 350, and > 350 cases per year), premature birth (gestational age <37 weeks) for neonates and age at

admission for older children (1 to 17 years for length of stay, 30 days to 17 years for in-hospital mortality).

Income quartile by ZIP code variable represents a classification of estimated median household annual income in the patient's ZIP code. For 2012, quartile 1 represents $1 to 38,999, quartile 2 represents $ 39,000 to 47,999, quartile 3 represents $48,000 to 62,999, and quartile 4 represents $63,000 and above.[18] Major non-cardiac structural anomalies included ICD-9-CM codes for central nervous system, airway, gastrointestinal, and renal congenital anomalies sometimes associated with CHD, and which may contribute to mortality and morbidity (See Table 1.).[16] Number of chronic conditions is a continuous variable defined within the KID, using a chronic condition indicator for ICD-9 diagnoses codes. A chronic condition is defined as a condition that lasts 12 months or longer and meets one or both of the following tests: (a) it places limitations on self-care, independent living, and social interactions; (b) it results in the need for ongoing intervention with medical products, services, and special equipment. Genetic abnormalities were identified through ICD-9-CM diagnoses codes. Hospital-acquired or medical injuries, as defined by the Wisconsin Medical Injury Prevention Program (WMIPP), were identified through ICD-9-CM diagnoses codes.[19, 20] The WMIPP defines categories of medical injuries and complications, including medication-related, device/implant/graft-related, procedural, miscellaneous injuries, and “not elsewhere specified” complications including radiation-related. WMIPP injuries and complications were defined as a dichotomous variable indicating the presence of at least one complication, although some patients experienced more than one complication. Hospital volume was determined by the number of RACHS-1 eligible congenital heart surgical discharges by unique hospital number.

Statistical Analysis

The primary outcomes were in-hospital mortality and LOS. Generalized linear regression methods for complex survey data were used. Because the KID uses a complex sampling design, sampling weights supplied in the KID were utilized to obtain valid standard errors. More specifically, multivariable logistic regression models with sample weights, stratification and clustering were used to assess the effects of race and other risk factors on in-hospital mortality. For LOS, multivariable linear regression models with sample weights, stratification and clustering were used to assess the association of race and other risk factors on hospital LOS. LOS was analyzed after the logarithmic transformation, log (LOS+1), to correct skewness in the distribution of LOS. For ease of interpretation, we also provide results for LOS in days in its original scale, without logarithmic transformation. SAS version 9.4 procedures SURVEYLOGISTIC and SURVEYREG (SAS Institute, Cary, NC) were used for analysis. Two-sided tests with $p < 0.05$ were considered statistically significant.

Results

Baseline Characteristics of the Cohort and Outcomes

Demographics and clinical characteristics for all admissions are summarized in Table 2, stratified by each age cohort. There were 13,130 eligible admissions. Among those

admissions, 2,945 were neonates (< 30 days of age), 4,524 were infants (aged 30 days to 1 year), and 5,661 were children (1 to 17 years old).

Within the entire cohort, 45.8% were whites, 10.9% were blacks, 18.8% were Hispanics, 3.6% were Asians or Pacific Islanders, 8.2% were Other race, and 12.7% were missing race and ethnicity information. Race and ethnicity are not reported to HCUP from all 44 participating states, or may be missing. Forty seven percent of admissions were covered under government-sponsored insurance, 43.7% were under private insurance, 9.1% were covered by other insurance, and 0.2% were missing primary payer information.

Premature birth was identified in 11.7% of neonatal admissions, 2.3% of infants, and none of the children. This reflects coding practices in non-neonates and not actual differences between groups, so premature birth was included in regression modeling only in the neonates. Genetic conditions were identified in 8.4% of neonates, 23.9% of infants, and 7.5% of children. The most commonly identified genetic condition was Trisomy 21 (73.4% of all genetic conditions).

The average unadjusted mortality rate was 3% for the entire cohort (8.7% for neonates, 1.9% for infants, and 0.9% for children). Unadjusted mortality rate by race/ethnic group was 2.55% for white patients, 3.92% for black patients, 3.2% for Hispanic patients, 3.09% for “other” group patients, and 3.29% for those missing race/ethnic information. The mean LOS was 17.8 days for the entire cohort (40.9 days for neonates, 15.4 days for infants, and 7.8 days for children). Details for all characteristics and outcomes can be found in Table 2.

In-Hospital Mortality

Neonates—There were no differences in mortality across all race and ethnicity groups. Factors associated with increased mortality included female gender (OR=1.40, p=0.0101), government-sponsored insurance (OR=1.51, p=0.0055) compared to private insurance, premature birth (OR=1.86, p=0.0016), RACHS-1 category 2 (OR 0.30, p = 0.0148) compared to RACHS-1 category 1, and increased number of chronic conditions (OR=1.20 per each additional chronic condition, p<0.0001). No significant differences in mortality were found by other RACHS-1 categories and other variables. See Table 3 for details.

Older cohort: 30 days to 17 years of age—No differences in mortality were found across all race and ethnicity groups in patients 30 days to 17 years old. Older children had lower risk of mortality (OR=0.93 per 1 year increase, p = 0.0368). Mortality was significantly associated with non-elective admissions (OR = 1.74, p = 0.0092), increased number of chronic conditions (OR = 1.46 per each additional chronic condition, p < 0.0001), absence of genetic abnormality (OR = 1.70, p = 0.0343), and the presence of any hospital-acquired or medical injury code (OR = 2.55, p < 0.0001). Higher RACHS-1 score (3 to 6) was associated with a 2 to nearly 7 fold increase in the odds of death, compared to patients with a RACHS-1 score of 1. Details can be found in Table 3.

Length of Stay

Neonates—Black neonates had a longer LOS (Estimate = 8.73 [days], p = 0.0034) compared to white neonates; no other differences were found in any other race and ethnicity

categories. Longer LOS was also associated with female gender (Estimate = 3.29, p = 0.0106), government-sponsored insurance (Estimate = 4.26, p = .0009), and first income quartile (Estimate= 4.58, p = 0.0325) compared to fourth quartile. Additional factors associated with increased LOS included the presence of major non-cardiac congenital abnormalities (Estimate = 15.34, p < 0.0001), premature birth (Estimate = 16.70, p < 0.0001), increased number of chronic conditions (Estimate = 8.39 each additional chronic condition, p < 0.0001), any genetic abnormality (Estimate = 3.01, p = .011), presence of any hospital-acquired or medical injury (Estimate = 6.77, p < 0.0001), and admissions within smaller programs (volume < 150 cases vs. >350 cases per year, Estimate = 11.34, p < .0.001, volume 150-250 cases vs > 350 cases, Estimate = 7.39, p = 0.0298). Details can be found in Table 4a.

Infants—Black infants had longer LOS (blacks: Estimate = 1.10, p = 0.0253) compared to white infants. Admissions under government-sponsored insurance had a longer LOS than private insurance (Estimate = 1.52, p = 0.0181). Other factors associated with longer LOS were non-elective admissions (Estimate = 13.92, p < 0.0001), presence of major non-cardiac congenital abnormalities (Estimate = 7.86, p < 0.0001), increased number of chronic conditions (Estimate = 3.60 per unit increase, p < 0.0001), absence of genetic abnormality (Estimate = 5.53, p < 0.0001), presence of any hospital-acquired or medical injury (Estimate = 5.29, p < 0.0001), and higher RACHS-1 category (all $p < 0.001$ for each RACHS-1 category). See details in Table 4b.

Children—No race and ethnicity differences were found for LOS in children. Older age was associated with shorter LOS (Estimate = -0.26 per 1 year older, p < 0.0001). Longer LOS was associated with non-elective admissions (Estimate = 6.00, p < 0.0001), increased number of chronic conditions (Estimate = 1.87 per unit increase, p < 0.0001), absence of genetic abnormality (Estimate = 2.87, p < 0.0001), presence of any hospital-acquired or medical injury (Estimate = 2.79, p < 0.0001), and higher RACHS-1 category (all $p < 0.001$ for each RACHS-1 category, compared to RACHS-1 category 1. See details in Table 4c.

Effect of insurance type on surgical complexity, chronic conditions, and medical injuries

Because the effect of insurance type on LOS in neonates and infants was significant, we further analyzed differences between insurance types and surgical complexity, as well as number of chronic conditions, and the incidence of any medical injury or complication (See Table 5). Differences between insurance groups were tested using Chi-square for categorical variables and one-way ANOVA for continuous variables. We defined higher surgical complexity as operations within RACHS-1 category 4, 5, or 6 because of the small number of RACHS-1 category 5 or 6 procedures performed outside of the neonatal period. Neonates with government-sponsored insurance and “other” insurance did not have a higher percentage of RACHS-1 category 4, 5 or 6 procedures compared to neonates with private insurance. There were no also significant differences in neonates between insurance type and the incidence of medical complications and injuries. However, neonates with government-sponsored and “other” insurance had more chronic conditions (mean 3.23 ± 1.99 and 3.29 ± 2.12, respectively) than neonates with private insurance (mean 3.02 ± 1.99, p = 0.006).

In the infant group, patients with “other” insurance had increased incidence of medical injuries or complications (35.0% versus 29.2% and 28.4%, p = 0.030). In both infants and children, there were no significant differences in RACHS-1 surgical complexity between patients with different insurance types. However, infants and children with government-sponsored or “other” insurance had significantly more chronic conditions than those with private insurance (infants 3.45 ± 1.99, 3.65 ± 2.12, versus 3.33 ± 1.99, respectively, p = 0.009, and child group 2.83 ± 1.90, 2.98 ± 2.29, versus 2.72 ± 1.80, respectively, p = 0.005).

Sensitivity Analysis

Two sensitivity analyses were conducted. The first sensitivity analysis used the raw length of stay as outcome. The second sensitivity analysis removed admissions that were missing patients' race and ethnicity information, as opposed to a separate category of “missing” race/ethnicity. The results were quite similar and the conclusion remained unchanged (results not shown).

Discussion

This study reports changes in the effect of race/ethnicity on in-hospital mortality and LOS in children from the United States who were hospitalized following congenital heart surgery in 2012. In-hospital mortality was not different between racial/ethnic groups in either age cohort. The lack of racial and ethnic differences in mortality in our study is in contrast to previous studies.[3–5] The low overall incidence of mortality (3.0%) could have contributed to the difficulty of assessing the significance between racial/ethnic groups, however, this overall mortality rate is similar to previous studies that did identify racial/ethnic disparities in mortality. One possible explanation for our findings is that the effect of non-elective admissions, chronic conditions and medical injuries/complications on mortality reduced the impact of race and ethnicity on mortality in multivariate analysis, since there were differences in unadjusted mortality between racial/ethnic groups. Other large database studies that have reported racial/ethnic disparities in congenital heart surgery outcomes have used different variables in their regression analyses, such as not including insurance type or complications, or have asked slightly different research questions, which may lead to different results.[2,3,5] Given that the KID accounts for only in-hospital mortality, it is also possible that racial/ethnic disparities in mortality would be evident in longer term survival analysis. Another hypothesis for our findings is that improvements in health care access and increased availability of health insurance may have reduced racial/ethnic disparities in congenital heart surgery mortality. While one study is certainly not sufficient to make this conclusion, our results raise this question and warrant further investigation by other researchers, using other sources of data.

Increased congenital heart surgery mortality in females has been reported in previous studies. One study also using the KID reported increased adjusted risk of in-hospital death for females who underwent congenital heart surgery (OR 1.21, 95% CI 1.08-1.36), which was due to increased mortality for high risk procedures in neonates.[21] Another study using the Pediatric Cardiac Care Consortium also found female sex as a risk factor for both 30 day and in-hospital mortality (p = 0.002, and 0.001, respectively) due to increased mortality in

females during the first 6 months of life and for RACHS-1 category 3 to 6 procedures, thought due to sex differences in cardiac metabolism noted in animal studies.[22] However, Dibardino and colleagues did not find sex differences in congenital heart surgery mortality, after adjusting for age and other clinical factors.[3] Our results support previous findings of increased mortality in female neonates undergoing high-risk congenital heart surgery.

Increasing RACHS-1 complexity score was not associated with increased neonatal mortality. RACHS-1 has been validated as a congenital heart surgical mortality predictor, but associated neonatal co-morbidities may play more of a role in outcomes than the complexity of the cardiac surgical repair.[15,17,23] Simsic and colleagues found that RACHS-1 complexity score was not predictive of in-hospital mortality in a study of neonates who underwent congenital heart surgery.[24] RACHS-1 complexity was validated as a predictive tool for the spectrum of congenital heart surgery, and not specifically to predict mortality in individual, high-risk groups. In this study, RACHS-1 complexity score was a highly significant predictor of non-neonatal mortality and LOS in all age groups.

Income quartile by ZIP code was not associated with mortality or LOS in any age group, except for neonatal LOS in the first income quartile, compared to the fourth income quartile. Government-sponsored insurance was associated with increased risk of mortality in neonates, but not in older children. Government-sponsored insurance was also associated with increased LOS in the neonatal and infant age groups. Many other studies have reported that Medicaid insurance and nonwhite race were associated with increased CHD surgical mortality and/or LOS.[3–6,8] One explanation for the association of government-sponsored insurance and neonatal mortality, as well as LOS in neonates and infants, is expansion of government-sponsored insurance programs to provide healthcare to low income children, and especially to children with chronic illnesses. Since passage of the State Children's Health Insurance Program (SCHIP) in 1997, federal assistance has been provided to states to increase health insurance availability to children from families whose incomes exceeded Medicaid thresholds but who could not afford private health insurance, through expansion of Medicaid or development of new programs.[25] As a result, the proportion of children covered under Medicaid in the US increased from 21.4% in 1997 to 42.0% in 2012, while the proportion of uninsured children decreased from 13.9% to 6.6% during the same time.[25] This increase in Medicaid enrollment was also seen in Chan's study of the effect of race and insurance type on congenital heart surgery mortality using the KID from 3 successive triennial samples; the percentage of children covered by Medicaid increased from 33.5% in 1997 to 34.7% in 2000 and 38.5% in 2003.[5] Children with one or more chronic illnesses accounted for 5.8% of children covered by Medicaid in one study, and almost 19% of children in that study had a cardiovascular chronic condition.[26] Our study did not find differences in surgical complexity or incidence of medical injuries/complications by insurance type, but we did find that neonates, infants, and children with government-sponsored or “other” insurance had significantly more chronic conditions than those with private insurance. We hypothesize that our findings related to disparities in LOS are explained by increased number of chronic conditions in the group with government-sponsored insurance, due to increased coverage of children with medical complexity by Medicaid programs.

Chronic conditions were strongly associated with increased mortality and increased LOS in all age groups. Chronic conditions are identified within the KID through an algorithm based on ICD-9-CM codes developed by Hwang.[27] A review of childhood chronic illness identified that chronic illness incidence had quadrupled from 1960 to 2005, and that children from racial/ethnic minorities were 1.5 to 2 times more likely to have a major chronic illness such as asthma, diabetes, cancer, obesity, hypertension, dental disease, mental illness, or a congenital condition.[28] Non-genetic complex chronic conditions have been associated with increased mortality, LOS and complications following congenital heart surgery.[29]

Medical injuries, as defined by WMIPP criteria, were not associated with increased neonatal mortality, but were strongly associated with increased non-neonatal mortality and with increased LOS in all age groups. We did not examine FTR specifically, because it is difficult to identify the temporality of injury diagnoses to procedures in an administrative dataset. It is clear that medical injuries and complications are extremely important in hospital mortality and LOS; other studies have demonstrated racial/ethnic disparities in incidence of medical injuries and complications.[1,2,30]

Concomitant genetic abnormality was associated with a decreased risk of mortality in the 30 day to 17 year old group, but had an age-dependent effect on LOS. Genetic abnormality was associated with longer LOS in the neonatal group, but with a shorter LOS in the infant group as well as the child age group. Trisomy 21 was the most common genetic condition identified (N = 1286, 73.4% of all genetic diagnoses). In other studies, Trisomy 21 has been associated with decreased or similar mortality but increased or similar LOS following CHD surgery, compared to patients with normal karyotype.[31,32] Reduced mortality in Trisomy 21 patients may be related to many factors but without examining the comparative anatomy of each Trisomy 21 patient and their surgical therapy, any discussion would be speculative. Chan and colleagues found varying effects of genetic chronic conditions on congenital heart surgery outcomes, depending on whether the genetic condition was associated with other non-genetic chronic conditions, but genetic conditions by themselves were not associated with increased mortality, LOS, or complications.[29] It is possible that infants and children in this study with genetic abnormalities also had additional chronic conditions that contributed to their increased LOS, or that coding of genetic or other comorbid conditions differs between age groups.

This study has several limitations that should be considered. Administrative databases have known drawbacks related to miscoding, as well as lack of control over the data points. However, the ability to obtain large sample sizes of rare conditions (including CHD) in a cost-effective manner makes administrative databases an important tool for outcomes research.[33] We utilized established methodology to assign RACHS-1 complexity scores, non-cardiac congenital anomalies, and medical injuries/complications to the available ICD-9-CM codes in order to be consistent with previous studies utilizing administrative data. In addition, the 3% overall mortality rate in this study is congruent with the 3.1% average 4 year mortality rate reported by the Society of Thoracic Surgeons Congenital Heart Surgery Database 2011-2015 Executive Summary.[34] Missing racial/ethnic demographic information in 12.7% of the records is an important limitation, but sensitivity analysis indicated that the group missing race/ethnicity was not significantly different from those

with race/ethnicity information. In addition, the proportion of entries missing race/ethnicity information in the 2012 KID is not substantially different from previous KID studies. We did not use multiple imputation for missing race/ethnicity information because disclosure of race/ethnicity information is voluntary and therefore the incomplete data is likely not missing at random.

Our results suggest that racial/ethnic disparities in congenital heart surgery mortality may be improving, and that racial/ethnic disparities in LOS may be related to insurance coverage that is driven partly by medical complexity and chronic conditions. Other risk factors for morbidity and mortality in the neonatal population may be related to CHD complexity and preoperative conditions, and may therefore be more amenable to modification by prenatal interventions that improve maternal health and access to prenatal care, as well as early recognition and management of suspected CHD in the neonatal period. The role of newborn pulse oximetry screening for critical congenital heart disease in reducing racial/ethnic disparities has yet to be determined, but this technology holds promise to improve recognition of severe CHD. In all age groups, chronic medical conditions and hospital-acquired or medical injuries were also highly important factors predicting mortality and LOS. Racial/ethnic disparities in both chronic conditions and medical injuries/complications are reported.

In conclusion, this study reports a lack of racial and ethnic disparities in congenital heart surgical mortality, in contrast to previous studies. Future research and other independent analyses are required to validate whether improvements in CHD care mean that mortality may no longer be an effective outcome to measure racial/ethnic disparities. Changes in eligibility for government-sponsored insurance have impacted the distribution of public and private insurance for children with CHD, and these changes also reflect the complexity of care that some children with CHD require. Our findings also support continued disparities in LOS following congenital heart surgery in black neonates and infants. Irrespective of mortality, focusing on specific quality outcomes including incidence of major morbidity, readmission rate, and LOS may give us more insight into the deeper mechanisms of racial and ethnic disparities in this patient population. It would be beneficial to also study other factors that are not contained in large clinical or administrative databases, such as prenatal care, access to cardiology care, age at diagnoses, management of chronic conditions, and the effect of significant postoperative residual lesions such as aortic arch obstruction or valvar regurgitation.

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Table 1
Major Non-Cardiac Structural Abnormalities and ICD-9-CM Codes

740.0 Anencephalus
740.1 Craniorachischisis
740.2 Iniencephaly
741.0 Spina bifida, with hydrocephalus
741.9 Spina bifida, without mention of hydrocephalus
742.0 Encephalocele
742.1 Microcephalus
742.2 Reduction deformities of brain
742.3 Congenital hydrocephalus
742.4 Other specified anomalies of brain
742.5× Other specified anomalies of spinal cord
742.9 Unspecified anomaly of brain, spinal cord, and nervous system
748.0 Choanal atresia
748.2 Web of larynx
748.3 Other anomalies of larynx, trachea, and bronchus
748.4 Congenital cystic lung
749.0× Cleft palate
749.1× Cleft lip
749.2× Cleft palate with cleft lip
750.3 Tracheoesophageal fistula, esophageal atresia and stenosis
751.1 Atresia and stenosis of small intestine
751.2 Atresia and stenosis of large intestine, rectum, and anal canal
751.4 Anomalies of intestinal fixation
751.61 Biliary atresia
753.0 Renal agenesis and dysgenesis
753.15 Cystic kidney disease, renal dysplasia
753.2 Obstructive defects of renal pelvis and ureter
753.5 Exstrophy of urinary bladder
756.6 Anomalies of diaphragm
756.7 Anomalies of abdominal wall

Source:
Standardized Mortality Ratio for Congenital Heart Surgery, Risk Adjustment for Congenital Heart Surgery (RACHS-1) Adjusted. 2009. www.qualityforum.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=40662. Accessed July 5, 2016.

Table 2

Characteristics of study cohorts

Variable	Neonates (N=2945)		Infants 30d-1y (N=4524)		Children 1-17 y (N=5661)		Overall (N=13130)	
	Count*/mean	%[1]/std	Count/mean	%/std	Count/mean	%/std	Count/mean	%/std
Age (in years)	--	--	--	--	6.2	4.9	2.7	4.4
Length of stay (in days)	40.9	43.4	15.4	24.1	7.8	11.6	17.8	29.0
Length of stay (days) (median, IQR)	26 (15-49)		8 (5-14.5)		5 (3-8)		8 (4-18)	
Hospital death								
No	2688	91.3	4440	98.1	5611	99.1	12739	97.0
Yes	257	8.7	84	1.9	50	0.9	391	3.0
Gender								
Male	1718	58.3	2423	53.6	3063	54.1	7204	54.9
Female	1225	41.6	2101	46.4	2598	45.9	5924	45.1
Missing	†		†		†			
Elective admission								
Missing	†		†		12	0.2	1†8	0.1
Non-elective	2689	91.3	1110	24.5	449	7.9	4248	32.4
Elective	255	8.7	3409	75.4	5200	91.9	8864	67.5
Any ED codes in this admission								
No	2852	96.8	4253	94.0	5566	98.3	12671	96.5
Yes	93	3.2	271	6.0	95	1.7	459	3.5
Primary payer								
Government-sponsored	1490	50.6	2226	49.2	2463	43.5	6179	47.1
Private Insurance	1243	42.2	1892	41.8	2599	45.9	5734	43.7
Other	208	7.1	397	8.8	586	10.4	1191	9.1
Missing	†		†		13	0.2	26	0.2
Race/ethnicity								
White	1271	43.2	2047	45.2	2689	47.5	6007	45.8
Black	297	10.1	506	11.2	626	11.1	1429	10.9
Hispanic	555	18.8	828	18.3	1089	19.2	2472	18.8
Asian/Pacific Islander	92	3.1	173	3.8	208	3.7	473	3.6

Variable	Neonates (N=2945)		Infants 30d-1y (N=4524)		Children 1-17 y (N=5661)		Overall (N=13130)	
	Count*/mean	%[1]/std	Count/mean	%/std	Count/mean	%/std	Count/mean	%/std
Other including Native American	302	10.3	396	8.8	380	6.7	1078	8.2
Missing	428	14.5	574	12.7	669	11.8	1671	12.7
Median household income by national quartile for ZIP code								
First quartile	835	28.4	1211	26.8	1470	26.0	3516	26.8
Second quartile	793	26.9	1158	25.6	1444	25.5	3395	25.9
Third quartile	729	24.8	1120	24.8	1345	23.8	3194	24.3
Fourth quartile	545	18.5	947	20.9	1256	22.2	2748	20.9
Missing	43	1.5	88	1.9	146	2.6	277	2.1
Major non-cardiac congenital anomalies								
No	2523	85.7	4156	91.9	5491	97.0	12170	92.7
Yes	422	14.3	368	8.1	170	3.0	960	7.3
Number of chronic conditions	3.1	1.9	3.4	2.0	2.8	1.9	3.1	1.9
Premature birth								
Term gestation	2601	88.3	4421	97.7	5661	100.0	12683	96.6
Premature birth	344	11.7	103	2.3	†		447	3.4
Risk-Adjustment for Congenital Heart Surgery (RACHS-1) category								
1	67	2.3	359	7.9	1219	21.5	1645	12.5
2	353	12.0	2257	49.9	1668	29.5	4278	32.6
3	1254	42.6	1744	38.5	2483	43.9	5481	41.7
4	702	23.8	137	3.0	280	4.9	1119	8.5
5 and 6	569	19.3	27	0.6	11	0.2	607	4.6
Any genetic abnormality								
No	2698	91.6	3441	76.1	5238	92.5	11377	86.6
Yes	247	8.4	1083	23.9	423	7.5	1753	13.4
Any hospital-acquired or medical injury								
No	1717	58.3	3196	70.6	3902	68.9	8815	67.1
Yes	1228	41.7	1328	29.4	1759	31.1	4315	32.9
Geographic region of hospital								
Northeast	465	15.8	735	16.2	954	16.9	2154	16.4
Midwest	727	24.7	1099	24.3	1423	25.1	3249	24.7

Variable	Neonates (N=2945)		Infants 30d-1y (N=4524)		Children 1-17 y (N=5661)		Overall (N=13130)	
	Count*/mean	%[1]/std	Count/mean	%/std	Count/mean	%/std	Count/mean	%/std
South	1063	36.1	1551	34.3	1961	34.6	4575	34.8
West	690	23.4	1139	25.2	1323	23.4	3152	24.0
Volume of congenital heart surgery cases per year								
< 150 cases per year	1403	47.6	2299	50.8	2979	52.6	6681	50.9
150-250 cases per year	1003	34.1	1449	32.0	1665	29.4	4117	31.4
250-350 cases per year	166	5.6	216	4.8	246	4.3	628	4.8
>350 cases per year	373	12.7	560	12.4	771	13.6	1704	13.0

*Given are count/frequency and percent (%) for categorical variables; mean and standard deviation (std) for continuous variables. ED = Emergency Department

†HCUP DUA prohibits reporting of fewer than 11 observations

Table 3

Factors associated with in-hospital mortality in neonates and patients 30 days to 17 years old

Variables	Neonates				30d-17y			
	OR*	95%CI†		p value	OR*	95% CI†		p value
Age (in years)	N/A	--	--	--	0.93	0.87	1.00	0.0368
Race/ethnicity								
White	ref	--	--	--	ref	--	--	--
Blacks	1.17	0.78	1.77	0.4392	1.55	0.92	2.59	0.0978
Hispanic	0.78	0.53	1.16	0.2277	1.45	0.86	2.43	0.1610
Other including Native American/ Asian/Pacific Islander	0.99	0.60	1.64	0.9672	1.59	0.86	2.94	0.1385
Missing	1.44	0.93	2.22	0.1034	1.14	0.53	2.45	0.7448
Gender								
Male	ref	--	--	--	ref	--	--	--
Female	1.40	1.08	1.80	0.0101	1.06	0.70	1.59	0.7869
Primary payer								
Government-sponsored	1.51	1.13	2.03	0.0055	1.24	0.82	1.89	0.3125
Private Insurance	ref	--	--	--	ref	--	--	--
Other	1.49	0.94	2.36	0.0878	1.09	0.62	1.92	0.7580
Elective admission								
Nonelective	2.11	0.70	6.35	0.1861	1.74	1.15	2.65	0.0092
Elective	ref	--	--	--	ref	--	--	--
Median household income national quartile for ZIP code								
First quartile	1.06	0.68	1.63	0.8071	1.23	0.59	2.56	0.5727
Second quartile	0.92	0.62	1.36	0.6625	1.43	0.76	2.68	0.2695
Third quartile	0.68	0.42	1.11	0.1269	1.63	0.86	3.08	0.1367
Fourth quartile	ref	--	--	--	ref	--	--	--
Major non-cardiac congenital anomalies								
No	ref	--	--	--	ref	--	--	--
Yes	0.85	0.58	1.25	0.4224	1.10	0.61	2.00	0.7511
Premature birth								
Term gestation	ref	--	--	--				

Variables	Neonates				30d-17y			
	OR*	95% CI†		p value	OR*	95% CI†		p value
Premature birth	1.86	1.27	2.74	0.0016				
Risk-Adjustment for Congenital Heart Surgery (RACHS-1) score								
1	ref	--	--	--	ref	--	--	--
2	0.30	0.12	0.79	0.0148	1.16	0.51	2.66	0.7272
3	0.70	0.32	1.53	0.3703	1.95	0.98	3.89	0.0583
4	0.98	0.45	2.12	0.9609	3.08	1.11	8.57	0.0314
5 and 6	1.49	0.68	3.25	0.3160	6.62	1.53	28.7	0.0115
Number of chronic conditions	1.20	1.11	1.29	<0.0001	1.46	1.34	1.59	<0.0001
Any genetic abnormality								
No	1.39	0.79	2.47	0.2537	1.70	1.04	2.78	0.0343
Yes	ref	--	--		ref	--	--	
Any injury code (WMIPP)								
No	ref	--	--	--	ref	--	--	--
Yes	1.35	0.96	1.91	0.0851	2.55	1.62	4.01	<0.0001
Congenital heart surgery volume								
< 150 cases per year	1.29	0.78	2.16	0.3216	1.18	0.63	2.20	0.5988
150-250 cases per year	0.81	0.46	1.43	0.4707	0.61	0.28	1.31	0.2061
250-350 cases per year	0.55	0.29	1.06	0.0726	0.89	0.24	3.28	0.8671
>350 cases per year	ref	--	--	--	ref	--	--	--

*OR = odds ratio;

†95% confidence interval; ref = reference group WMIPP = Wisconsin Medical Injury Prevention Program.

Table 4a

Factors associated with (log of) length of stay in neonates

	LOS (days)*	Estimate Log (LOS +1)*	95% CI*		P value*
Intercept	1.43	2.64	2.47	2.82	<0.0001
Race/ethnicity					
White	ref†	ref†	--	--	--
Black	8.73	0.15	0.05	0.25	0.0034
Hispanic	0.41	0.00	-0.09	0.09	0.9380
Asian/Pacific Islander	0.97	0.04	-0.10	0.18	0.5665
Other including Native American	1.11	0.08	-0.02	0.17	0.1077
Missing	2.10	-0.01	-0.13	0.11	0.9033
Gender					
Male	ref†	ref†	--	--	--
Female	3.29	0.07	0.02	0.12	0.0106
Primary payer					
Government-sponsored	4.26	0.11	0.04	0.17	0.0009
Private Insurance	ref†	ref†	--	--	--
Other	1.62	0.03	-0.06	0.11	0.5419
Admission type					
Non-elective	ref†	ref†	--	--	--
Elective	-4.93	-0.20	-0.32	-0.08	0.0008
Median household income national quartile for ZIP code					
First quartile	4.58	0.08	0.01	0.16	0.0325
Second quartile	2.48	0.02	-0.05	0.10	0.5944
Third quartile	0.17	0.00	-0.07	0.07	0.9979
Fourth quartile	ref†	ref†	--	--	--
Major non-cardiac congenital anomalies					
No	ref†	ref†	--	--	--
Yes	15.34	0.29	0.21	0.36	<0.0001
Premature birth					

	LOS (days)*	Estimate Log (LOS +1)*	95% CI*		P value*
Term gestation	ref†	ref†	--	--	--
Premature birth	16.70	0.33	0.23	0.44	<0.0001
Risk-Adjustment for Congenital Heart Surgery (RACHS-1) score					
1	ref†	ref†	--	--	--
2	-1.58	-0.13	-0.35	0.09	0.2622
3	-0.52	0.09	-0.12	0.30	0.3852
4	-4.51	0.03	-0.20	0.25	0.8118
5 and 6	4.80	0.33	0.12	0.54	0.0020
Number of chronic conditions	8.39	0.18	0.16	0.19	<0.0001
Any genetic abnormality					
No	ref†	ref†	--	--	--
Yes	3.01	0.13	0.03	0.23	0.0110
Any hospital-acquired or medical injury code (WMIPP)					
No	ref†	ref†	--	--	--
Yes	6.77	0.14	0.08	0.20	<0.0001
Congenital heart surgery volume					
< 150 cases per year	11.34	0.24	0.13	0.35	<0.0001
150-250 cases per year	7.39	0.13	0.01	0.25	0.0298
250-350 cases per year	5.01	0.04	-0.08	0.16	0.4914
>350 cases per year	ref†	ref†	--	--	--

*Given are point estimate LOS, without logarithmic transformation for ease of interpretation, as well as point estimate of log (LOS +1) with corresponding 95% confidence intervals and p value;

†reference group; WMIPP = Wisconsin Medical Injury Prevention Program.

Table 4b

Factors associated with (log of) length of stay in infants 30 days to 1 years old

Variables	LOS (days)*	Estimate log (LOS +1)*	95% CI*		P value*
Intercept	31.47	2.73	2.28	3.17	<0.0001
Age (in years)					
Race/ethnicity					
White	ref†	ref†	--	--	--
Black	1.10	0.08	0.01	0.14	0.0253
Hispanic	0.26	0.05	-0.02	0.12	0.1894
Asian/Pacific Islander	0.19	0.01	-0.08	0.10	0.8472
Other including Native American	-0.33	0.00	-0.07	0.07	0.9929
Missing	0.76	0.02	-0.13	0.17	0.7846
Gender					
Male	ref†	ref†	--	--	--
Female	-0.38	0.02	-0.02	0.06	0.3653
Primary payer					
Government-sponsored	1.52	0.05	0.01	0.10	0.0181
Private Insurance	ref†	ref†	--	--	--
Other	-1.15	-0.04	-0.12	0.04	0.3458
Admission type					
Non-elective	ref†	ref†	--	--	--
Elective	-13.92	-0.67	-0.76	-0.59	<0.0001
Median household income national quartile for ZIP code					
First quartile	0.89	0.03	-0.04	0.09	0.4297
Second quartile	-0.97	0.01	-0.05	0.06	0.8034
Third quartile	-0.88	-0.03	-0.08	0.02	0.2834
Fourth quartile	ref†	ref†	--	--	--
Major non-cardiac congenital anomalies					
No	ref†	ref†	--	--	--
Yes	7.86	0.21	0.11	0.30	<0.0001

Variables	LOS (days)*	Estimate log (LOS +1)*	95% CI*		P value*
Premature birth					
Term gestation	ref†	ref†	--	--	--
Premature birth	10.43	0.24	0.07	0.41	0.0063
Risk-Adjustment for Congenital Heart Surgery (RACHS-1) score					
1	ref†	ref†	--	--	--
2	1.41	0.17	0.10	0.23	<0.0001
3	5.54	0.34	0.27	0.41	<0.0001
4	4.85	0.37	0.24	0.51	<0.0001
5 and 6	23.00	0.71	0.35	1.07	<0.0001
Number of chronic conditions	3.60	0.16	0.14	0.17	<0.0001
Any genetic abnormality					
No	ref†	ref†	--	--	--
Yes	-5.53	-0.19	-0.24	-0.14	<0.0001
Any hospital-acquired or medical injury code (WMIPP)					
No	ref†	ref†	--	--	--
Yes	5.29	0.23	0.17	0.29	<0.0001
Congenital heart surgery volume					
< 150 cases per year	0.60	0.00	-0.13	0.12	0.9381
150-250 cases per year	-0.96	-0.06	-0.17	0.06	0.3234
250-350 cases per year	0.88	-0.01	-0.19	0.18	0.9311
>350 cases per year	ref†	ref†	--	--	--

*Given are point estimate LOS, without logarithmic transformation for ease of interpretation, as well as point estimate of log (LOS +1) with corresponding 95% confidence intervals and p value;

†reference group; WMIPP = Wisconsin Medical Injury Prevention Program.

Table 4c

Factors associated with (log of) length of stay in children 1 to 17 years of age

	LOS (days)*	Estimate log (LOS +1)*	95% CI*		P value*
Intercept	13.71	2.43	2.13	2.73	<0.0001
Age (in years)	-0.26	-0.02	-0.02	-0.01	<0.0001
Race/ethnicity					
White	ref†	ref†	--	--	
Black	0.40	0.02	-0.03	0.08	0.3872
Hispanic	-0.10	-0.01	-0.07	0.05	0.8024
Asian/Pacific Islander	0.25	0.04	-0.02	0.10	0.1475
Other including Native American	-0.19	0.00	-0.07	0.07	0.9958
Missing	-.015	-0.04	-0.17	0.08	0.5186
Gender					
Male	ref†	ref†	--	--	
Female	0.00	-0.01	-0.04	0.02	0.5755
Primary payer					
Government-sponsored	0.64	0.01	-0.03	0.06	0.4889
Private insurance	ref†	ref†	--	--	
Other	0.53	0.05	-0.01	0.11	0.0934
Admission Type					
Non-elective	ref†	ref†	--	--	
Elective	-6.00	-0.37	-0.49	-0.24	<0.0001
Median household income national quartile for ZIP code					
First quartile	0.22	0.03	-0.02	0.08	0.2675
Second quartile	0.00	0.02	-0.02	0.07	0.3388
Third quartile	0.23	0.01	-0.03	0.05	0.7612
Fourth quartile	ref†	ref†	--	--	
Major non-cardiac congenital anomalies					
No	ref†	ref†	--	--	
Yes	1.89	0.04	-0.08	0.15	0.5302

	LOS (days)*	Estimate log (LOS +1)*	95% CI*		P value*
Risk-Adjustment for Congenital Heart Surgery (RACHS-1) score					
1	ref†	ref†	--	--	
2	0.88	0.14	0.10	0.18	<0.0001
3	4.07	0.46	0.41	0.50	<0.0001
4	2.82	0.33	0.26	0.40	<0.0001
5 and 6	6.53	0.74	0.55	0.94	<0.0001
Number of chronic conditions	1.87	0.12	0.11	0.13	<0.0001
Any genetic abnormality					
No	ref†	ref†	--	--	
Yes	-2.87	-0.21	-0.27	-0.14	<0.0001
Any hospital-acquired or medical injury code (WMIPP)					
No	ref†	ref†	--	--	
Yes	2.79	0.19	0.16	0.23	<0.0001
Congenital heart surgery volume					
< 150 cases per year	-0.39	0.02	-0.11	0.14	0.8004
150-250 cases per year	-0.99	-0.04	-0.17	0.09	0.5664
250-350 cases per year	1.02	0.07	-0.09	0.22	0.3989
> 350 cases per year	ref†	ref†	--	--	

*Given are point estimate LOS, without logarithmic transformation for ease of interpretation, as well as point estimate of log (LOS +1) with corresponding 95% confidence intervals and p value;

†reference group; WMIPP = Wisconsin Medical Injury Prevention Program.

Table 5
Insurance type and surgical complexity, medical injuries, and chronic conditions

	Government-sponsored insurance	"Other" insurance	Private insurance	P value*
RACHS-1 category 4 through 6 N (%)				
Neonates	651 (43.7%)	100 (48.1%)	517 (41.6%)	0.177
Infants	75 (3.4%)	16 (4.0%	73 (3.9%)	0.639
Children	111 (4.5%)	33 (5.6%)	147 (5.7%)	0.155
Any medical injury/complication N (%)				
Neonates	624 (41.9%)	502 (40.4%)	100 (48.1%)	0.112
Infants	651 (29.2%)	139 (35.0%)	537 (28.4%)	0.030
Children	740 (30.0%)	184 (31.4%)	834 (32.1%	0.288
Number of chronic conditions (mean, SD)				
Neonates	3.23 ± 1.88	3.29 ± 2.00	3.02 ± 1.82	0.006
Infants	3.45 ± 1.99	3.65 ± 2.12	3.33 ± 1.99	0.009
Children	2.83 ± 1.90	2.98 ± 2.29	2.72 ± 1.80	0.005

*P value for Chi-square test between groups with categorical variables (RACHS category 4-6, any medical injury/complications), one-way ANOVA for continuous variables (number of chronic conditions).