Association Between Race, Illness Severity, and Mortality in Children Undergoing Cardiac Surgery

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Abstract

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Background: Prior studies have demonstrated that non-white race/ethnicity and insurance status are associated with mortality after congenital heart surgery. It remains unknown whether non-white children have a higher mortality due to limited access to care, resulting in higher illness severity scores on admission. We hypothesize that non-white children undergoing congenital heart surgery have a higher severity of illness score on admission and, in turn, have higher odds of mortality than their white counterparts.

Methods: We performed a retrospective analysis of registry data from the Virtual Pediatric Systems dataset from 2009-2016. All children (less than 18 years of age) undergoing congenital

cardiac surgery and admitted to an intensive care unit (ICU) in one of the 81 participating institutions were included (n= 37,056).

Results: In a univariate analysis, there was significant variation in severity of illness scores across race/ethnicity groups. Multivariate regression models demonstrated a small but significant association between black race and higher severity of illness scores compared with white race, after adjustment for insurance status and other covariates. In multivariate models that examined ICU mortality, black patients remained at increased odds of mortality (Odds Ratio: 1.31, 95% Confidence Interval: 1.07-1.61) when compared with white children, adjusting for illness severity, age, gender, prematurity, weight, operating room (OR) status, number of complex chronic conditions, Risk Adjustment for Congenital Heart Surgery (RACHS) category, and type of insurance.

Conclusions: Black children undergoing cardiac surgery have higher odds of death compared with white children, despite adjustment for illness severity on admission to the ICU. These results suggest that severity of illness may not be the main driver of health disparities in children undergoing congenital heart surgery.

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Thesis

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Introduction

Congenital heart disease affects 40,000 children per year in the United States, with 25% requiring intervention within the first year of life.[1] Heart defects are the leading cause of infant mortality due to birth defects, accounting for 30% of all infant deaths due to birth defects.[1,2] Studies have shown that non-white race is associated with a higher risk of mortality after cardiac surgery in both adult and pediatric populations.[3–6] We aim to evaluate whether non-white race is associated with a higher severity of illness score on admission to the intensive care unit (ICU), and whether higher severity of illness is the mechanism by which non-white children have higher mortality.

In Figure 1, we present a conceptual model demonstrating our hypothesized role of severity of illness as a mediator in the causal pathway between race and mortality, adapted from Williams.[7] In our model, we hypothesize that race affects healthcare access and utilization, impacting the severity of illness on admission to the ICU due to delayed access to the health care system. As a result of a higher severity of illness on admission, patients go on to have a higher likelihood of morbidity and mortality, acting as a mediator between race and mortality. There are a number of other factors that we present in the model, including socioeconomic status, which can also affect access to the medical system, and other medical issues that a patient may encounter before their ICU admission. Additionally, the patient and family's direct interaction with the care team during an ICU stay has the potential to impact patient outcomes as well, which we have indicated in the post-admission hospital course.

Race/Ethnicity as a Predictor of Illness Severity

We hypothesize that patients from minority races/ethnicities will have higher severity of illness scores than their white counterparts due to barriers to accessing health care services (Figure 1). These disparities result in higher rates of unmet health care needs, lower rates of primary care services, and greater odds of delays in specialty care.[8] We hypothesize that these barriers may prevent children from accessing the health care system in a timely manner, leading to a greater severity of illness for non-white children on presentation to the health care system from delayed diagnoses or late presentations to care. In pediatric cardiology, inadequate prenatal care or lack of access to a primary care physician could lead to a delayed diagnosis of congenital heart disease. These access factors can be due to insurance limitations, parental difficulty in being excused from work to get to specialty appointments, or transportation to appointments that

may only be available at regionalized tertiary centers. Additionally, even if the diagnosis of congenital heart disease is made, frequent follow-up appointments with a cardiologist may be difficult for families who are non-white and of a lower socioeconomic status to consistently attend for the same reasons listed above. As a result, we expect patients of a minority race/ethnicity who require heart surgery to be more ill when they present to the ICU.

Several adult studies have examined the association between race/ethnicity and severity of illness at hospital admission, demonstrating that black patients present to the health care system with more physiologic derangements than white patients.[9–11] The association between race/ethnicity and severity of illness is present across a variety of adult populations, including general admission to the ICU[9], acute lung injury[10], and severe sepsis.[11] These studies suggest that differences in severity of illness scores on admission may be due to delays in either ICU admission or presentation to care.[9,10]

However, studies examining this relationship in the pediatric cardiac population are limited and inconsistent with the adult literature. Lopez et al examined variation in PICU outcomes by race, gender, and insurance status, and found that patients without insurance had significantly higher severity of illness on admission.[12] Boudreaux et al examined racial variation in disease severity of patients with asthma presenting to the emergency department, concluding that race was not associated with more severe asthma presentation.[13] In the pediatric cardiac literature, Ingaramo et al did not find significant racial variation in Pediatric Index of Mortality 2 scores in children undergoing Glenn and Fontan procedures for single ventricle congenital heart disease.[14] Based on the limited literature, the association between race and severity of illness on presentation to the health care system in children is inconclusive.

Race/Ethnicity as a Predictor of Mortality

The association between race/ethnicity and mortality has been examined in various settings. One study from England and Wales examined the association of socioeconomic status and incidence rate of admission to the PICU.[15] The researchers found that children from high deprivation areas and southeast Asian populations had higher PICU rates of admission and higher odds of mortality. They concluded that the higher risk of mortality for minority race was associated with a higher deprivation score and reflected higher severity of illness on presentation.[15]

In cardiology, strong evidence exists that non-white race is associated with increased mortality in adults and children undergoing cardiac surgery.[3–6] However, these studies did not examine the role of illness severity as a mediator between race and mortality. Two of the studies did not have access to this data[3,5], and one study did not collect illness severity scores.[4] The authors of these studies speculated that the differences in mortality across race can be explained by either delayed access to care[3,5,6] versus differences in treatment.[3]

Illness Severity as a mediator between Race/Ethnicity and Mortality

Current limited pediatric literature would suggest that severity of illness on admission to the PICU for all critically ill children does not vary by race, which is inconsistent with the adult data on sepsis and critically ill adults. However, one study did conclude that non-white race was associated with higher mortality in pediatric cardiac post-operative patients, though severity of illness was not evaluated in this study.[5] Presently, there is no clear understanding of the relationship between race/ethnicity, severity of illness, and mortality in pediatric cardiac surgical patients. Understanding this relationship would help determine whether racial disparities in

mortality are due to access to timely medical services or differences in care after admission to the hospital. We hypothesize that non-white children who undergo congenital heart surgery have a higher severity of illness on admission to the ICU, contributing to an increased risk of in-hospital post-operative mortality.

Methods

We performed a secondary retrospective cohort study using retrospectively collected data from the Virtual PICU Systems, LLC (VPS). VPS is a clinical registry that includes over 135 hospital units in the United States and Canada reporting pediatric, cardiac, and neonatal ICU data. Hospitals that participate in VPS report demographic data, multiple severity of illness scores, and ICU specific data, including days on mechanical ventilation, mortality, diagnoses and procedures, and cardiac surgery data. All data is de-identified prior to entry into the registry, qualifying for exemption from human subjects review by the Seattle Children's Hospital Institutional Review Board.

Our study population included patients less than 18 years old who underwent cardiac surgery during or immediately before admission to the intensive care unit between 2009-2016, when the Pediatric Risk of Mortality 3 (PRISM 3) score was most recently validated and updated. We included only the 81 centers that reported race for greater than 85% of their entries and limited the population to the United States, given variations in health systems, structural discrimination, and demographics between countries. All patients with a Risk Adjustment for Congenital Heart Surgery[16] category were included in the analysis (n = 37,056).

Race/ethnicity was the independent variable of interest in our analysis and categorized into non-Hispanic white ("white"), non-Hispanic black ("black"), Hispanic ethnicity, Asian,

American Indian, other, or missing. Asian race included Asian, Indian, and Pacific Islander races. “Other”, “mixed”, and “unspecified” races were combined into one “other” category. Because race was missing from 2180 entries, “missing” race/ethnicity was used as a separate category in the data analysis.

We analyzed additional variables to account for confounding factors that would influence severity of illness and mortality, including diagnostic codes for chronic conditions and proxies for socioeconomic status, such as insurance status. Weight in kilograms was coded as a continuous variable. Age at time of ICU admission was categorized into less than one month, one month to less than twelve months, one year to less than ten years, and ten years to less than eighteen years old. Using ICD-9 codes for gestational age and prematurity (765.2, 765.20, 765.21, 765.22, 765.23, 765.24, 765.25, 765.26, 765.27, 765.28, 765.29), patients born at less than 37 weeks gestation were identified as premature. Primary insurance status was divided into one of three categories: private insurance (commercial or managed care), governmental insurance (Medicare or Medicaid), or other (unknown, self-pay, military, National Health Services, foreign payers, other). For patients who listed more than one insurance type, we assigned the insurance type that suggested higher socioeconomic status. For example, if both private insurance and Medicaid insurance were listed, private insurance was assigned as the primary insurance type.

Complex Chronic Conditions (CCC) were analyzed for each non-cardiac organ system as defined by Feudtner using ICD-9 codes and summed.[17] Patients were then categorized as having 0, 1, 2, or ≥ 3 non-cardiac organ systems involved as a proxy for underlying medical complexity. There are 4 out of 28 non-cardiac CCCs that could potentially be a result of congenital heart disease and surgery, including chronic respiratory failure, renal failure, cognitive delay, and

epilepsy, contributing to higher odds of mortality. For this reason, we evaluated the number of CCCs as a mediator between race and mortality, looking first at our primary effect of race on mortality, then controlling for CCCs to see whether the difference in mortality changed.

Surgical complexity was ascertained using the Risk Adjustment Congenital Heart Surgery (RACHS) category, a clinical tool that categorizes congenital heart surgical procedures from one to six, with six being the most complex and associated with the highest risk of mortality.[16] RACHS categories were further grouped into low complexity (RACHS 1 or 2), medium complexity (RACHS 3 or 4), and high complexity categories (RACHS 5 or 6). Patients who had multiple surgeries during their admission were categorized into the RACHS category of their most complex surgery.

Pediatric Index of Mortality 2 (PIM 2), Pediatric Risk of Mortality (PRISM 3), and Pediatric Index of Cardiac Surgical Intensive Care Mortality (PICSIM) scores were analyzed as continuous variables. All three scores have been derived and validated through training and testing datasets with an area under the receiver operating curve greater than 0.88.[18–20] The PIM 2 score is a revised Pediatric Index of Mortality derived from data from 20,787 patients under 16 years old in 14 intensive care units in Australia, the United Kingdom, and New Zealand in 1997, with a final model including 10 variables.[18] PIM 2 scores are exponentiated and transformed into a probability of death. The more negative a PIM 2 score, the lower the probability of death. PRISM 3 scores were developed from 32 PICUs in the United States and include 14 variables, with a higher score indicating a higher risk of mortality.[19] The PICSIM score is a more recently developed severity of illness score for use in the pediatric cardiac critical care population that predicts the probability of mortality across a population of patients with congenital heart disease. A higher PICSIM score is associated with a higher probability of death. It was derived from the

VPS dataset across 55 PICUs and includes 13 variables, including Society of Thoracic Surgeons-European Association of Cardio-Thoracic Surgery Congenital Heart Surgery Mortality (STAT) category, an alternate categorization of cardiac surgical complexity, and a variable for pre- versus post-operative status.[20] All three severity of illness scores have a right-skewed distribution; however, linear regression has been effectively used to estimate differences and trends in large, non-normally distributed datasets.[21]

Operating Room (OR) status was categorized as an admission direct from the OR or not direct from the OR (ie. cardiac catheterization lab, post-anesthesia care unit (PACU), emergency department (ED), home, outside hospital, in-hospital transfer, or other). OR status was included as a covariate, because patients who are admitted directly from the OR are likely to have higher severity of illness scores. Furthermore, the scores from children admitted directly from the operating room reflect a different health care experience, where the severity of illness score may be an indicator of both pre-operative course as well as intra-operative care.

A univariate analysis was conducted on all potential covariates to assess predictors of illness severity and mortality, using a p-value < 0.05 as a significant association. The Mann-Whitney rank sum test and the Kruskal-Wallis test were used for non-normally distributed continuous and ordinal variables. The Chi-squared test was used to assess covariates as predictors of mortality.

Analysis for the association between race/ethnicity, illness severity, and mortality were done in two parts, with white race serving as the reference group. First, we examined the relationship between race/ethnicity and severity of illness scores on admission to the ICU using iterative linear regression modeling for each severity of illness score, including PIM 2, PRISM 3, and PICSIM scores. The independent variable for the linear regression model was race/ethnicity,

with severity of illness scores as the dependent variable. Baseline characteristics were included in our model, including age, weight, and gender. Other covariates were included if univariate analysis demonstrated a p-value < 0.05. Demographic covariates were included first, including age, gender, prematurity status, and weight, followed by adjustment for direct admission from the OR, number of CCC groups, and maximum RACHS category. Finally, the model was adjusted for type of insurance as a proxy for socioeconomic status. In order to examine potential differences in care that may occur to patients in the operating room, we also performed a stratified analysis, separately examining patients admitted directly from the operating room and those who were not.

We then constructed logistic regression models to evaluate the association between race/ethnicity and mortality in the post-surgical period, with race as the independent variable and mortality as the binary dependent variable. Using the same covariates from the previously constructed linear regression models, we also adjusted for severity of illness scores in the final iteration of the model using the PIM 2 and PRISM 3 scores. We controlled for CCCs in our models regardless of mediation analysis, given our original aim to evaluate the strength of the pathway between race and mortality through severity of illness. Because the PICSIM score includes the Society of Thoracic Surgeons-European Association of Cardio-Thoracic Surgery Congenital Heart Surgery Mortality (STAT) category and OR status in its calculation, we did not adjust for RACHS category or OR status in the logistic regression model adjusting for PICSIM score. Additionally, in order to examine within-hospital effects, a fixed effects logistic regression model for each severity of illness score was also constructed. The fixed effects models would model the effect of race for patients admitted to the same hospital. A c-statistic was calculated for each of the logistic regression models to assess goodness-of-fit.

Standardized mortality rates (SMR) were calculated for each hospital to examine whether greater disparities existed in hospitals with higher mortality rates compared with the sample population. Using the mortality rate for the entire sample population as the standard, an SMR was calculated for each hospital, signifying what each hospital's mortality rate would be if their surgical caseload reflected the entire cohort. Hospital SMR was divided into bottom, middle or top tertiles. Using the logistic regression model with the highest c-statistic (PRISM 3), we re-constructed the model for each SMR tertile to evaluate whether any differences in disparities were present.

Finally, sensitivity analysis was performed using the STAT category in place of the RACHS category to test our findings over different validated risk adjustment categories for cardiac surgery.

Results

We included a total of 37,056 patients from the VPS dataset who underwent cardiac surgery between January 1, 2009 and December 31, 2016 who were less than 18 years old at the time of their admission. Patient characteristics are described in **Table 1**. Fifty-one percent of patients identified as white race, with the next most represented group being Hispanic (16%) and black (12%). The majority of patients were male and under 1 year of age. More than 75% of the patients were admitted to the ICU directly from the operating room. There was significant variation across all race/ethnicity groups for gender, age, insurance status, prematurity, number of complex chronic conditions, RACHS category, and severity of illness scores, including PIM 2, PRISM 3, and PICSIM scores. White patients were more likely to have private insurance and be < 1 month of age on admission compared with black patients.

Black, Hispanic, and other races/ethnicities had a higher proportion of children who had governmental insurance and a lower proportion of private insurance when compared with white race. The proportion of patients admitted directly from the OR and the maximum RACHS category for admission appeared to be relatively equally distributed among all races/ethnicities. There was a statistically significant difference in PIM 2, PRISM 3, and PICSIM scores across race/ethnicities. However, among the PIM 2 scores, the median scores were all -4.0 except for other race/ethnicity, which was -3.9, suggesting little clinical difference in severity of illness across race/ethnicity groups. For PRISM 3 scores, the median score for all race/ethnicities was 6.0, except for American Indian, whose median was 5.0. Similarly, while these differences were statistically significant, there was little clinical difference across race/ethnicities. PICSIM scores had slightly more variability, with median probability of death ranging between 0.0047 for Asian race/ethnicity to 0.0089 for other race/ethnicity. White, black, and Hispanic race/ethnicity groups had similar PICSIM scores with black (0.0063) and Hispanic patients (0.0060) having a lower risk of mortality than their white counterparts (0.0065).

Predictors of severity of illness scores are presented in **Table 2**. There was significant variation in severity of illness scores across gender, age, OR status, insurance type, prematurity, number of complex chronic conditions, maximum RACHS category, and weight. Age < 1 month, prematurity, a greater number of complex chronic conditions, and increasing surgical complexity were associated with greater severity of illness for three measures (PIM 2, PRISM 3 and PICSIM). Government and other insurance were associated with higher PICSIM scores, but there was no significant difference in PRISM 3 scores by insurance.

A univariate analysis examining predictors of mortality was also performed (**Table 3**). Race, age, OR status, insurance status, prematurity, number of complex chronic conditions,

RACHS category, and weight were all significantly associated with ICU mortality. Specifically, black race, younger age, prematurity, admission not from the OR, and increasing surgical complexity were associated with increased mortality. As expected, increasing severity of illness scores (PIM 2, PRISM 3, and PICSIM scores) were significantly associated with mortality (**Table 3**).

Multivariable linear regression models examining predictors of severity of illness scores were constructed (**Table 4**). In models examining PRISM 3 and PICSIM scores, black race was associated with higher severity of illness scores after adjusting for age, gender, prematurity status, weight, number of CCC groups, insurance status, maximum RACHS category (for PRISM 3 model), and direct admission from the OR (for PRISM 3 model) (PRISM3: $\beta = 0.24$, 95% Confidence Interval (CI) 0.01-0.46; PICSIM $\beta = 0.004$, 95% CI 0.001 to 0.007). After adjusting for all other co-variates, the mean PRISM 3 score for white patients was 6.8, while the mean PRISM 3 score among black patients was 7.0 (Figure 2). In models using the PIM 2 score, black race was not associated with severity of illness ($\beta = 0.10$, 95% CI 0.00 to 0.20).

We then constructed a multivariate logistic regression model to examine the association between race and mortality after adjustment for severity of illness and other predictors of mortality. Additional analysis evaluating CCCs as a mediator between race and mortality showed minimal difference in the odds of mortality between race and mortality before and after controlling for CCCs (data not shown), indicating that the association between race and mortality is not explained by comorbid conditions. After adjusting for PIM 2 and PRISM 3 severity of illness, black race was associated with a 30-31% higher odds of mortality when compared with white race (PRISM 3 score: OR = 1.31, 95% CI 1.07 to 1.61; PIM 2: OR = 1.30, p-value = 0.02, 95% CI 1.05 to 1.61) (**Table 5, Figure 3**). In the mortality model that adjusted for PICSIM

score, RACHS category and OR status were not included, because the PICSIM score includes adjustment for surgical complexity using the STAT category and OR status. In this model, black race was associated with a 30% higher odds of mortality (OR = 1.30, p-value = 0.01, 95% CI 1.05 to 1.59). In fixed effects models, black race remained associated with increased odds of mortality when compared with white race (PRISM 3 score: OR = 1.28, 95% CI 1.03 to 1.58; PIM 2: OR = 1.28, 95% CI 1.03 to 1.60). In the fixed effects model that adjusted for PICSIM, black race was not associated with increased odds of mortality (OR = 1.24, 95% CI 0.98 to 1.58).

A c-statistic analysis was performed to test the goodness of fit of the logistic regression models. All logistic regression models had a c-statistic greater than 0.80, with the model including PRISM 3 scores demonstrating the highest concordance at 0.86 (95% CI 0.85 to 0.87). The c-statistic for fixed effects models were slightly lower, but the PRISM 3 logistic regression model maintained a c-statistic greater that 0.80, demonstrating excellent model fit.

Finally, we calculated standardized mortality rates (SMR) by intensive care unit and divided intensive care units into tertiles based on SMR. Mortality logistic regression models stratified by tertile were performed using the PRISM 3 model, which had the highest c-statistic. Across all tertiles, black patients had increased risk of mortality when compared with their white counterparts (**Table 6**). Black patients treated in highest mortality hospitals had a 32% higher odds of mortality (OR = 1.32, 95% CI 1.07 to 1.63) while black patients in the lowest mortality tertile had a 26% higher odds of mortality (OR = 1.26, 95% CI 1.01 to 1.58).

In the sensitivity analysis, linear and logistic regression models were re-constructed using the STAT category in place of the RACHS category. In these models, black race remained associated with higher odds of mortality than white race (data not shown).

Discussion

In this cohort of children undergoing congenital heart surgery, black children had a statistically significant, but not clinically significant, greater severity of illness on admission to the ICU. Furthermore, despite adjustment for severity of illness, black children continued to have higher odds of post-surgical mortality than their white counterparts. These findings suggest that while access to care may be evidenced by greater physiological derangements at ICU presentation, severity of illness is unlikely to be the main driver for the higher odds of mortality in black children after congenital heart surgery.

Our study adds insight into the many drivers of health disparities that disproportionately impact non-white patients. Prior conceptual models have focused on basic and proximal causes of health disparities that have previously been outlined by Link and Phelan[22] and Ben-Shlomo.[23] In these conceptual models, structural racism and socioeconomic status are emphasized as factors in the mechanism for the development of disease. As a result of these basic causes, minorities and those of lower socioeconomic status face a number of barriers to accessing the healthcare system, making late presentation more common for non-white race, as seen in adult cardiology literature.[24–26] However, we do not draw the same conclusion from our own study. Instead, in this study, across races and different severity of illness methodologies, there does not appear to be a clinically meaningful difference in illness severity on presentation to care. We also did not find a significant difference when we separately examined patients who came directly from the OR and those who did not, suggesting that operating room factors also do not drive differences in severity of illness across race.

The minimal difference in severity of illness scores across multiple measurements demonstrates that severity of illness is not the main driver of health disparities in this patient

population, and that black race continues to be associated with higher mortality compared with white children, despite adjustment for severity of illness. From previous studies regarding barriers to accessing care for minority races/ethnicities, we originally hypothesized that minority races/ethnicities would have higher severity of illness scores. Timely detection of congenital heart disease requires good prenatal care and access to consistent pediatric primary care visits. Additionally, once the diagnosis is made, management of the clinical course of heart disease requires consistent access to specialty services, including a specialized care team, imaging services, and cardiac catheterization. Failure to access these services reliably at any point in time due to insurance coverage, geographic limitations, financial considerations for transportation, or excused absences from work can lead to suboptimal medical management and delayed surgical intervention. However, our study suggests that despite these barriers, minority race/ethnicity patients do not present with a clinically significant difference in illness severity. This conclusion would suggest that timely access to specialized medical care is not what drives the difference in mortality between black and white children. Past studies also support this conclusion, finding that there is no significant difference in age of referral to a pediatric cardiologist and for cardiac surgery between black and white children.[27,28] In one study, Chang et al examined factors associated with age of operation in patients with congenital heart disease and concluded that there was no difference in age of operation between black and white patients.[29] If timely access to medical care is not the main driver for congenital heart surgery disparities, then we must consider events after entry into the medical system that are contributing to this disparity.

In previous studies of adult cardiac disease, differences in mortality have been attributed to referral of minority races to institutions with less surgical volume, leading to worse outcomes.[30–33] In these studies, hospitals with higher surgical volume typically had lower

mortality rates. However, multiple studies demonstrated that surgical volume did not account for the entirety of the racial disparity, and concluded that black race and Hispanic ethnicity remained independent predictors of mortality.[31–33] In order to examine the impact of referral patterns in congenital heart surgery, we performed a fixed-effects logistic regression model to evaluate if patients of different race/ethnicity receive different care within the same hospital. In these models, black patients remained at increased odds of mortality when compared with their white counterparts treated at the same hospital. These increased odds suggest that the differences in mortality in pediatric post-operative patients are not due to hospital referral patterns. In a similar manner, when hospitals were stratified by standardized mortality rates, black patients remained at increased risk of mortality at all levels of hospital SMR, again suggesting that referral patterns were not the main driver for surgical disparities. We did not see a statistically significant difference between white patients and any other race that was included in our analysis.

One important contributor to surgical survival disparities is variation in the delivery of care, which we were unable to measure in our study. In the adult literature, studies have demonstrated differences in the delivery of care across race for myocardial infarctions.[4,34,35] One study by Bradley et al found that black race, Hispanic ethnicity, and Asian/Pacific Islander race/ethnicity were associated with longer time to fibrinolytic therapy compared with white race, demonstrating differences in care delivery after presentation to care.[4] Another study found that black patients went to hospitals that provided less evidence based care than white patients.[34] In 2016, Graham summarized treatment differences across races/ethnicities in acute coronary syndrome (ACS) and myocardial infarction (MI), demonstrating that black patients were more likely than white patients to experience delays in treatment and were less likely to undergo invasive procedures, such as cardiac catheterization, percutaneous coronary intervention,

coronary artery bypass grafting (CABG), or revascularization.[35] In the pediatric population, one recent study found that black patients were less likely to be placed on extracorporeal life support (ECLS) than white patients, which could partially explain the higher odds of mortality in black patients.[36] Studies examining the presence of implicit bias as a contributor to variation in care delivery to non-white patients demonstrate that health care providers prefer white race, categorizing black patients as less cooperative.[37–40] While these studies concluded that providers have an implicit bias favoring white race, the evidence regarding the association between implicit racial bias and clinical decision making remains unclear.[37,39] However, it is important to continue studying the impact of implicit bias on health outcomes to fully assess the potential causes of racial disparities.

Our paper has several limitations. Recent manuscripts suggest that PRISM 3 scores are inadequate for accurately predicting mortality in the pediatric cardiac population.[20,41] However, in contrast to the present study, these prior studies evaluated the performance of the PRISM 3 score without adjusting for surgical complexity. Additionally, we performed all analyses on the three most commonly utilized severity of illness scores for this population: PIM 2, PRISM 3, and PICSIM. For the linear regression models examining PRISM 3 and PICSIM, black patients consistently had higher severity of illness scores. Furthermore, the point estimates for the odds of mortality were similar across all severity of illness scores with c-statistics for all 3 models demonstrating excellent fit.

Given the observational and retrospective nature of our study, it is subject to limitations involving the collection of data and misclassification. We requested data only from sites reporting at least 85% of race, but some covariates, such as insurance, had incomplete data. These incomplete entries may result in residual confounding in our final models and incomplete

assessment for the impact of socioeconomic status on severity of illness or mortality. Additionally, other socioeconomic factors are not completely captured in the dataset, including primary language or parental education, which are likely to mediate the association between race/ethnicity and severity of illness or mortality.

Our results may not be generalizable, as not all centers that perform cardiac surgery submit data to VPS. We are also missing centers that did not report race for less than 85% of their patient population, which may have geographic implications.

Future areas of research include secondary outcome measures, such as lengths of stay and days on mechanical ventilation. We also focused on a subpopulation of pediatric cardiac patients undergoing congenital heart surgery, and it may be helpful to evaluate other pediatric cardiac populations, such as pediatric myocarditis and cardiomyopathy, to understand the extent of racial disparities in the pediatric critically ill cardiac population. Given the growing body of evidence on the existence of racial disparities in the pediatric population, it will be important to focus future efforts on establishing and trialing interventions to reduce disparities.

Conclusion

Our study demonstrates the presence of racial disparities in the pediatric cardiac surgical population. We show that black pediatric patients undergoing congenital heart surgery are at higher odds of mortality that white children, despite adjustment for severity of illness. This finding suggests that disparities in access to care that result in increased severity of illness is not the main driver of health disparities for children undergoing congenital heart surgery. Further research is needed to identify disparities in other health outcomes for pediatric cardiac critically ill populations.

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Tables.

Table 1. Patient Characteristics

	White	Black	Hispanic	Asian	American Indian	Other	Missing
n (%) = 37056	19029 (51)	4330 (12)	5936 (16)	1488 (4)	317 (1)	3776 (10)	2180 (6)
Gender							
Female	8322 (44)	1997 (46)	2704 (46)	677 (46)	139 (44)	1720 (46)	992 (46)
Age Groups							
<1 Month	4262 (22)	804 (19)	1215 (20)	217 (15)	68 (21)	1091 (29)	570 (26)
1 to < 12 Months	6791 (36)	1681 (39)	2165 (36)	516 (35)	136 (43)	1438 (38)	756 (35)
1 to < 10 Years	5765 (30)	1402 (32)	1997 (34)	564 (38)	87 (27)	998 (26)	638 (29)
10 to <18 Years	2211 (12)	443 (10)	559 (9)	191 (13)	26 (8)	249 (7)	216 (10)
Weight in kg	6.8 (4.0,15.3)	7.2 (4.2,15.4)	7.0 (4.1,15.4)	8.3 (4.9,15.9)	6.4 (4.1,13.7)	5.9 (3.6,11.3)	6.2 (3.7,13.7)
OR Status							
From OR	15260 (80)	3433 (79)	4584 (77)	1233 (83)	248 (78)	2700 (72)	1563 (72)
Overall Insurance							
Private	5594 (29)	692 (16)	916 (15)	526 (35)	16 (5)	942 (25)	0 (0)
Government	3323 (17)	1527 (35)	2698 (45)	329 (22)	39 (12)	1060 (28)	0 (0)
Other	222 (1)	65 (2)	120 (2)	29 (2)	0 (0)	165 (4)	0 (0)
Missing	9890 (52)	2046 (47)	2202 (37)	604 (41)	262 (83)	1609 (43)	2180 (100)
Premature							
< 37 weeks	579 (3)	130 (3)	197 (3)	37 (2)	27 (9)	129 (3)	24 (1)
Complex Chronic Conditions							
No CCC	14735 (77)	3377 (78)	4573 (77)	1219 (82)	244 (77)	3004 (80)	1943 (89)
1 CCC	3114 (16)	668 (15)	982 (17)	188 (13)	60 (19)	551 (15)	193 (9)
2 CCC	912 (5)	219 (5)	273 (5)	58 (4)	9 (3)	168 (4)	38 (2)
3 or more CCC	268 (1)	66 (2)	106 (2)	23 (2)	4 (1)	53 (1)	6 (0)
Max RACHS score							
1 or 2	2120 (49)	3052 (51)	867 (58)	155 (49)	1780 (47)	1041 (48)	1039 (44)
3 or 4	2006 (46)	2644 (45)	590 (40)	146 (46)	1793 (47)	1012 (46)	1008 (43)
5 or 6	204 (5)	240 (4)	31 (2)	16 (5)	203 (5)	127 (6)	127 (5)
PIM 2 Score*	-4.0 (-4.7,-3.3)	-4.0 (-4.5,-3.3)	-4.0 (-4.6,-3.2)	-4.1 (-4.6,-3.4)	-4.0 (-4.7,-3.3)	-3.9 (-4.5,-3.1)	-4.0 (-5.3,-3.3)
PRISM 3 Score*	6 (3,10)	6 (3,10)	6 (3,10)	6 (3,9)	5 (3,8)	6 (3,10)	6 (3,10)
PICSIM Score × 100*	0.65 (0.26,2.15)	0.63 (0.26,1.97)	0.60 (0.25,2.00)	0.47 (0.21,1.31)	0.69 (0.23,2.56)	0.89 (0.32,3.17)	1.12 (0.40,3.41)

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment for Congenital Heart Surgery Score for admission, PIM = Pediatric Index of Mortality, PRISM = Pediatric Risk of Mortality, PICSIM = Pediatric Index of Cardiac Surgical Intensive Care Mortality

* Severity of illness scores by race reported as median values and interquartile range

Table 2: Predictors of Illness Severity

	PIM2	PRISM3	PICSIM × 100
	50th (25th, 75th)	50th (25th, 75th)	50th (25th, 75th)
Gender			
Male	-4.0 (-4.6,-3.2)	6 (3,10)	0.68 (0.27,2.35)
Female	-4.0 (-4.7,-3.3)	6 (3,9)	0.63 (0.25,2.03)
p-value	<0.01	<0.01	<0.01
Age Groups:			
<1 Month	-3.5 (-4.2,-2.4)	8 (4,13)	4.93 (2.43,9.50)
1 to < 12 Months	-3.9 (-4.4,-3.3)	5 (3,9)	0.70 (0.35,1.50)
1 to < 10 Years	-4.3 (-5.4,-3.7)	5 (3,8)	0.31 (0.17,0.66)
10 to <18 Years	-4.4 (-5.5,-3.9)	6 (3,9)	0.21 (0.12,0.40)
p-value	<0.01	<0.01	<0.01
Weight in kilograms*	-0.20	-0.10	-0.19
p-value	<0.01	<0.01	<0.01
OR Status			
Direct from OR	-4.0 (4.8,3.4)	6 (3,10)	0.48 (0.22,1.27)
Not Direct from OR	-3.9 (4.5,2.7)	5 (2,9)	3.40 (1.13,7.94)
p-value	<0.01	<0.01	<0.01
Overall Insurance			
Private	-4.0 (-4.7,-3.3)	6 (3,10)	0.59 (0.24,2.00)
Government	-4.0 (-4.5,-3.3)	6 (3,10)	0.65 (0.26,2.10)
Other	-3.8 (-4.4,-2.8)	6 (3,10)	0.79 (0.26,3.05)
Missing	-4.0 (-4.8,-3.3)	6 (3,10)	0.69 (0.27,2.34)
p-value	<0.01	<0.01	<0.01
Premature			
< 37 weeks	-3.8 (-4.3,-3.0)	8 (3,12)	1.61 (0.55,4.56)
≥37 weeks	-4.0 (-4.7,-3.3)	6 (3,10)	0.64 (0.25,2.13)
p-value	<0.01	<0.01	<0.01
Complex Chronic Conditions			
No CCC	-4.0 (-4.8,-3.3)	6 (3,9)	0.60 (0.24,2.22)
1 CCC	-4.0 (-4.4,-3.4)	6 (3,10)	0.77 (0.35,1.95)
2 CCC	-4.0 (-4.5,-3.4)	7 (4,11)	0.92 (0.39,2.63)
3 or more CCC	-3.9 (-4.4,-3.3)	7 (4.0,11)	1.10 (0.49,3.35)
p-value	<0.01	<0.01	<0.01
Max RACHS Score			
1 or 2	-4.2 (-5.2,-3.6)	5 (3,8)	0.32 (0.17,0.74)
3 or 4	-3.9 (-4.4,-3.1)	7 (4,11)	1.34 (0.52,3.78)
5 or 6	-2.4 (-3.3,-1.5)	10 (5,16)	7.75 (4.28,13.16)
p-value	<0.01	<0.01	<0.01

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment
*Illness severity versus weight in kilograms reported as Pearson's Correlation coefficient

Table 3. Predictors of Mortality

	Survived	Died	p-value
	n (%)	n (%)	
Race			0.02
White	18568 (98)	461 (2)	
Black	4193 (97)	137 (3)	
Hispanic	5786 (97)	150 (3)	
Asian/Indian/Pacific Islander	1458 (98)	30 (2)	
American Indian	311 (98)	6 (2)	
Other/Mixed/Unspecified	3656 (97)	120 (3)	
Missing	2127 (98)	53 (2)	
Gender			0.37
Male	19984 (97)	516 (3)	
Female	16110 (97)	441 (3)	
Age Groups:			<0.01
<1 Month	7652 (93)	575 (7)	
1 to < 12 Months	13213 (98)	270 (2)	
1 to < 10 Years	11377 (99)	74 (1)	
10 to <18 Years	3857 (99)	38 (1)	
Weight in kg*	7.0 (4.1,15.1)	3.3 (2.8,5.0)	<0.01
OR Status			<0.01
Direct from OR	28551 (98)	470 (2)	
Not Direct from OR	7548 (94)	487 (6)	
Overall Insurance			<0.01
Private	8508 (98)	178 (2)	
Government	8743 (97)	233 (3)	
Other	576 (96)	25 (4)	
Missing	18272 (97)	521 (3)	
Premature			<0.01
< 37 weeks	1057 (94)	66 (6)	
≥ 37 weeks	35042 (98)	891 (2)	
Complex Chronic Conditions			<0.01
No CCC	28424 (98)	671 (2)	
1 CCC	5567 (97)	189 (3)	
2 CCC	1603 (96)	74 (4)	
3 or more CCC	503 (96)	23 (4)	
Max RACHS Score			<0.01
1 or 2	18091 (99)	145 (1)	
3 or 4	16470 (97)	584 (3)	
5 or 6	1538 (87)	228 (13)	
PIM 2 Score*	-4.0 (-4.7,-3.3)	-2.7 (-3.7,-1.8)	<0.01
PRISM 3 Score*	6 (3,9)	12 (6,19)	<0.01
PICSIM Score × 100*	0.6 (0.3,2.0)	8.1 (3.4,22.9)	<0.01

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment for Congenital Heart Surgery Score for admission, PIM = Pediatric Index of Mortality, PRISM = Pediatric Risk of Mortality, PICSIM = Pediatric Index of Cardiac Surgical Intensive Care Mortality

*Median (interquartile range)

Table 4. Multivariate Linear Regression Models for Severity of Illness on Admission to the Intensive Care Unit

	White	Black	Hispanic	Asian	American Indian	Other	Missing
		β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
PIM2 Score	Ref	0.10 (0.00,0.20)	0.13 (-0.02,0.27)	0.06 (-0.03,0.15)	-0.07 (-0.39,0.25)	0.10 (0.00,0.20)	-0.10 (-0.51,0.31)
Direct from OR	Ref	0.10 (-0.01,0.21)	0.12 (-0.02,0.27)	0.06 (-0.03,0.16)	-0.04 (-0.37,0.29)	0.10 (-0.01,0.20)	-0.12 (-0.56,0.32)
Not Direct from OR	Ref	0.10 (0.00,0.21)	0.12 (-0.03,0.27)	0.06 (-0.03,0.16)	-0.07 (-0.40,0.25)	0.10 (0.00,0.21)	-0.09 (-0.50,0.31)
PRISM3 Score	Ref	0.24 (0.01,0.46)	0.37 (-0.02,0.76)	0.17 (-0.21,0.56)	-0.72 (-1.45,0.01)	0.27 (0.00,0.55)	0.00 (-1.93,1.93)
Direct from OR	Ref	0.20 (-0.02,0.42)	0.22 (-0.15,0.59)	0.13 (-0.25,0.50)	-0.57 (-1.33,0.19)	0.12 (-0.15,0.39)	0.00 (-1.86,1.87)
Not Direct from OR	Ref	0.19 (-0.03,0.41)	0.27 (-0.11,0.64)	0.15 (-0.22,0.52)	-0.61 (-1.35,0.14)	0.17 (-0.09,0.44)	-0.01 (-1.99,1.98)
PICSIM × 100	Ref	0.41 (0.11,0.72)	-0.16 (-0.41,0.08)	-0.16 (-0.38,0.06)	-0.33 (-0.90,0.24)	0.11 (-0.15,0.38)	1.01 (0.25,1.77)
Direct from OR	Ref	0.41 (0.13,0.70)	-0.08 (-0.33,0.18)	-0.11 (-0.34,0.11)	-0.23 (-0.82,0.36)	0.19 (-0.09,0.47)	0.96 (0.35,1.57)
Not Direct from OR	Ref	0.43 (0.13,0.74)	-0.02 (-0.22,0.19)	-0.03 (-0.26,0.20)	-0.13 (-0.70,0.43)	0.31 (0.02,0.60)	1.24 (0.52,1.95)

Final model adjusted for race, age, gender, prematurity, weight, OR status, CCC group, max RACHS score, overall insurance, and unit ID. PICSIM models were not adjusted for OR status or max RACHS score

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment for Congenital Heart Surgery Score for admission, PIM = Pediatric Index of Mortality, PRISM = Pediatric Risk of Mortality, PICSIM = Pediatric Index of Cardiac Surgical Intensive Care Mortality

Table 5. Multivariate Logistic Regression Models for Mortality with Adjustment for Severity of Illness

	White	Black	Hispanic	Asian	American Indian	Other	Missing	C-statistic
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	
Mortality PIM2 Score	Ref	1.30 (1.05,1.61)	1.07 (0.84,1.36)	1.19 (0.80,1.75)	0.76 (0.35,1.62)	1.11 (0.89,1.40)	0.80 (0.67,0.95)	0.83 (0.82,0.85)
Fixed Effects Model	Ref	1.28 (1.03,1.58)	1.25 (1.00,1.56)	1.35 (0.92,2.01)	0.73 (0.31,1.69)	1.20 (0.96,1.50)	0.42 (0.12,1.45)	0.76 (0.74,0.77)
Mortality PRISM3 Score	Ref	1.31 (1.07,1.61)	1.08 (0.83,1.40)	1.18 (0.77,1.80)	0.75 (0.37,1.49)	1.10 (0.86,1.40)	1.09 (0.90,1.31)	0.86 (0.85,0.87)
Fixed Effects Model	Ref	1.28 (1.03,1.60)	1.23 (0.98,1.55)	1.31 (0.88,1.96)	0.67 (0.28,1.60)	1.17 (0.93,1.48)	0.21 (0.05,0.91)	0.82 (0.81,0.84)
Mortality PICSIM	Ref	1.30 (1.05,1.59)	1.18 (0.88,1.56)	1.12 (0.73,1.70)	0.74 (0.29,1.88)	1.14 (0.86,1.53)	0.85 (0.70,1.03)	0.85 (0.84,0.87)
Fixed Effects Model	Ref	1.24 (0.98,1.58)	1.24 (0.98,1.58)	1.23 (0.80,1.90)	0.74 (0.29,1.86)	1.19 (0.93,1.52)	0.19 (0.04,0.83)	0.79 (0.78,0.81)

Final model adjusted for race, age, gender, prematurity, weight, OR status, CCC group, max RACHS score, overall insurance, unit ID, and PIM 2 Score, PRISM 3 score, and PICSIM scores. Models adjusted for PICSIM were not adjusted for OR status or max RACHS score

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment for Congenital Heart Surgery Score for admission, PIM = Pediatric Index of Mortality, PRISM = Pediatric Risk of Mortality, PICSIM = Pediatric Index of Cardiac Surgical Intensive Care Mortality

Table 6. Multivariate Logistic Regression Models for Mortality by Unit Standardized Mortality Rate (SMR)

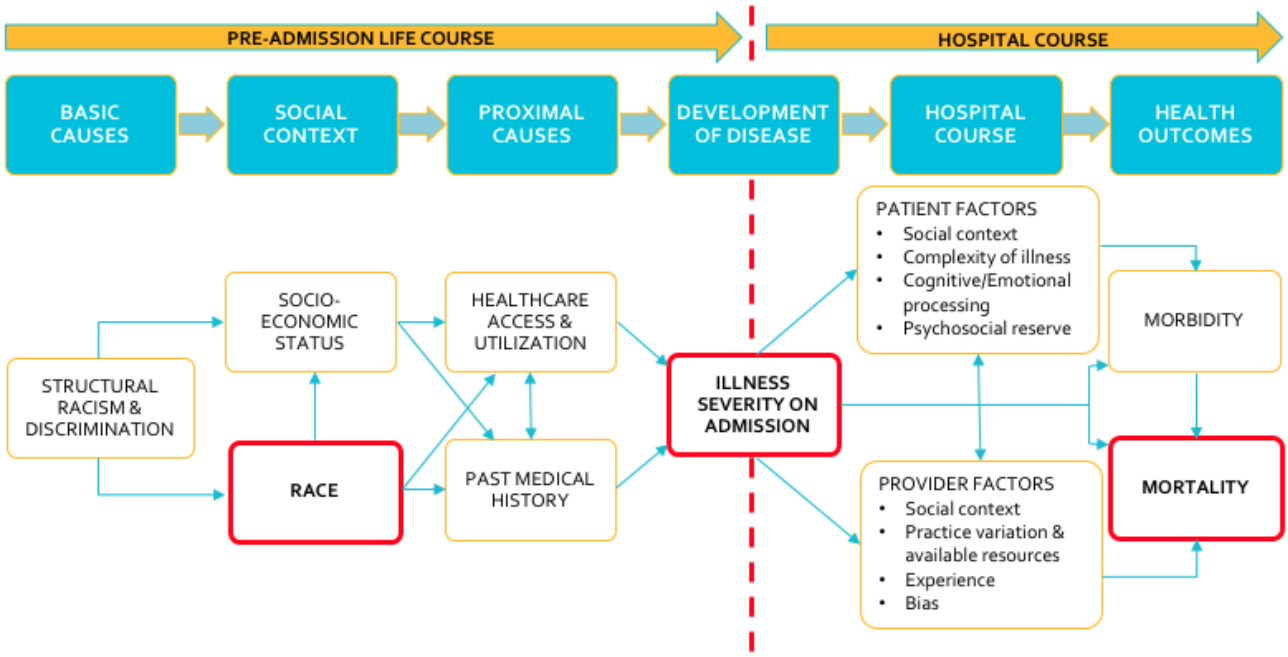
	White	Black	Hispanic	Asian	American Indian	Other	Missing
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Bottom Tertile for SMR	Ref	1.26 (1.01,1.58)	1.06 (0.77,1.46)	1.05 (0.64,1.72)	0.60 (0.29,1.22)	1.13 (0.86,1.48)	1.10 (0.94,1.30)
p-value		0.04	0.71	0.85	0.16	0.39	0.25
Middle Tertile for SMR	Ref	1.25 (1.01,1.55)	1.04 (0.78,1.37)	1.14 (0.74,1.76)	0.65 (0.29,1.46)	1.04 (0.81,1.33)	1.14 (0.95,1.37)
p-value		0.04	0.81	0.56	0.30	0.76	0.15
Top Tertile for SMR	Ref	1.32 (1.07,1.63)	1.13 (0.85,1.50)	1.11 (0.68,1.80)	0.72 (0.39,1.33)	1.21 (0.94,1.56)	1.03 (0.88,1.21)
p-value		0.01	0.40	0.69	0.29	0.15	0.74

Final model adjusted for race, age, gender, prematurity, weight, OR status, CCC group, max RACHS score, overall insurance, unit ID, and PRISM 3 score

OR Status = direct admission from operating room, CCC = complex chronic conditions, Max RACHS score = highest Risk Adjustment for Congenital Heart Surgery Score for admission, PRISM = Pediatric Risk of Mortality

Figures.

Figure 1. Conceptual Model



Adapted from Williams DR[7]

Figure 2.

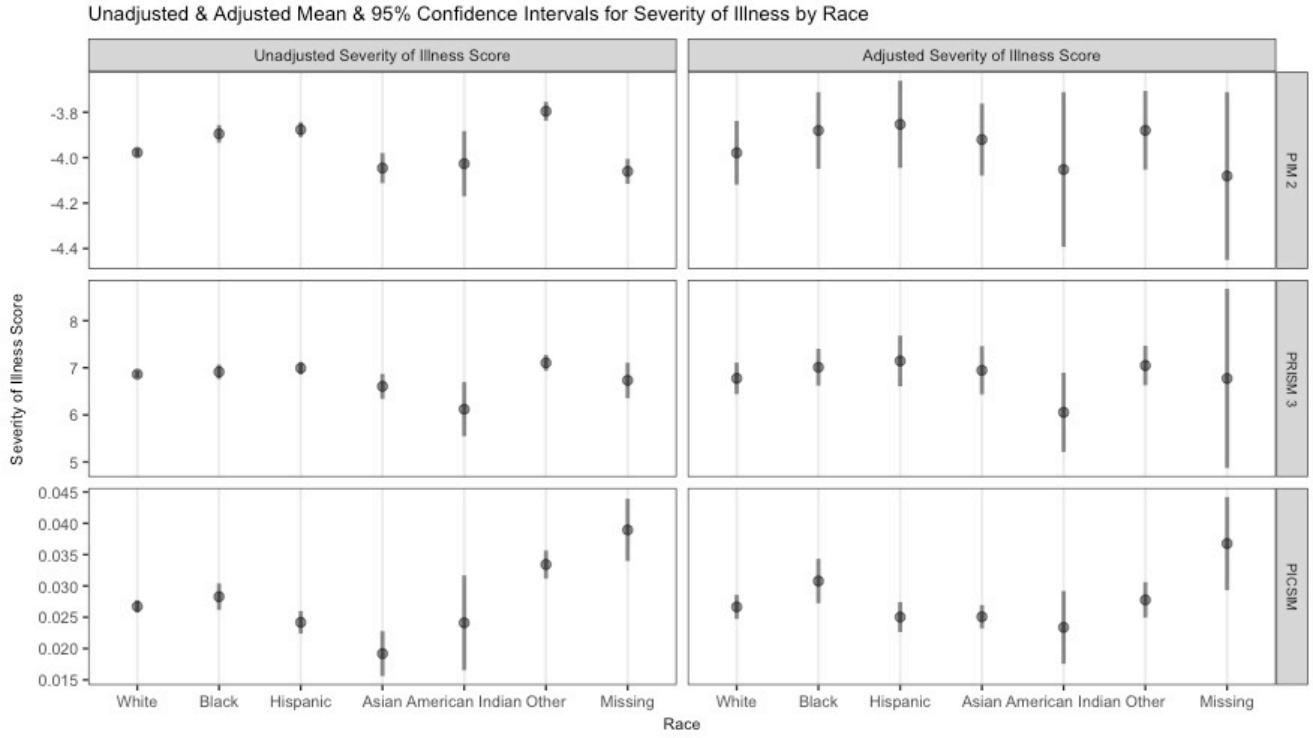
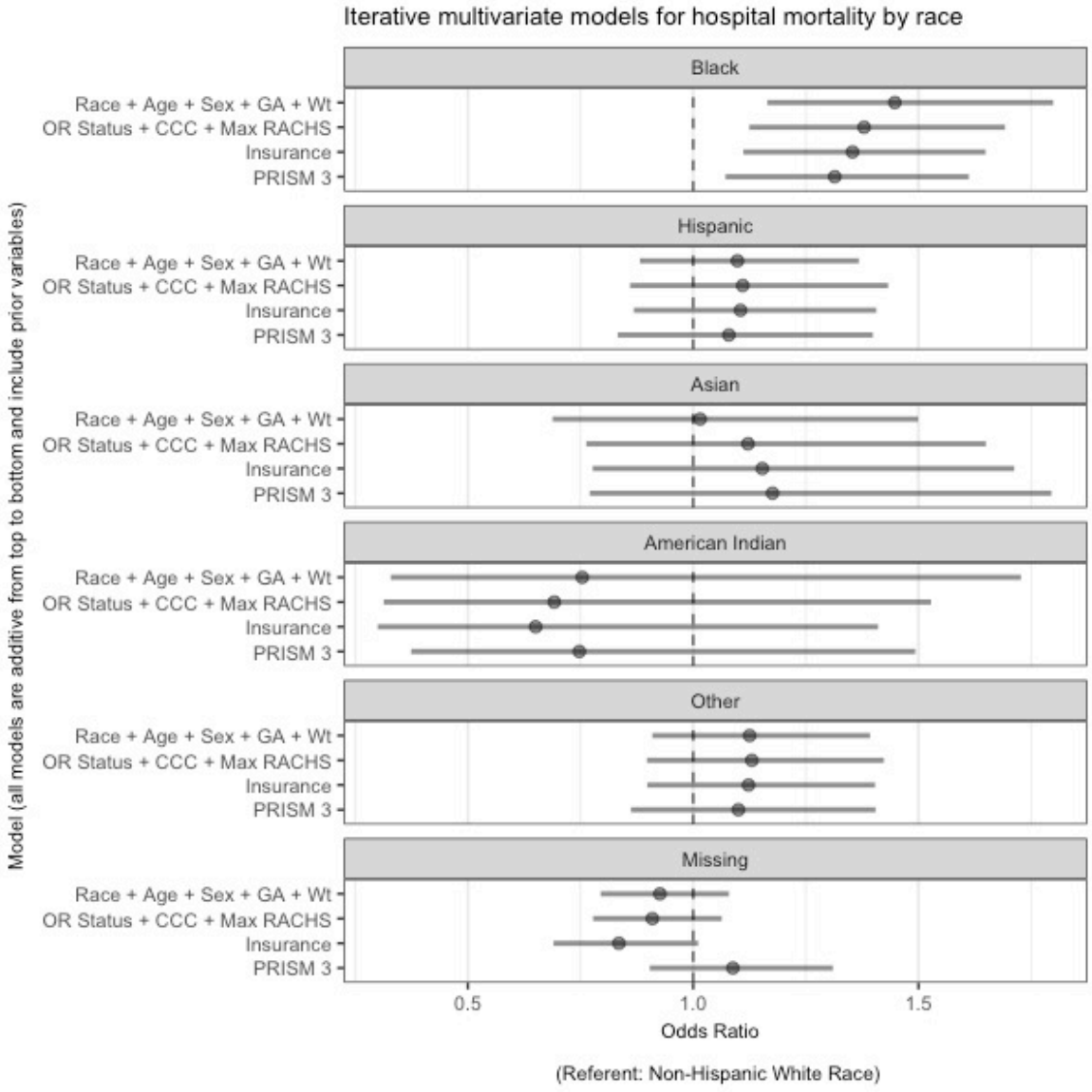

Unadjusted & Adjusted Mean & 95% Confidence Intervals for Severity of Illness by Race
Unadjusted Severity of Illness Score
Adjusted Severity of Illness Score
PIM 2
PRISM 3
PICSIM
Severity of Illness Score
-3.8
-4.0
-4.2
-4.4
8
7
6
5
0.045
0.040
0.035
0.030
0.025
0.020
0.015
White
Black
Hispanic
Asian American Indian
Other
Missing
Race

Figure 3.


Iterative multivariate models for hospital mortality by race
Black
Hispanic
Asian
American Indian
Other
Missing
Race + Age + Sex + GA + Wt
OR Status + CCC + Max RACHS
Insurance
PRISM 3
Model (all models are additive from top to bottom and include prior variables)
0.5
1.0
1.5
Odds Ratio
(Referent: Non-Hispanic White Race)