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Racial, ethnic, and socio-economic disparities in neonatal ICU admissions among neonates born with cyanotic CHD in the United States, 2009–2018

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Abstract

Introduction: Disparities in CHD outcomes exist across the lifespan. However, less is known about disparities for patients with CHD admitted to neonatal ICU. We sought to identify sociodemographic disparities in neonatal ICU admissions among neonates born with cyanotic CHD. *Materials & Methods:* Annual natality files from the US National Center for Health Statistics for years 2009–2018 were obtained. For each neonate, we identified sex, birthweight, pre-term birth, presence of cyanotic CHD, and neonatal ICU admission at time of birth, as well as maternal age, race, ethnicity, comorbidities/risk factors, trimester at start of prenatal care, educational attainment, and two measures of socio-economic status (Special Supplemental Nutrition Program for Women, Infants, and Children [WIC] status and insurance type). Multivariable logistic regression models were fit to determine the association of maternal socio-economic status with neonatal ICU admission. A covariate for race/ethnicity was then added to each model to determine if race/ethnicity attenuate the relationship between socio-economic status and neonatal ICU admission. *Results:* Of 22,373 neonates born with cyanotic CHD, 77.2% had a neonatal ICU admission. Receipt of WIC benefits was associated with higher odds of neonatal ICU admission (adjusted odds ratio [aOR] 1.20, 95% CI 1.1–1.29, $p < 0.01$). Neonates born to non-Hispanic Black mothers had increased odds of neonatal ICU admission (aOR 1.20, 95% CI 1.07–1.35, $p < 0.01$), whereas neonates born to Hispanic mothers were at lower odds of neonatal ICU admission (aOR 0.84, 95% CI 0.76–0.93, $p < 0.01$). *Conclusion:* Maternal Black race and low socio-economic status are associated with increased risk of neonatal ICU admission for neonates born with cyanotic CHD. Further work is needed to identify the underlying causes of these disparities.

CHD is the most common form of birth defect.[1] Over the past 20 years, infant mortality due to CHD has decreased significantly amidst improved care of premature births and advancements in surgical interventions to repair CHDs.[2] However, a growing body of work has found significant racial, ethnic, and socio-economic disparities in outcomes in infants and children with CHD, ranging from greater mortality in infancy to reduced quality of life in childhood and adolescence.[2–6] These disparities often begin prenatally, with decreased rates of prenatal detection of CHD in patients with lower socio-economic status, which ultimately delay access to appropriate cardiac care.[6–8] Health inequities in CHD are then perpetuated across the lifespan in part due to variable access to routine cardiac care, under- or un-insurance, structural racism, and poorer neighbourhood-level social determinants of health, among other factors.[9]

Our current understanding of the association between race, ethnicity, socio-economic status, and adverse birth outcomes in infants with CHD is primarily focused on mortality. One measure that has been understudied in this context is neonatal ICU admission, which is significantly associated with poor long-term outcomes such as increased healthcare utilisation, increased risk for altered school-age behaviour, and diminished economic potential as an adult.[10] Moreover, as daily neonatal ICU costs exceed $3,000 per neonate, evaluating neonatal ICU admissions among neonates with CHD may have important implications for understanding elevated healthcare costs in the CHD population.[11] Thus, in this nationally comprehensive study, we sought to

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determine if neonatal ICU admissions were associated with racial, ethnic, and socio-economic disparities among neonates born with cyanotic CHD.

Methods

Data source and measures

We conducted a retrospective observational study using natality data from the National Vital Statistics System of the National Center for Health Statistics. Annual natality data files provide information on all births occurring during each calendar year in the United States, and data are derived from birth certificates. We collected de-identified data on births in the 50 US states and District of Columbia. For each neonate, we identified sex, birthweight, pre-term birth, presence of cyanotic CHD, and neonatal ICU admission at the time of birth. A neonate was identified as having cyanotic CHD if in their natality file, the "Yes" box was checked for the presence of cyanotic CHD in the "congenital abnormalities of the newborn" section of the form. For each mother, we identified age, race, ethnicity, comorbidities, and risk factors (smoking, pre-pregnancy diabetes, gestational diabetes, pre-pregnancy hypertension, gestational hypertension, and eclampsia), trimester at start of prenatal care, educational attainment, and two measures of socio-economic status (Special Supplemental Nutrition Program for Women, Infants, and Children [WIC] status and insurance type) as of the time of birth of the neonate. The final analytical cohort was then limited to neonates with cyanotic CHD and maternal race/ethnicity of non-Hispanic White, non-Hispanic Black, or Hispanic.

Statistical analysis

First, we summarised the maternal and neonatal characteristics of all cyanotic CHD births in the analytical cohort using frequencies and proportions for binary measures, as well as medians and IQRs for continuous measures. We compared the distribution of maternal and neonatal characteristics across racial and ethnic groups for non-Hispanic White, non-Hispanic Black, and Hispanic neonates and tested for significant differences in characteristics using Chi-Square and Kruskal–Wallis tests.

Second, we visualised trends in neonatal ICU admission rates (i.e., percentages of neonates admitted to the neonatal ICU) for racial, ethnic, and socio-economic subgroups by plotting line graphs of annual, group-level neonatal ICU admission rates. We performed Mann–Kendall tests to test for significant trends in group-level neonatal ICU admission rates over time.

The primary analysis aimed to identify if maternal socio-economic status was associated with likelihood of a neonatal ICU admission. We built two separate logistic regression models in which the dependent variable was neonatal ICU admission. Each model included one measure of socio-economic status as an independent variable: WIC status and insurance type. In each model, we also included sex (male versus female), a binary variable for low birthweight (≤2,500 g), a binary variable for pre-term birth (<37 weeks), categorical bins for maternal age (<17 years, 17–35 years, and > 35 years), binary variables for maternal comorbidities/risk factors (gestational diabetes, pre-pregnancy diabetes, gestational hypertension, pre-pregnancy hypertension, and smoking status), and trimester at start of prenatal care as covariates.

In the secondary analysis, we added a covariate for combined race/ethnicity group (non-Hispanic White, non-Hispanic Black, and Hispanic) into each of the multivariable logistic regression models to determine the extent to which race and ethnicity modify the effect of socio-economic status on neonatal ICU admission risk. We tested for possible interaction between each measure of socio-economic status and race/ethnicity. No interaction terms were found to be statistically significant and were, consequently, excluded from the final models. Additionally, variance inflation factors were calculated for all covariates in the multivariable logistic regression models. All variance inflation factors were less than 5, suggesting no significant multicollinearity between covariates included in the final models.

Statistical analyses were performed using R version 4.1.0 (R Foundation for Statistical Computing). All statistical testing was two-tailed with P values<0.05 designated statistically significant.

Results

Baseline characteristics of the study cohort

Between 2009 and 2018, there were 24,067 births of neonates with cyanotic CHD identified in the natality files. Of those, 22,373 (93%) births had maternal race/ethnicity identified as non-Hispanic White, non-Hispanic Black, or Hispanic. Characteristics of these births are summarised in Supplemental Table 1. Overall, 44.4% of neonates were female, 40.3% of neonates were born pre-term, and the median (IQR) birthweight was 3,030 (2,440–3,460) grams. Non-Hispanic Black mothers had a 44.8% rate of pre-term births, compared to 41.9% among Hispanic mothers and 39.1% among non-Hispanic White mothers ($p < 0.001$). The median (IQR) birthweight for non-Hispanic Black neonates was 2,860 (2,260–3,320) grams, whereas the median (IQR) birthweight for non-Hispanic White neonates was 3,060 (IQR, 2,490–3,490) grams ($p < 0.001$). Non-Hispanic White mothers had a significantly higher smoking rate than Hispanic mothers (14.4 versus 4.6%, $P < 0.001$). Hispanic mothers had a higher rate of gestational diabetes than non-Hispanic Black mothers (10.7 versus 7.4%, $p < 0.001$), whereas non-Hispanic Black mothers had a higher rate of pre-pregnancy hypertension than Hispanic mothers (6.9 versus 2.9%, $p < 0.001$). Additionally, non-Hispanic White mothers tended to start receiving prenatal care earlier in pregnancy, with 72.2% of non-Hispanic White mothers starting prenatal care in the first trimester, compared to only 61% of non-Hispanic Black mothers and 63.2% of Hispanic mothers beginning care in the first trimester ($p < 0.001$).

Overall, 36.1% of mothers received WIC benefits. Among Hispanic mothers, 59.1% received WIC benefits, compared to 26.7% of non-Hispanic White mothers ($p < 0.001$). Hispanic mothers also tended to have lower educational attainment, with 34.8% of Hispanic mothers having less than a high school diploma/GED, compared to 7.9% of non-Hispanic White mothers and 18.5% of non-Hispanic Black mothers having less than a high school diploma/GED ($p < 0.001$). Notably, 63.1% of non-Hispanic White mothers had private insurance, compared to only 26.9% of Hispanic mothers and 27.5% of non-Hispanic Black mothers ($p < 0.001$).

Temporal trends in neonatal ICU admissions

The overall neonatal ICU admission rate for the entire study period was 77.2%, with non-Hispanic Black neonates having the highest neonatal ICU admission rates (Table 1). The non-Hispanic White neonatal ICU admission rate increased from 73.1% in 2009 to 83.4% in 2018 ($P = 0.04$ for trend), and the Hispanic neonatal ICU

Table 1. Association between socio-economic status and NICU admission among NH Black, NH White, and Hispanic US neonates born with cyanotic CHD. Models were unadjusted for race and ethnicity

	NICU Admission	
	Model 1	Model 2
Covariate	aOR[1] (95% CI)	aOR (95% CI)
Mother receiving WIC[2] benefits	1.20 (1.1–1.29)	–
Insurance type		
Private	–	Reference
Medicaid and other public	–	1.07 (0.98–1.16)
Self-pay	–	**0.65 (0.54–0.78)**
Other[3]	–	**1.42 (1.04–1.93)**
Maternal educational attainment		
Less than high school or GED[4]	Reference	Reference
High school diploma or GED	**1.30 (1.15–1.46)**	**1.24 (1.10–1.40)**
Some college	**1.22 (1.08–1.38)**	1.11 (0.98–1.25)
Associate's or bachelor's degree	**1.14 (1.01–1.29)**	1.02 (0.90–1.15)
Masters and higher	1.03 (0.89–1.19)	0.91 (0.78–1.05)
Trimester of start of prenatal care		
First trimester	Reference	Reference
Second trimester	**1.33 (1.21–1.45)**	**1.32 (1.20–1.44)**
Third trimester	**2.16 (1.85–2.53)**	**2.23 (1.91–2.62)**
Maternal gestational diabetes	**1.43 (1.25–1.65)**	**1.44 (1.25–1.65)**
Maternal pre-pregnancy diabetes	**2.08 (1.64–2.63)**	**2.16 (1.71–2.74)**
Maternal gestational hypertension	**1.28 (1.12–1.47)**	**1.24 (1.08–1.42)**
Maternal pre-pregnancy hypertension	**1.28 (1.04–1.58)**	**1.30 (1.06–1.60)**
Maternal smoking	**1.22 (1.09–1.37)**	**1.23 (1.09–1.37)**
Maternal age		
<17 years	Reference	Reference
17–35 years	1.19 (0.82–1.75)	1.21 (0.83–1.77)
>35 years	1.14 (0.77–1.68)	1.18 (0.80–1.74)
Neonatal male sex	**1.19 (1.11–1.27)**	**1.19 (1.11–1.27)**
Low birthweight	**1.48 (0.77–1.68)**	**1.47 (1.34–1.62)**
Pre-term birth	**1.17 (1.07–1.27)**	**1.16 (1.07–1.26)**

NH, non-Hispanic; NICU, neonatal ICU.
Bolded values indicate aOR with $p < 0.05$.
[1]aOR = adjusted odds ratio.
[2]WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.
[3]"Other" includes Indian health Service, CHAMPUS/TRICARE, and other federal, state, or local government insurance.
[4]GED = tests of general educational development.

admission rate increased from 74.5 to 80.9% in the same period ($p = 0.03$ for trend) (Fig. 1a). Neonatal ICU admission rates were higher among CHD neonates born to mothers receiving WIC benefits than mothers not receiving WIC benefits, with admission rates for WIC increasing from 76.7% in 2009 to 85.1% in 2018 ($p = 0.04$ for trend) (Fig. 1b). Admission rates tended to be lower among births where the source of payment for delivery was private insurance or self-pay (Supplemental Figure 1). Further, neonates born to mothers with higher educational attainment tended to have lower neonatal ICU admission rates. Of note, neonatal ICU admission rates for neonates born to mothers without high school degrees/GEDs increased from 71% in 2009 to 80% in 2018 ($p = 0.007$ for trend) (Fig. 1c).

Association of maternal socio-economic status with neonatal ICU admission

The results of the primary analysis to identify associations between maternal socio-economic status and likelihood of neonatal ICU admission for neonates with CHD are summarised in Table 1. Receipt of WIC benefits was associated with increased odds of neonatal ICU admission for the neonate (Model 1: adjusted odds ratio [aOR] 1.20, 95% CI 1.1–1.29, $p < 0.001$). Further, self-payment for delivery was associated lower odds of neonatal ICU admission (Model 2: aOR 0.65, 95% CI 0.54–0.78, $p < 0.001$). In both models, maternal educational attainment of high school diploma or GED was associated with higher odds of neonatal ICU admission for the neonate (Model 1: aOR 1.30, 95% CI 1.15–1.46, $p < 0.001$, Model 2: aOR: 1.24, 95% CI 1.10–1.40, $p < 0.001$) relative to maternal educational attainment of less than a high school diploma or GED. Notably, third trimester start of prenatal care, maternal gestational diabetes, pre-pregnancy diabetes, gestational hypertension, pre-pregnancy hypertension, smoking, and neonatal low birthweight and pre-term birth were all associated with significantly increased odds of neonatal ICU admission for the neonate in both models.

Association of maternal race and ethnicity with neonatal ICU admission

The results of the secondary analysis to identify associations between maternal race, ethnicity, and likelihood of neonatal ICU admission for neonates with CHD are summarised in Table 2. After adjusting for WIC status, Black race was associated with significantly greater odds (aOR 1.20, 95% CI 1.07–1.35, $p < 0.001$) of neonatal ICU admission for the CHD neonate, while Hispanic ethnicity was associated with significantly lower odds (aOR 0.84, 95% CI 0.76–0.93, $p < 0.001$) of neonatal ICU admission. Similar results were obtained when insurance type was introduced into the model as a marker of socio-economic status.

Discussion

To our knowledge, this is the first nationally comprehensive study to identify racial, ethnic, and socio-economic disparities in neonatal ICU admission rates among a large cohort of neonates born with cyanotic CHD. Markers of low socio-economic status were independently associated with increased odds of neonatal ICU admission. Additionally, even after adjusting for pre-term birth, Black race was independently associated with increased odds of neonatal ICU admission, while Hispanic ethnicity was associated with decreased odds of neonatal ICU admission. Taken together, these findings suggest that race, ethnicity, and socio-economic status are important determinants of disparate birth outcomes among neonates born with cyanotic CHD.

Neonatal ICU admission rates in the study cohort increased significantly throughout the study period, echoing a similar trend in neonatal ICU admission rates in the general neonatal population.[12] This increase may be explained by the considerable growth in number and size of neonatal ICUs in recent years, as well

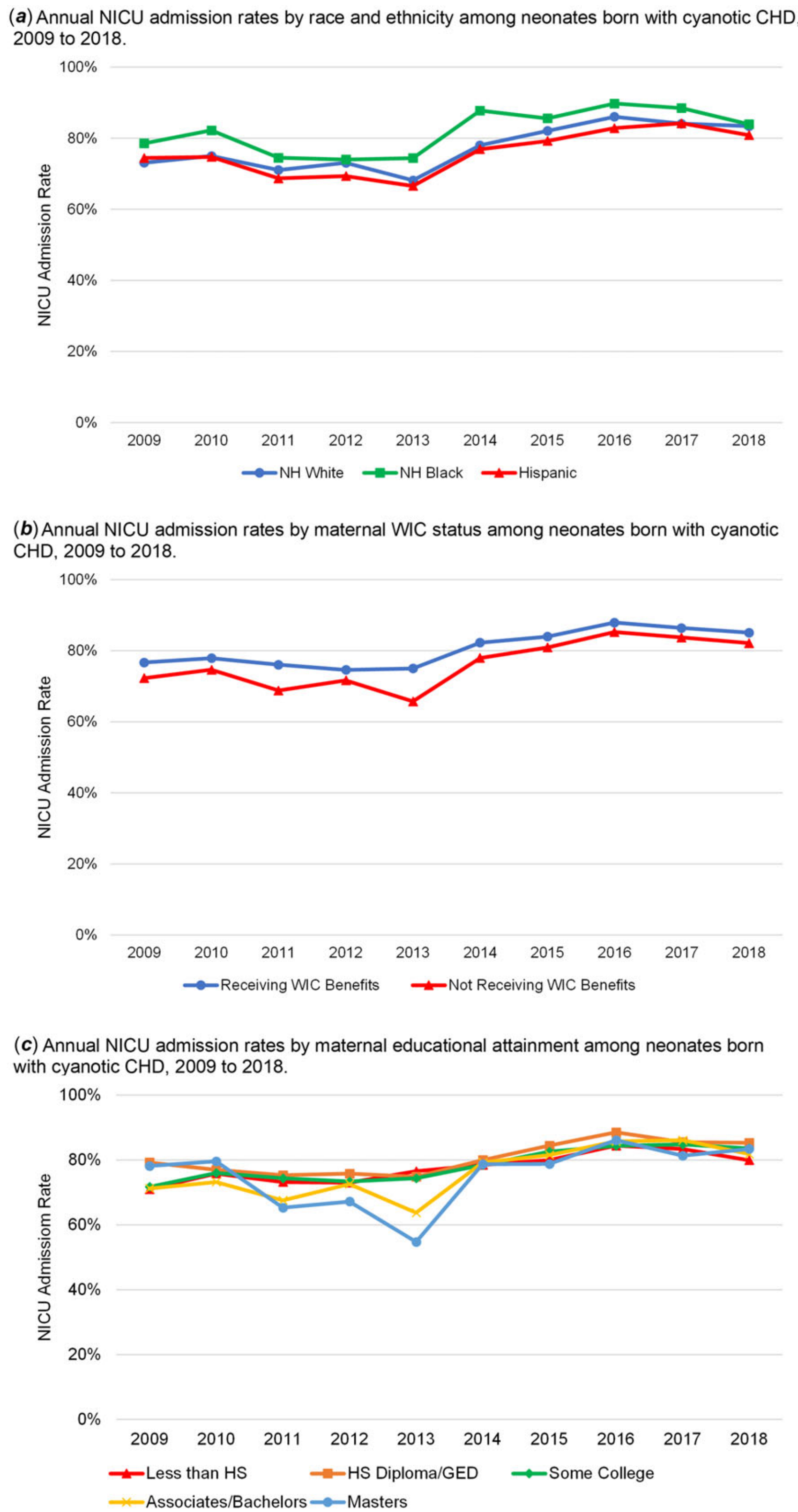

Figure 1. [***a***] Annual NICU admission rates by race and ethnicity among neonates born with cyanotic CHD, 2009–2018. [***b***] Annual NICU admission rates by maternal WIC status among neonates born with cyanotic CHD, 2009–2018. [***c***] Annual NICU admission rates by maternal educational attainment among neonates born with cyanotic CHD, 2009–2018. NICU, neonatal ICU.

as increased prenatal screening for CHD and improved prenatal detection rates over time.[13–16] However, neonatal ICU admission rates remained consistently high for non-Hispanic Black neonates as well as neonates with markers of low maternal socio-economic status and low maternal educational attainment. While neonatal ICU rates were overall higher in the neonatal CHD population than in the general neonatal population, our findings highlight persistent disparities in the likelihood of neonatal ICU admission even after

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Table 2. Association between socio-economic status, race, ethnicity, and NICU admission among NH Black, NH White, and Hispanic US neonates born with cyanotic CHD. Models were adjusted for race and ethnicity

	NICU admission	
	Model 1	Model 2
Covariate	aOR[1] (95% CI)	aOR (95% CI)
Mother receiving WIC[2] benefits	**1.20 (1.10–1.30)**	–
Insurance type		
Private	–	Reference
Medicaid and other public	–	1.05 (0.97–1.15)
Self-pay	–	**0.66 (0.55–0.80)**
Other[3]	–	**1.41 (1.04–1.92)**
Maternal race/ethnicity		
Non-Hispanic White	Reference	Reference
Non-Hispanic Black	**1.20 (1.07–1.35)**	**1.27 (1.13–1.42)**
Hispanic	**0.84 (0.76–0.93)**	**0.89 (0.80–0.98)**
Maternal educational attainment		
Less than high school or GED[4]	Reference	Reference
High school diploma or GED	**1.25 (1.11–1.41)**	**1.20 (1.07–1.36)**
Some college	**1.16 (1.02–1.31)**	1.07 (0.94–1.21)
Associate's or bachelor's degree	1.08 (0.95–1.22)	0.98 (0.86–1.12)
Masters and higher	0.98 (0.84–1.13)	0.87 (0.75–1.02)
Trimester of start of prenatal care		
First trimester	Reference	Reference
Second trimester	**1.32 (1.20–1.45)**	**1.31 (1.19–1.43)**
Third trimester	**2.16 (1.85–2.52)**	**2.22 (1.90–2.60)**
Maternal gestational diabetes	**1.45 (1.26–1.67)**	**1.45 (1.26–1.67)**
Maternal pre-pregnancy diabetes	**2.10 (1.66–2.66)**	**2.18 (1.72–2.77)**
Maternal gestational hypertension	**1.27 (1.11–1.46)**	**1.21 (1.08–1.41)**
Maternal pre-pregnancy hypertension	**1.24 (1.01–1.53)**	**1.26 (1.02–1.55)**
Maternal smoking	**1.18 (1.06–1.33)**	**1.21 (1.08–1.36)**
Maternal age		
<17 years	Reference	Reference
17–35 years	1.21 (0.83–1.77)	1.22 (0.83–1.79)
>35 years	1.16 (0.79–1.71)	1.19 (0.81–1.76)
Neonatal male sex	**1.19 (1.11–1.27)**	**1.19 (1.11–1.28)**
Low birthweight	**1.27 (1.34–1.62)**	**1.46 (1.33–1.61)**
Pre-term birth	**1.17 (1.07–1.27)**	**1.16 (1.07–1.26)**

NH, non-Hispanic; NICU, neonatal ICU.
Bolded values indicate aOR with $p < 0.05$.
[1]aOR = adjusted odds ratio.
[2]WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.
[3]"Other" includes Indian health Service, CHAMPUS/TRICARE, and other federal, state, or local government insurance.
[4]GED = tests of general educational development.

accounting for known clinical neonatal ICU admission risk factors, including pre-term birth and low birthweight. This finding is consistent with previous literature that has found wide racial, ethnic, and socio-economic gaps in adverse birth outcomes.[17–20]

Neonates born to Hispanic mothers had decreased odds of neonatal ICU admission, despite high rates of WIC enrolment and later onset of prenatal care among Hispanic mothers. These results agree with prior work that has found that rates of adverse birth outcomes can be lower among Hispanic neonates than among non-Hispanic White and non-Hispanic Black neonates, despite prevalent social risk factors (e.g., low socio-economic status and low health literacy) among Hispanic mothers.[10,21] This "Hispanic Paradox" has been documented in the literature and may be explained by differential prenatal experiences and birth outcomes among Hispanic mothers born in the United States versus those born outside of the United States.[22,23] A recent study identified considerable heterogeneity in adverse birth outcomes among Hispanic mothers after disaggregation by country of origin.[24] Sociocultural factors that contribute to this phenomenon are maintained by local community networks that provide informal social supports and systems of prenatal care that often diminish with acculturation.[22,23,25] Decreased odds of neonatal ICU admission among Hispanic neonates in this study may reflect this paradox. Reduced risk of neonatal ICU admission among Hispanic neonates may also reflect reduced access to risk-appropriate neonatal care among Hispanic mothers, which may be influenced by the geographic distribution of the Hispanic population in the United States as well as variable access to neonatal ICUs along the rural–urban continuum.[26]

While disparities in CHD outcomes across the lifespan are well documented, the causal mechanisms by which sociodemographic disparities in CHD outcomes arise remain poorly understood.[3,9,27] One factor that may drive disparities in CHD outcomes is prenatal care and corresponding prenatal CHD diagnosis, which has been shown to reduce the likelihood of perinatal and pre-operative morbidity and mortality in neonates with CHD.[8,28–30] Consistent with this, our study found that delayed prenatal care was associated with significantly increased odds of neonatal ICU admission. This relationship is exacerbated among Black mothers and mothers of low socio-economic status due to increased barriers to accessing prenatal care that are affected by geographic proximity to care, implicit bias, structural racism, affordability, and community-level social acceptance, among other factors.[31–34] It is possible that the disparities observed in this study are explained by socio-demographic differences in prenatal CHD diagnosis, which could not be identified in the data source underlying this study.

The increased odds of neonatal ICU admission among neonates born to mothers of Black race and low socio-economic status in our study may also indicate increased severity of disease in these neonates or other complicating risk factors. Several prior studies have found that Black infants tend to have more complex types of CHD.[35,36] Moreover, previous work has found that CHD mortality remains the highest among non-Hispanic Black individuals and that a significant portion of inferior outcomes among Hispanic and non-Hispanic Black infants with CHD can be explained by varied exposure to adverse maternal-fetal environments.[2,37] In the general neonatal population, non-Hispanic Black neonates have higher rates of neonatal ICU admissions than non-Hispanic White and Hispanic neonates, but these differences diminish after risk

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stratification. Racial and ethnic differences in neonatal ICU admission are pronounced in birthweight-stratified analyses, with the largest differences among neonates with normal to high birthweights. While this study did adjust for birthweight and preterm birth in modelling neonatal ICU admission risk, CHD lesion type, clinical severity, and additional risk factors could not be measured. It is possible that these variables explain some portion of the sociodemographic disparities in neonatal ICU admissions observed in this study.

Increased rates of neonatal ICU admission among Black and low socio-economic status neonates are concerning for various reasons. First, there are well-documented racial, ethnic, and socio-economic inequities in the quality of neonatal intensive care received by neonates, with Black neonates consistently receiving neonatal care at lower-quality neonatal ICUs than White neonates.[26,38,39] Among neonates with CHD, equitable access to high-quality neonatal care is crucial, as there are known survival advantages for neonates born in neonatal ICUs with high levels of care and high patient volumes.[40] Furthermore, when complex CHD is diagnosed prenatally, perinatal care coordination at tertiary centres with dedicated paediatric cardiac surgical teams has been shown to improve perioperative outcomes in neonates with CHD.[41,42] Second, the CHD population is known to consume a disproportionate share of health resources, with neonatal ICU patients among the highest utilisers of hospital resources.[43–45] Neonatal ICU admissions in the CHD population may, therefore, pose significant financial burdens to families from historically marginalised and disadvantaged communities. Further work is needed to understand how differences in neonatal ICU admission rates correlate with differential resource use among neonates with CHD, with a particular focus on racially minoritised neonatal patients and patients of low socio-economic status.[43,44]

Limitations

There are several limitations to this study. First, this study was observational and cross-sectional, so causality cannot be inferred. Second, as the data source lacked detailed geographic information, no geocoded analyses evaluating neighbourhood-level factors (e.g., residential segregation and geographic proximity to neonatal ICU hospitals) could be performed. Additionally, the data did not specify the type of CHD, and risk for neonatal ICU admission can vary by lesion type and severity of disease. Moreover, some forms of cyanotic CHD require admission to a neonatal ICU for neonatal intervention, in which case neonatal ICU admission would not necessarily be considered an adverse birth outcome. However, the data source does not distinguish between planned versus unplanned neonatal ICU admissions, precluding granular analyses based on the planned nature of a neonatal ICU admission. Third, this study was limited to only non-Hispanic Black, non-Hispanic White, and Hispanic mothers. Further work is needed to investigate the association between socio-economic status and neonatal ICU admission risk among mothers belonging to other racial and ethnic groups. Fourth, data on admission to cardiac ICU is not provided in the natality files. There may be geographic variation in admission practices (e.g., the possibility of all neonates with critical CHD presenting to cardiac ICU and only premature neonates with CHD presenting to neonatal ICU) that cannot be detected by the natality files used in this study. While birth certificate forms define neonatal ICU admissions, variations in coding practices across states and hospitals may mean that some certificates are marked "Yes" for neonatal ICU admission when the neonate was admitted to a dedicated cardiac ICU, and other certificates are marked "No" in similar situations.[12] The direction of bias is unclear and cannot be determined using the underlying data source. However, data on neonatal ICU admissions from National Center for Health Statistics natality files have been validated in previous studies with regard to accuracy and adequate agreement between birth certificates compared to hospital records.[46] Further, previous work has found that more neonates undergoing congenital heart surgery are admitted to neonatal ICUs relative to cardiac ICUs.[45] Prior studies evaluating neonatal ICU versus cardiac ICU admissions among neonates with CHD have noted significant data limitations in alternative administrative databases with regard to distinguishing cardiac ICU admissions from other ICU admissions (e.g., miscoding of charges for cardiac ICU versus PICU admissions, lack of data on the level of specialisation of care within ICUs).[45] Additional work is needed to understand if similar sociodemographic disparities exist in cardiac ICU admission risk for neonates born with CHD. Fifth, the study period spans 2009–2019, but the 2003 revision US Standard Certificate of Live Birth was not adopted in all US states until 2016.[47] As this may introduce bias into the interpretability of the data, a temporal analysis of neonatal ICU admission rates was performed to mitigate this limitation. Sixth, the natality files do not provide information on prenatal diagnosis of CHD, which can influence odds of neonatal ICU admission for the neonate. We attempted to minimise consequent confounding by controlling for trimester of start of prenatal care. Lastly, the data source did not specify neonatal ICU care levels (i.e., Levels I, II, III, and IV), which reflect the nature of services and therapies offered at each neonatal ICU and the complexity of medical conditions each facility has capabilities to treat. Additional work is warranted to determine if disparities in neonatal ICU admission rates reflect underlying differences in access to risk-appropriate neonatal ICU care.

Conclusion

There are significant racial, ethnic, and socio-economic disparities in neonatal ICU admissions among neonates born with cyanotic CHD in the United States between 2009 and 2018, of which maternal Black race and low socio-economic status were the most significant risk factors. Identifying and addressing the root causes of these disparities is essential to mitigating sociodemographic disparities in CHD outcomes in neonates.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1047951124024971.

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