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DETERMINING THE RACIAL AND ETHNIC DIFFERENCES IN NEONATAL INTENSIVE CARE UNIT ADMISSION RATES

YOUNGRAN KIM

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DETERMINING THE RACIAL AND ETHNIC DIFFERENCES
IN NEONATAL INTENSIVE CARE UNIT ADMISSION RATES

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2020

DEDICATION

To Jusang Yang

DETERMINING THE RACIAL AND ETHNIC DIFFERENCES
IN NEONATAL INTENSIVE CARE UNIT ADMISSION RATES

by

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BS, Seoul National University, 2000
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Presented to the Faculty of The University of Texas

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS
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DETERMINING THE RACIAL AND ETHNIC DIFFERENCES
IN NEONATAL INTENSIVE CARE UNIT ADMISSION RATES

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The University of Texas
School of Public Health, 2020 Numeric Year

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Background: Recent trends show that the utilization of neonatal intensive care unit (NICU) has extended beyond severely ill infants and increased substantially across all birth weights. However, little is known about what drives the growth of NICU admission rates and whether these trends differ by race/ethnicity. **Methods:** The study used 2008-2018 Natality Files with restricted use of state and county-level information. Crude and risk-adjusted NICU admission rates, overall and stratified by birth weight group, were compared between black and white infants and between Hispanic and white infants. Kitagawa decomposition and Oaxaca-Blinder decomposition analyses were conducted for the temporal increase in NICU admission rates by race/ethnicity. **Results:** Overall NICU admission rates increased by 37% from 2008 to 2018, and the increasing trends were observed among all racial and ethnic groups. The absolute and percent increases were the smallest among white infants. NICU admission rates remained highest among black infants. Hispanic infants had the lowest NICU admission rates in early study years but reached rates similar to those of white infants in later years. Most differences in overall NICU admission rates by race/ethnicity disappeared after the risk adjustment but birth weight stratified analyses showed different patterns.

Racial/ethnic differences diminished in the very low birth weight and moderately low birth weight groups while risk-adjusted NICU admission rates remained higher among black and Hispanic infants in the normal to high birth weight group. Kitagawa decomposition found that the overall increase in NICU admission rates was decomposed into 3.4% attributed to changes in the birth weight distribution and 96.6% attributed to changes in the birth weight-specific NICU admission rate. Oaxaca-Blinder decomposition analysis showed that changes in infant health risk contributed 0.87 and 0.47 of NICU admission rate increase per 100 infants among black and Hispanic infants respectively, while it mitigated the increase by 0.14 among white infants. Increased NICU bed supply contributed 0.48, 0.04, and 0.28 per 100 infants among white, black, and Hispanic infants, respectively. Maternal socioeconomic characteristics did not change but changes in their association with NICU admission contributed most to the NICU admission increase among all race/ethnic groups.

Conclusions: Racial/ethnic differences in risk-adjusted NICU admission rates diminished among high-risk infants while black and Hispanic infants maintained higher risk-adjusted NICU admission rates among low-risk infants. The contributions of the factors affecting NICU admission growth substantially differed by race/ethnicity.

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BACKGROUND

Development of Neonatal Intensive Care

As the scientific understanding of human development and disease improved and technology of treating premature infants advanced, pediatricians assumed an increasing role in providing active interventions to newborn infants.^{1,2} In 1960, the term neonatology was coined by Alexander Schaffer and the first American neonatal intensive care units (NICU), designed by Dr. Louis Gluck, was opened in 1965.^{1,3} In the past 50 years, remarkable advances in neonatal intensive care, such as improvements in the respiratory management of the premature infant in the 1970s and the introduction of surfactant therapy in the 1980s, improved survival and reduced morbidity of premature and sick newborns.^{1,2}

Risk-Appropriate Care and Regionalization

Neonatal intensive care has significantly improved mortality of premature and sick newborns.⁴ In the US, the number of neonatal deaths per 1000 live births dropped from 18.73 in 1960 to 3.78 in 2018 and most of the reduction is attributed to neonatal intensive care.^{5,6} As neonatal intensive care was proven to improve neonatal outcomes, perinatal stakeholders initiated efforts to better distribute and organize perinatal services within geographic regions. Perinatal regionalization was first proposed by the March of Dimes in 1976 in *Towards Improving the Outcomes of Pregnancy* (TIOP) to promote risk-appropriate care to pregnant women and newborns.⁷ The premise of regionalized perinatal care is that newborn outcomes are better when maternal and fetal risks are identified early and care is provided in hospitals with the appropriate capacity, including advanced technology and specialized health providers, to address

the identified risks. For newborn care, the American Academy of Pediatrics (AAP) defines four levels of neonatal care.⁸

- Level I (well newborn nursery) units have the capability to 1) provide neonatal resuscitation at every delivery, 2) evaluate and provide postnatal care to healthy newborn infants, and 3) are staffed with pediatricians, family physicians, nurse practitioners, and other advanced practice registered nurses.
- Level II (special care nursery) units are able to 1) provide care for infants born ≥ 32 -week gestation and weighing ≥ 1500 g who have physiologic immaturity or who are moderately ill with problems that are expected to resolve rapidly and are not anticipated to need subspecialty services on an urgent basis, 2) provide mechanical ventilation for a limited duration (< 24 h) or continuous positive airway pressure, and 3) are staffed with pediatric hospitalists, neonatologists, and neonatal nurse practitioners in addition to Level I health care providers.
- Level III (neonatal intensive-care unit) units provide 1) comprehensive care for infants born < 32 wks gestation and weighing < 1500 g and infants born at all gestational ages and birth weights with critical illnesses, 2) a full range of respiratory support that may include ongoing assisted ventilation for 24 hours or more, and 3) have access to a full range of pediatric medical subspecialists, pediatric surgical specialists, pediatric anesthesiologists, and pediatric ophthalmologists.
- Level IV (regional NICU) units provide the highest level of neonatal care and are required to have pediatric surgical subspecialists in addition to the care providers required for Level III units

Regionalized systems of perinatal care have contributed to significant reductions in neonatal and infant mortality rates. The delivery of very low birth weight (VLBW) or very preterm (VPT) infants at hospitals with a level III or IV unit is known to be associated with lower mortality and morbidity and is now a standard of care.⁸⁻¹⁰ Lasswell et al conducted a meta-analysis of 41 published studies on associations between hospital level at birth and neonatal mortality and concluded that very low birth weight infants born in non-level III hospitals had a 62% increase in odds of neonatal or pre-discharge mortality compared with those born in level III hospitals (adjusted odds ratio [aOR], 1.62; 95% confidence interval [CI], 1.44–1.83).¹⁰

Deregionalization and Expansion of NICU Beds

Despite efforts to develop systems of perinatal regionalization, perinatal regionalization faltered in the late 1980s.¹¹ The introduction of prospective payment based on diagnosis-related groups (DRGs), increasing hospital competition and expansion of managed health care systems motivated hospitals to expand the scope of care and retain high-risk patients.¹¹⁻¹³ This change was accompanied by the diffusion of advanced technology and a dramatic increase in the supply of neonatal clinicians.^{14,15} Deregionalization resulted in the proliferation of NICU units and beds in a higher proportion of hospitals with maternity services and provision of neonatal intensive care extended beyond regional or academic centers.^{11,16}

However, studies found that the availability of NICU beds and neonatologists was not necessarily associated with newborns' needs or outcomes.^{17,18} Goodman et al. showed that neonatal intensive care capacity was not preferentially located in regions with greater low birth weight rates.¹⁷ Their subsequent study also found no consistent association between the regional supply of NICU beds and neonatal mortality.¹⁸

Growth of NICU admission rates

Some studies underscore the association between NICU bed supply and additional NICU utilization.¹⁹⁻²¹ Recent trends show that NICU admissions have increased for all birth weights, particularly in larger and less premature newborns among whom neonatal mortality is low.²² Harrison and Goodman reported that from 2007 to 2012, NICUs increasingly admitted term infants of higher birth weights and by 2012, more than half of all newborns admitted to a NICU were at least 2500g at birth.²² Expanding the NICU admitted newborn population to less acutely ill newborns suggests that some NICU utilization may be unnecessary. There is evidence that greater bed supply associated with high NICU utilization, especially among low-risk newborns. Shulman et al found among infants born at GA of 34 weeks or more, inborn admission rates for specific GA strata correlated strongly with overall inborn admission rates and did not significantly correlate with the percentage of admissions with high illness acuity.²⁰ Ziegler et al found significant between-hospital variation in NICU admission rates among infants 35 to 42 weeks' gestation and ≥ 2500 g without identifiable infant health conditions.²³ Harrison et al found that NICU admissions among VLBW infants are not related to regional NICU bed supply but non-VLBW infants are more likely to be admitted to a NICU in regions with the highest NICU bed supply indicating possible overuse.²¹

Treatment decision beyond medical necessity

Current trends of NICU utilization can be summarized as follows: First, NICU supply and utilization are not necessarily aligned with health risk and need. Second, there are increasing NICU admission rates among all birthweights and unwarranted variation (i.e. not caused by regional differences in newborn needs and family preferences of NICU utilization) among low

risk infants indicating potential overutilization.²⁴ Misaligned neonatal resources can also lead to difficulty in receiving timely NICU care among some high-risk infants.²⁵

These raise important concerns regarding access to NICU care. Given that birth outcomes determining the need for NICU care tend to be worse among infants who are non-White and with lower socioeconomic status,²⁶ infants born to minority and lower socioeconomic populations could suffer disproportionately more from less-than-optimal NICU care access. For example, VLBW and premature infants are often required to be admitted to a NICU and the percentage of VLBW infants is three times as high among non-Hispanic black infants compared to non-Hispanic white infants (2.92% vs 1.02% in 2018)²⁷ and rates of preterm birth are more common among women living in poverty than for higher-income women.²⁶ Another concern is related to the multitude of potential factors affecting decision making on NICU admission. When NICU utilization is supply sensitive to some degree and the infant's condition is uncertain for intensive care, the decision on NICU admission can be discretionary. The effect of traditional factors affecting health care access and utilization, such as race/ethnicity and socioeconomic characteristics can then become additional determinants of NICU admission. There are studies demonstrating that significant variation exists in NICU care not explained by infant health condition.^{20,23,28} However, studies of the determinants of NICU admission beyond the infant's health risk are rare and focusing only on VLBW infants.²⁹

Race/Ethnicity and NICU admission

Race and ethnicity are important factors when assessing health risks and access to health care.³⁰ While studies on racial/ethnic differences among children address a wide range of areas, such as access to care, health care utilization, and prevalence of chronic disease,³¹ researches on

racial/ethnic differences among infants have focused mostly on birth outcomes and infant mortality.^{6,27,32} Neonatal mortality accounts for two-thirds of infant mortality and is primarily related to birth outcomes and access to risk-appropriate care.^{6,32} Due to distinct racial/ethnic differences in the percentage of VLBW and neonatal mortality risk, clinical and public health efforts have focused on preventing premature births among minorities. Studies on racial/ethnic differences in neonatal health care utilization are rare and most NICU studies focused on evaluating the quality of care based on hospital characteristics such as level of care or patient volume among VLBW infants while controlling for race/ethnicity in a statistical model as a covariate. There are only a few studies that compared NICU utilization by race/ethnicity and evaluated the effect of race/ethnicity as a primary interest but mostly among VLBW. Table 1 summarizes relevant studies.

Table 1. Studies on NICU utilization by race/ethnicity

Study	Objective	Population & Analysis	Results	Comments
Barfield, 2010 ²⁹	Predictors of NICU admission	22,427 VLBW in 19 states, 2006. Multivariate log-binomial regression with generalized estimating equations to account for variation among states in NICU admission of VLBW infants	Crude NICU admission rates in white 80.5%, Black 79.5%, and Hispanic 71.8% and racial/ethnic differences in NICU admission varied by state. No differences after adjusting infant gestational age, sex, mother's parity, age group, years of education, plurality, and delivery mode. Gestational age, multiple births and c-section identified as predictors for NICU	Wide variation in racial/ethnic differences in NICU admission across states, White vs Black: 68.1% vs 60.4% in CA, 76.1% vs 82.0% in Texas

de Jongh, 2012 ³³	Effects of maternal age, race/ethnicity and insurance on NICU admission rates	167,160 live births from 19 US hospitals 2002–2008. GLM and 3 way-stratification	OR Black and White:OR >1 among private insurance (and <1 among public insurance	Analysis by 3 ways comparision race/ethnicity x insurance x maternal age. Not clear comparison of race/ethnicity. Limited covariates (maternal age, insurance status, and history of previous c-section)
Profit, 2017 ³⁴	Racial/ethnic disparity in quality of care using a composite indicator	18,616 VLBW infants in CA 2010-2014. Risk adjusted standard score stratified by race/ethnicity	Significant racial and/or ethnic variation in quality of care between and within NICUs	Stratification by race/ethnicity rather than adjustment for race/ethnicity
Wallace, 2017 ³⁵	Racial/ethnic differences in preterm perinatal outcomes	19,325 preterms (<37 weeks of gestation) in CA, 2002-2008. Multivariate Poisson models	NICU admission higher in Black and lower in Hispanic but not significant	No neonatal characteristics other than sex included. Birth weight not specified but would have been in a wide range
Harrison, 2018 ²¹	Geographic variation in NICU admission rates in relation to bed supply	3,304,364 across the entire birth cohort in 2013. Analyses for the overall cohort and stratified by birth weight: 500-1499 g, 1500-2499 g, and ≥2500 g using multilevel logistic regression adjusting for race and other factors	Overall OR:Hispanic 0.86, Black 0.96, 500-1499g OR: Black 1.18, 1500-2499g OR: Hispanic 0.86, Black 0.85, ≥2500g OR: Hispanic 0.86	Race included in the model to account for. Second study in NICU use covering the entire birth weights
Horbar, 2019 ³⁶	Racial/ethnic segregation and inequaltiy in NICU care	117,982 VLBW and VPT infants across the 743 NICUs in the Vermont Oxford Network, 2014-2016. NICU segregation and NICU inequality indices were calculated by race/ethnicity	Black, Hispanic, and Asian infants were segregated across NICUs and compared with white infants, black infants were concentrated at NICUs with lower-quality scores.	Racial/ethnic differences in quality of NICU care remain after accounting for geographic differences in NICU quality

Statement of the Problem

Timely and appropriately provided neonatal intensive care can significantly improve the health outcomes of newborns and substantially impact the quality of life. Understanding

racial/ethnic difference in NICU admissions is particularly relevant given that the proportion of births to non-White and Hispanic mothers is increasing while racial/ethnic differences in birth outcomes are persistent. Only half of the births in the U.S. are non-Hispanic whites and the general fertility rate (GFR) for non-Hispanic whites is lower than for non-Hispanic black and Hispanic women (57.2 vs 63.1 vs 67.6 births per 1000 females aged 15–44 in 2017).³⁷ The percentage of low birth weight (LBW) infants remains twice as high among non-Hispanic blacks compared to non-Hispanic whites (14.07% vs 6.91% in 2018)²⁷ and the neonatal mortality rate among non-Hispanic black infants is more than twice that of non-Hispanic white infants (7.06 vs 3.00 per 1000 births in 2018).⁶

Racial/ethnic differences in NICU utilization among similar risk groups not only raise equity concerns but also results in the inefficiency of health care by limiting a cost-effective early intervention.⁴ Given the trends in increasing NICU admissions across all birth weights²² and rapid change in racial/ethnic composition,³⁸ a comprehensive study needs to be done to determine racial/ethnic differences in the NICU admission rate covering all birth weight ranges at the national level.

Objectives

This research studied racial/ethnic differences in the NICU admission rate covering all birth weight ranges at the national level with three aims.

Aim 1: Describe temporal trends of racial/ethnic differences in crude and risk-adjusted NICU rates from 2008 to 2018

Aim 2: Decompose the temporal change of NICU admission rates into changes in the birth weight distribution and birth weight-specific NICU admission rates between 2008 and 2018 by race/ethnicity

Aim 3: Quantify the contribution of neonatal characteristics, NICU bed supply and maternal socioeconomic characteristics to the growth of NICU admission rates between 2009 and 2018 by race/ethnicity

Conceptual Framework

The study adopted the 1995 version of Andersen's Behavioral Model for the conceptual framework.³⁹ The model was initially developed in the late 1960s and is one of the most widely used models as a framework identifying individual and contextual determinants of health care utilization. According to the model, an individual's access to and use of health services is considered to be a function of three characteristics: predisposing, enabling, and need factors. Predisposing factors indicate the socio-cultural characteristics of individuals that exist prior to their illness. They include the demographic characteristics such as age and sex, social structure such as education, ethnicity and social network, and health beliefs such as attitudes, values, and knowledge related to health and health services. Enabling factors are financial and organizational resources enabling services utilization. They include personal/family factors such as income and health insurance and community characteristics such as available health personnel and facilities, per capita community income, and the rate of health insurance coverage at the community level. Neighborhood income is not only highly correlated with individual level income but also independently affects individual health risk.⁴⁰⁻⁴⁴ Need factors are immediate causes for health

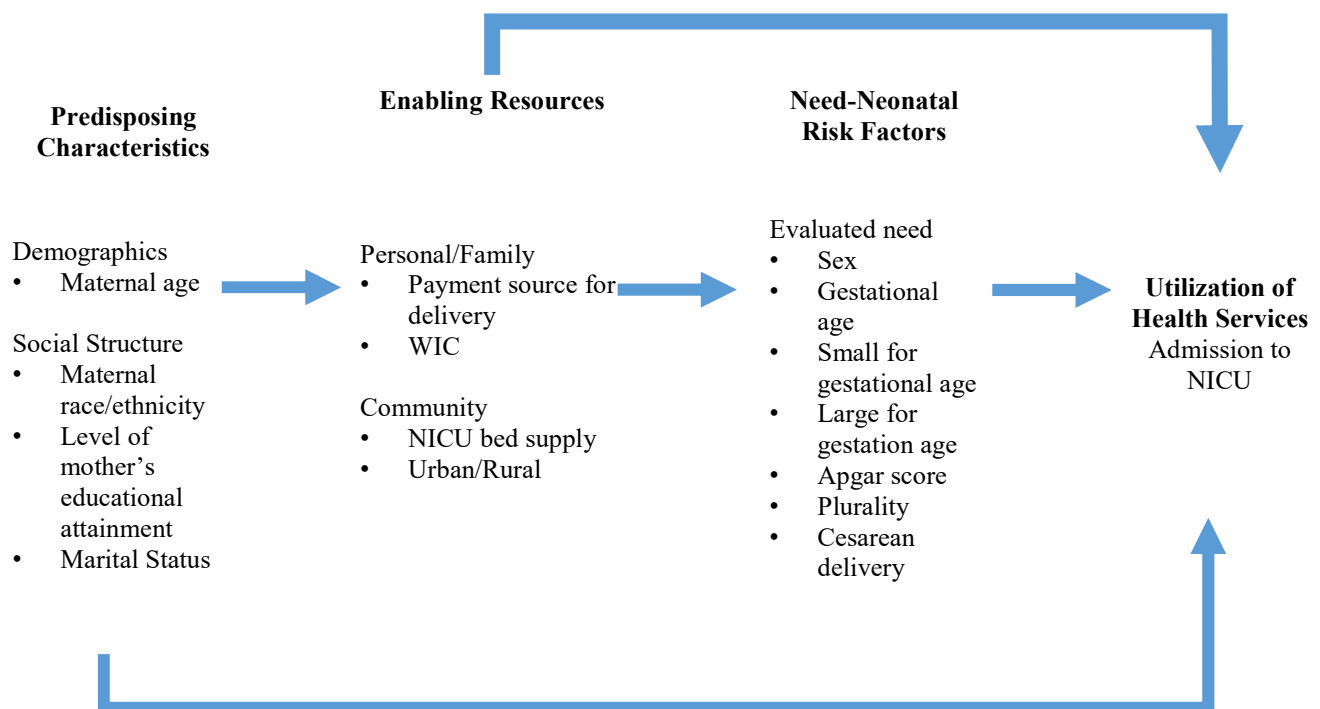
service use and are differentiated into perceived need and evaluated need for health services.

Perceived need is the health status perceived by the population and evaluated need is

professional assessments of patients' health status and their need for medical care.

Figure 1 summarizes the conceptual model for this study including relevant characteristics identified as predisposing, enabling, and need factors for this study. Need factors were identified and used for the risk adjustment in the analysis of Aim 1 and 2 and all three factors were considered for contributing factors to NICU admission rate growth.

Figure 1. Conceptual Framework adopted from Andersen Model



Public Health Significance

There are only a few studies done to determine the racial/ethnic differences in the NICU admission rate and mostly limited to the VLBW population. To the best of my knowledge, this

study is the first to examine racial/ethnic differences in the use of NICU across all birth weights and its temporal trends. This study aims to analyze temporal trends of NICU utilization by race/ethnic group and provide a better understanding of comparable importance of factors contributing to NICU admission growth by race/ethnicity. The results of Aim 1 provide the information on whether race/ethnic differences in the NICU admission rate are persistent and vary by birth weight category over the years. This will help us to identify which birth weight and racial/ethnic groups need improvement in access to NICU care. The results of Aim 2 identify the relative effects of both birth weight distribution and birth weight-specific NICU admission component by race/ethnicity. If the distribution of birth weight in a certain racial/ethnic group is identified as having a greater effect on the increase of NICU admission by shifting toward lower birth weight, the effort to improve birth weight in that racial/ethnic group should be paid more attention. The results of Aim 3 identify the relative importance of various factors affecting the growth of NICU admission rates and quantify the extent to which specific factors can reduce the growth in NICU admission rates for each race/ethnic group.

METHODS

Data Sources

This is a population-based retrospective study using restricted 2008-2018 Natality Files with geographic information from the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC). All states require the reporting of live births regardless of the length of gestation or birth weight⁴⁵ and Natality Files contain all live births occurring within the United States. Natality files are based on information derived from birth

certificate data which is collected using the U.S. Standard Certificate of Live Birth issued by the U.S. Department of Health and Human Services. The latest version of the U.S. Standard Certificate of Live Birth was introduced in 2003 to improve the collecting process and data quality. The 2003 revision of U.S. Standard Certificate of Live Birth contains many new items which never collected before including information on abnormal conditions of the newborn such as NICU admission or use of assisted ventilation at birth. The 2003 revision was phased in replacing the previous 1989 revision and full implementation in all states was phased in over several years. Natality files for the transition period of 2003-2015 include data items common to both the 1989 and 2003 revisions and items exclusive to the 2003 revision.

Table 2: Implementation of the 2003 U.S. Standard Certificate of Live Birth, 2003-2016

Year	Revised reporting area
2003	2 states
2004	7 states
2005	12 states
2006	19 states
2007	22 states
2008	27 states
2009	28 states
2010	33 states and the District of Columbia
2011	36 states and the District of Columbia
2012	38 states and the District of Columbia
2013	41 states and the District of Columbia
2014	47 states and the District of Columbia
2015	48 states and the District of Columbia
2016	All states and the District of Columbia

*Source User Guide to the 2015 Natality Public Use File

The information on the number of NICU beds at the county level was available from the area health resources files (AHRF), previously known as the area resource files (ARF). The

AHRF is publicly available to download at the Health Resources and Services Administration (HRSA) website (<https://data.hrsa.gov/>). The AHRF data used the hospital-level data from the American Hospital Association (AHA) Annual Survey Database and aggregated to the county level.

Study Population

The study population included live births from 2008 to 2018 in U.S. states and the District of Columbia for Aim 1 and Aim 2 and live births in 2009 and 2018 for Aim 3. The 2003 U.S. Standard Certificate of Live Birth defines live birth as complete expulsion or extraction of a product of conception that gives a sign of life after birth, regardless of the length of the pregnancy.

Since our primary interest was NICU admission, which is exclusive to the 2003 Standard Certificate of Live Birth, we excluded births recorded using the earlier version. Births to mothers whose state of residence is not one of the 50 US states or District of Columbia were excluded, which is expected to be about 0.2% in 2018.⁴⁶ Births weighing less than 500 grams or occurring before 23 completed weeks of gestational age were excluded as they are not considered viable with current technology⁴⁷⁻⁵⁰ and wide variation in practices exists regarding the initiation of resuscitation and active treatment.⁵¹⁻⁵⁴ We also excluded births with unknown birth weight or gestational age, or implausible combinations of birth weight and gestational age. Further exclusions were applied for other unknown information specific to each Aim.

Variables and Measurement

NICU admission

According to the CDC's guideline to complete the 2003 Standard Certificate of Live Birth, NICU admission is defined as "admission into a facility or unit staffed and equipped to provide continuous mechanical ventilator support for a newborn."⁵⁵ This definition of NICU excludes units not providing continuous mechanical ventilation, which makes it comparable to levels III and IV of neonatal care by the American Academy of Pediatrics (AAP). To facilitate the evaluation of health outcomes, resource use and health care costs using uniform definitions, the 2012 policy statement by the AAP updated the classification of neonatal care into 4 levels: Level I for well newborn nursery, level II for specialty care nursery, level III for NICU and level IV for regional NICU.⁸ Level II nurseries may provide mechanical ventilation for a brief duration (less than 24 hours) but not continuously.⁸ Ongoing assisted ventilation for 24 hours or more is available only at levels III and IV facilities.⁸ Therefore, infants whose birth records show NICU admission were assumed to be born at level III or IV facilities. We acknowledge that a validation study for selected measures from the 2003 revision of the birth certificate by comparing birth certificate data with information abstracted from hospital medical records shows a variation in the quality of NICU admission data by state and hospital⁵⁶ and that no study validated that hospitals are applying this definition of a NICU. It should also be noted that the CDC's guideline includes NICU admission at any time during the infant's hospital stay following delivery.⁵⁵ However, since the Certificate of Birth is required to be filed within 5 days of the date of birth⁵⁷, late NICU admissions in a prolonged hospitalization occurring after the filing were not captured. Finally, the infants who stayed at the NICU for observation without being admitted to NICU were excluded according to CDC's guideline.⁵⁵

Race/ethnicity

Mother's race and Hispanic origin are reported separately on birth certificates. Combined race/ethnicity was classified as non-Hispanic White (white), non-Hispanic Black (black), Hispanic and other. In 1997, the Office of Management and Budget (OMB) revised Race and Ethnic Standards for Federal Statistics allowing the responses of multiple races. However, the multiple-race reporting states varied throughout the study period before the transition completed starting in 2016. We used the bridged race to a single race for the responses of those who reported more than one race, which was accounted for 2.7% of births in 2018.⁴⁶ Comparisons were made between black and white infants and between Hispanic and white infants. Others were included in the total analysis but excluded in the comparison analysis.

Birthweight

Birthweight is recommended to be collected directly from the medical record in the units in which the weight of the infant at birth is measured, either grams or pounds and ounces.⁵⁵ If birthweight is entered in pounds and ounces, it is converted and rounded to the nearest whole gram in the Natality data. Any birthweight outside of the range of 0227-8165grams is edited as 9999. The study stratified birthweight as VLBW (500-1499g), moderately low birth weight (MLBW, 1500-2499g), normal to high birth weight (NHBW, ≥ 2500 g) for Aim 1 and 2.

Gestational age

The study used the obstetric estimate of gestation at delivery (OE) rather than the measure based on the date of the last normal menses (LMP). Both the OE- and LMP-based data were available for the study period but the OE-based gestational age was preferred for the

following reasons. Studies have shown that the OE- based gestational age agrees better with a gold standard estimate from early ultrasound⁵⁸⁻⁶⁰, is more sensitive and specific for neonatal risk indicators associated with prematurity⁶¹, and shows higher consistency with the distribution of birth weight for gestational age.⁶² Beginning with the 2014 data year, NCHS transitioned to the use of the OE as its standard, primary measure of gestational age. The OE in the Natality data is defined as the best obstetric estimate of the infant's gestation based on the clinician's estimate of gestational age at delivery and recommended to be collected directly from the medical record.⁵⁵ It is reported in completed weeks and any fraction of a week is rounded down to the nearest whole week.⁵⁵ If the OE is outside of 17 through 47 completed weeks or missing, it is edited as an invalid value of 99.⁶³ We categorized gestational age for Aim 3 as <32wk, 32-36wk (intermediate and late-preterm), 37-38wk (early-term), 39-40wk (full-term), 41wk (late-term), ≥ 42 wk (post-term).⁶⁴

Sex

It has been known that mortality and morbidity of premature births are greater in male infants than female infants ("male disadvantage").^{65,66} Sex differences appear to be insignificant as the maturity of infants increases, we accounted for it as a baseline.⁶⁷

Small/large for gestational age

It is known that infants either undergrown (small for gestational age [SGA]) or overgrown (large for gestational age [LGA]) have higher rates of neonatal mortality and morbidity.⁶⁸ In this study, SGA and LGA were defined as below the 10th percentile and above

the 97th percentile for birth weight respectively, given the infant's gestational age, race/ethnicity and sex.⁶⁹⁻⁷⁰

Apgar score

The Apgar score is a summary measure of evaluating the physical condition of infants shortly after delivery based on **A**ppearance (skin color), **P**ulse, **G**rimace (reflex irritability), **A**ctivity (muscle tone), and **R**espiration.⁷¹ The Apgar score in the Natality file is recommended to be collected directly from the medical record.⁵⁵ Each of the five factors is evaluated on a scale from 0 to 2 and the sum of these 5 values results in Apgar score ranging from 0 to 10. A score of 0 to 3 is considered as critically low requiring immediate resuscitation; 4 to 6, intermediate; 7 or above, good to excellent. We used the Apgar score assessed at 5 minutes after delivery and categorized the score into 3 groups: <7, 7-8, and 9-10.

Plurality

The plurality in the Natality file is recommended to be collected directly from the medical record and imputed as singletons if unknown.⁵⁵ Plurality was classified as single or multiple births (twins, triplets, and higher-order births).

Delivery mode: Cesarean or not

Cesarean delivery is associated with a greater risk for NICU admission.²⁹ It is recommended to report final delivery mode as vaginal/spontaneous, vaginal/forceps, vaginal/vacuum, and cesarean. The study used it as a binary variable indicating cesarean or not.

Maternal age

In the Natality file, the maternal age is derived from the directly reported month and year of birth of the mother. We used the same categorization of age as CDC's reporting: ages ≤ 19 , 20-24, 25-29, 30-34, 35-39, or ≥ 40 years.

Maternal education level

Educational attainment is known to be associated with health disparities⁴⁰ and we used a mother's education level. Maternal education is associated with birth weight distributions and also independently affects infant mortality.⁷² It is recommended to be reported directly by the mother and defined as the highest degree or level of school completed at the time of the delivery. We categorized maternal educational level into less than high school graduate, high school graduate, some college, associate or bachelor's degree, and Master's degree or higher.

Payment source for delivery

Insurance status is known to be associated with health outcomes and resource utilization.⁷³ The primary source of payment for delivery was used as a proxy for the infant's insurance status. Infants born to mothers with private insurance at the time of delivery are likely to stay on private insurance while those born to mothers with Medicaid or uninsured are likely to get enrolled in Medicaid.⁷⁴ Payment source for delivery was classified as private insurance, Medicaid, self-pay and other. "Other" category includes Indian Health Service, CHAMPUS/TRICARE, other government and unknown.

Urban–Rural Classification

Urban-rural disparities in health measures have been well known.⁷⁵⁻⁷⁷ The study used the NCHS Urban-Rural Classification Scheme for Counties. NCHS uses a six-level urban-rural classification scheme for U.S. counties and county-equivalent entities as follows.

Table 3. NCHS Urban-Rural Classification Scheme for Counties

Category code	Category name	Category description
Metropolitan		
1	Large central metro	Central counties of MSAs of 1 million or more population
2	Large fringe metro	Suburban counties of MSAs of 1 million or more population
3	Medium metro	Counties within MSAs of 250,000-999,999 population
4	Small metro	Counties within MSAs of 50,000 to 249,999 population
Nonmetropolitan		
5	Micropolitan	Counties in micropolitan statistical areas
6	Noncore	Counties not within micropolitan statistical areas

There have been significant health differences between large central metro counties and large fringe (suburban) metro counties and wide variation in health across different levels of rurality.^{77,78} The NCHS Urban-Rural Classification Scheme allows us to distinguish between large central metro counties and large fringe (suburban) metro counties and better accommodates heterogeneity across the urban-rural continuum that dichotomous classification cannot capture.

Data Analysis for Aim 1

Aim 1: Describe temporal trends of racial/ethnic differences in crude and risk-adjusted NICU rates from 2008 to 2018.

Analysis: The study reports crude and adjusted NICU admission rates from 2008 to 2018 by racial/ethnic group. Analyses were conducted overall and stratified by birth weight group as VLBW (<1500g), MLBW (1500-2499g), and NHBW (\geq 2500g). Univariable analyses were conducted to assess the association between each of the risk factors -gestational age, SGA, LGA, 5-min Apgar, plurality, cesarean delivery, and sex- and NICU admission. Multivariable logistic regression models were specified with NICU admission as the dependent variable and race/ethnicity as a primary independent variable while adjusting for birth year and risk factors that were statistically significant in univariable analysis. To assess differential temporal trends for NICU admission across race/ethnicity, interaction terms between birth year and race/ethnicity were included in the models. The model-adjusted NICU admission rates were estimated with predicted probabilities using Stata command *margins* based on marginal standardization method and adjusted rate ratios (ARRs) for black and Hispanic infants compared with white infants were estimated using Stata command *nlcom*.⁷⁹

Risk Adjustment: Risk adjustment was done to account for the differences in the infant's health status by race/ethnicity over the study period. Neonatal characteristics indicating an infant's health status from well-established severity illness and mortality risk scores were assessed to identify risk factors associated with NICU care.^{29,80-84} We selected potential risk factors mainly from four well-known risk adjustment scores that have been widely used in the United States and the United Kingdom and included factors beyond physiologic variables, which were not available on the birth certificate: Score for Neonatal Acute Physiology Perinatal Extension (SNAP-PE), Clinical Risk Index for Babies (CRIB), Vermont Oxford Network Risk Adjustment (VON RA) and National Institute for Child Health and Development (NICHD). When the

updated or improved versions of risk adjustment score models were available, most updated ones were used (SNAP-PE II and CRIB II). Although these factors were mostly validated among VLBW infants for neonatal mortality, they were considered to be relevant to an infant's health status beyond VLBW and associated with NICU admission.^{22,29} Among known risk factors, gestational age using the obstetric estimate of gestation at delivery (OE), small for gestational age (SGA), large for gestational age (LGA), 5-min Apgar, plurality, cesarean delivery, and sex were associated with NICU admission and included in the risk adjustment.^{22,29,58,60,65,69,70,80-83,85} Birth defects were not included as there was very little variation because most of the infants were born without defects. Last, any maternal characteristics other than the mother's race/ethnicity were not considered because our primary research question was to assess the difference in NICU admission by race/ethnicity accounting for infant health status differences that would reflect need.⁸⁶ Socioeconomic characteristics of the mother and maternal risk factors are considered as underlying sources of race/ethnic disparities or risk factors for the infant's health.⁸⁷ Therefore, including them may obscure racial/ethnic differences in NICU admission.^{87,88}

Table 4. Comparison of Data Components in Mortality Risk Adjustment Scores for Neonatal Intensive Care Unit Settings

	NICU Mortality Risk Adjustment Scores			
	SNAP-PE II	CRIB II	VON-RA	NICHD 2008
Population				
All NICU patients	+	+	+	
<1500 g birth weight				
22 to 25 wk gestation				+
Excludes lethal anomalies				+
<31 wk gestation				
<32 wk gestation		+		
Birth characteristics				
Birth weight	+	+		+
Small for gestational age	+		+	
Apgar score	+		+	
Gestational age		+	+	+

Birth defects			+	
Gender		+	+	+
Plurality			+	+
Antenatal steroids				+
Transfer			+	
Mode of delivery			+	
Clinical characteristics	+	+		

Data Analysis for Aim 2

Aim 2: Decompose the temporal change of NICU admission rates into changes in the birth weight distribution and birth weight-specific NICU admission rates between 2008 and 2018 by race/ethnicity

Analysis: To identify the contributions of birth weight groups to the NICU admission rate increase between 2008 and 2018 and decompose the increase into the two contributing components using Kitagawa rate decomposition analysis.⁸⁹ One component is the contribution by the distributional change in birth weight holding birth weight-specific rate constant. The other is the contribution by changes in birth weight-specific rate holding the birth weight distribution constant.⁸⁹ If birth weight-specific NICU admission rates are constant over time, changes in temporal NICU admission trends may be predominantly associated with changes in birth weight distribution. If birth weight-specific NICU admission rates change over time while there is no change in birth weight distribution, this may reflect improved access or change in medical practice. The difference in crude NICU admission rates between 2008 and 2018 was decomposed as follows.

$$N_{2018} - N_{2008} = \sum_{i=1}^n \left[\frac{R_{2018i} + R_{2008i}}{2} (P_{2018i} - P_{2008i}) + \frac{P_{2018i} + P_{2008i}}{2} (R_{2018i} - R_{2008i}) \right]$$

where N_{year} = NICU admission rate in a given year, i = i th birth weight group

$P_{year\ i}$ = Proportion of births for birth weight group i in a given year

$R_{year\ i}$ = NICU admission rate for birth weight group i in a given year

The first half of the right- hand side represents the proportion of the NICU admission rate difference attributable to changes in birth weight-specific NICU admission rate. The second half of the right-hand side represents the proportion of the NICU admission rate difference attributable to changes in birth weight distribution. The study reports the results for the total and for white, black, and Hispanic groups.

Data Analysis for Aim 3

Aim 3: Quantify the contribution of neonatal characteristics, NICU bed supply and maternal socioeconomic characteristics to the growth of NICU admission rates between 2009 and 2018 by race/ethnicity

Analysis Plan: We used the Oaxaca Blinder (OB) decomposition that has been widely used in the study of labor market discrimination.^{90,91} It was developed by Ronald Oaxaca and Alan Blinder to decompose racial and sex wage differentials into a component attributable to differences in individual characteristics (“endowments”) and a component attributable to differences in the estimated effects of individual characteristics (“coefficients”).^{90,91} In health

care, several studies have used this approach to quantify the contribution of different factors in explaining differences in disease prevalence,⁹²⁻⁹⁴ health outcomes⁹⁵, and healthcare utilization across different sub-groups of the population.^{96,97} Multivariable decomposition uses the output from regression models to partition the components of a group difference in outcomes. When the outcome, Y is a function of a linear combination of predictors and regression coefficients,

$$Y=F(X\beta)$$

where Y is a dependent variable vector, X is a matrix of independent variables, and β is a vector of coefficients. The mean difference in Y between groups A and B can be decomposed as

$$\begin{aligned}\bar{Y}_A - \bar{Y}_B &= \overline{F(X_A\hat{\beta}_A)} - \overline{F(X_B\hat{\beta}_B)} \\ &= \underbrace{\left\{ \overline{F(X_A\hat{\beta}_A)} - \overline{F(X_B\hat{\beta}_A)} \right\}}_E + \underbrace{\left\{ \overline{F(X_B\hat{\beta}_A)} - \overline{F(X_B\hat{\beta}_B)} \right\}}_C\end{aligned}$$

The endowment component (E) represents the part of the differential attributable to differences in a set of predictors and reflects a counterfactual comparison of the difference if group A were given group B's distribution of predictors. The coefficients component (C) refers to the part of the differential attributable to differences in coefficients of predictors weighted by group B's distribution of predictors.

The outcome interest, NICU admission is a binary variable and we conducted multivariable logistic regressions using Stata command Oaxaca developed by Jann for nonlinear regression.⁹⁸ This command provides the detailed decomposition into contributions of individual drivers.⁹⁸ Using this method, we decomposed the growth of NICU admissions between 2009 (treated as Group B) and 2018 (treated as Group A) into two components; one that is explained

by differences in the distribution of infant health risk, regional availability of NICU bed supply, and maternal socioeconomic status, and another component that is explained by differences in the effect of these determinants on the NICU admissions. The detailed decomposition further decomposes E and C components into the unique contribution of each driver. This allow us to quantify the contribution of each driver to the growth in NICU admissions, thus identify which factors contribute most to the growth between the two time periods.^{90,91}

Human Subjects, Animal Subjects, or Safety Considerations

The study used 2008-2018 restricted Natality files. Public Use Files available to download from the website of NCHS no longer include geographic detail beginning with the 2005 data year. To request restricted Natality files with geographic information., the study has submitted a completed project review form to the National Association for Public Health Statistics and Information Systems (NAPHSIS) research review committee. The use of restricted Natality files was reviewed and approved by the NAPHSIS research review committee and the National Center for Health Statistics (NCHS).

The obtained data are de-identified and do not have protected health information. The study protocol was reviewed and approved by the Committee for the Protection of Human Subjects (CPHS) at the University of Texas Health Science Center (HSC-SPH-19-0619).

JOURNAL ARTICLE 1

Trends in Neonatal Intensive Care Unit Admissions by Race/Ethnicity in the United States, 2008-2018

Journal of Perinatology

Abstract

Importance: Recent trends show that the utilization of neonatal intensive care unit (NICU) has extended beyond severely ill infants and increased substantially across all birth weights. However, little is known whether these trends differ by race/ethnicity.

Objectives: To examine temporal trends of NICU admissions in the U.S. by race/ethnicity and to quantify the relative contributions of birth weight groups to the growth of NICU admissions from 2008 to 2018

Design, Setting, and Participants: In this retrospective cohort analysis, we used data from restricted natality files provided by the National Center for Health Statistics (NCHS) at the U.S. Centers for Disease Control and Prevention (CDC). Births were included that occurred in the U.S. between January 1, 2008, and December 31, 2018 and recorded using the 2003 revision of the U.S. birth certificate (N=38,011,843).

Main Outcomes and Measures: Crude and risk-adjusted NICU admission rates, overall and stratified by birth weight group, were compared between white, black and Hispanic infants. The

temporal increase in NICU admission rates was decomposed into birth weight distribution and birth weight-specific NICU admission rates.

Results: Crude NICU admission rates increased from 6.62% (95% CI 6.59-6.65) to 9.07% (95% CI 9.04-9.10) between 2008 and 2018. The largest percentage increase was observed among Hispanic infants (51.4%) compared to white (29.1%) and black (32.4%) infants. Overall risk-adjusted rates differed little by race/ethnicity, but birth weight-stratified analysis revealed that racial/ethnic differences diminished in the very low birth weight (VLBW) and moderately low birth weight (MLBW) groups while risk-adjusted NICU admission rates remained higher among black and Hispanic infants in the normal to high birth weight (NHBW) group. VLBW, MLBW and NHBW groups contributed 3.2%, 26.4% and 70.4%, respectively to the overall NICU admission rate increase. Overall increase in NICU admission rates was decomposed into 3.4% attributed to changes in the birth weight distribution and 96.6% attributed to changes in the birth weight-specific NICU admission rate.

Conclusions and Relevance: Racial/ethnic differences in risk-adjusted NICU admission rates diminished among high risk infants while black and Hispanic infants maintained higher risk-adjusted NICU admission rates among low risk infants.

Introduction

In the past 50 years, remarkable advances in the neonatal intensive care units (NICUs) have improved the survival and reduced the morbidity of premature and sick newborns.¹⁻³ Delivery of very low birth weight (VLBW) or very preterm (VPT) infants at hospitals with a Level III/IV NICU is now a standard of care in the United States.⁴

Recent U.S. trends show that NICU admissions have increased for all birth weights, particularly in larger and less premature newborns and, by 2012, more than half of all newborns admitted to a NICU were of normal birth weight.⁵ At the same time, some very premature newborns were still not admitted to Level III/IV NICUs. Other studies have found that regional NICU supply and utilization are not necessarily aligned with newborn health risk such as in regions with higher low birth weight rates.⁶⁻⁹ Furthermore, there is evidence that greater bed supply is associated with high NICU admissions, particularly among low-risk newborns.^{7,10,11} These findings raise concern regarding potential lack of access, particularly by race/ethnicity, for some newborns¹², while others may receive NICU care that could be provided in other inpatient settings.

In this study, we first examined temporal trends of NICU admissions by race/ethnicity in the U.S. for all birth weight ranges at the national level adjusting for newborn health risk factors. Second, we determined if the relative contributions of birth weight groups to NICU admissions differed by race/ethnicity by decomposing changes in NICU admission rates into birth weight distribution and birth weight-specific NICU admission rates.

Methods

Data Source and Study Population

This is a population-based retrospective cohort study using restricted natality files provided by the National Center for Health Statistics (NCHS) at the U.S. Centers for Disease Control and Prevention (CDC). All births to mothers whose state of residence was U.S. states and the District of Columbia between January 1, 2008, and December 31, 2018 were included.¹³ Since information on NICU admission was exclusive to the 2003 revision of the U.S. birth certificate, we excluded births recorded using the earlier version (12.1%). We also excluded those weighing less than 500 grams (0.1%) or born before 23 completed weeks of gestational age (0.1%) as they are generally not considered viable with current technology.¹⁴⁻¹⁷ Finally, we excluded births with unknown NICU information (0.3%), birthweight (0.1%), gestational age (0.1%), or Apgar score (0.4%).

NICU Admission and Race/Ethnicity

The primary outcome-of-interest was a NICU admission, which was measured as the proportion of live births who were admitted to a NICU. According to the CDC's guideline for completion of the 2003 U.S. birth certificate, NICU admission is defined as "admission into a facility or unit staffed and equipped to provide continuous mechanical ventilator support for a newborn."¹⁸ This definition of NICU care is comparable to Levels III and IV of neonatal care as established by the American Academy of Pediatrics (AAP).⁴ The primary exposure of interest was maternal race/ethnicity as reported separately on birth certificates. We used the bridged race for responses that included more than one race and combined the bridged race and Hispanic ethnicity into the

following categories: non-Hispanic white (“white”), non-Hispanic black (“black”), Hispanic, and other.

Risk Adjustment

We risk adjusted NICU admission rates to account for the differences in the infant health status by race/ethnicity over the study period. Neonatal characteristics indicating an infant’s health status from well-established severity illness and mortality risk scores were assessed to identify risk factors associated with NICU care.¹⁹⁻²⁴ Although these factors were mostly validated among VLBW infants for neonatal mortality, we considered them to be relevant to an infant’s health status beyond VLBW and associated with NICU admission.^{5,24} Among known risk factors, gestational age using the obstetric estimate of gestation at delivery (OE), small for gestational age (SGA), large for gestational age (LGA), 5-min Apgar, plurality, cesarean delivery, and sex were associated with NICU admission and included in the risk adjustment.^{5,19-30} We excluded birth defects, as there was very little variation because most of the infants were born without defects. Last, we did not consider any maternal characteristics other than the mother’s race/ethnicity because our primary research question was to assess the difference in NICU admission by race/ethnicity accounting for infant health status differences that would reflect need.³¹ Socioeconomic status of mother and maternal risk factors are considered as underlying sources of race/ethnic disparities or risk factors for the infant’s health.³² Therefore, including them may obscure racial/ethnic differences in NICU admission.³²⁻³⁴ Details of the modeling strategy are presented in the supplemental materials.

Statistical Analysis

Analyses were conducted overall and stratified by birth weight group as VLBW (<1500g), moderately low birth weight (MLBW, 1500-2499g) and normal to high birth weight (NHBW, ≥ 2500 g). Univariable analyses were conducted to assess association between each of risk factors -gestational age, SGA, LGA, 5-min Apgar, plurality, cesarean delivery, and sex- and NICU admission. Multivariable logistic regression models were specified with NICU admission as the dependent variable and race/ethnicity as a primary independent variable while adjusting for birth year and risk factors that were statistically significant in univariable analysis. To assess differential temporal trends for NICU admission across race/ethnicity, we included interaction terms between birth year and race/ethnicity in the models. The model-adjusted NICU admission rates were estimated with predicted probabilities using Stata command *margins* based on marginal standardization method and adjusted rate ratios (ARRs) for black and Hispanic infants compared with white infants were estimated using Stata command *nlcom*.³⁵

To identify the relative contributions of birth weight groups to the NICU admission increase, we partitioned the difference between 2008 and 2018 NICU admission rates into the two contributing components using Kitagawa rate decomposition analysis.³⁶ One component is the contribution by distributional change in birth weight holding birth weight-specific rate constant. The other is the contribution by changes in birth weight-specific rate holding the birth weight distribution constant.³⁶ If birth weight-specific NICU admission rates are constant over time, changes in temporal NICU admission trends may be predominantly associated with changes in birth weight distribution. If birth weight-specific NICU admission rates change over time while

there is no change in birth weight distribution, this may reflect improved access or change in medical practice.

We assessed the representativeness of our study cohort by comparing birth cohorts recorded with the 2003 revision to total U.S. birth cohorts for 2008-2015 before the 2003 revision had been implemented in all U.S. states and the District of Columbia. We conducted sensitivity analyses for temporal trends limiting analysis to births that occurred in the 27 U.S. states where the 2003 revision had been used throughout the entire study period (2008-2018). All statistical analyses were performed using Stata, version 16.0 (StataCorp LLC., College Station, TX). The study protocol was approved by the Committee for the Protection of Human Subjects (CPHS) at the University of Texas Health Science Center at Houston.

Results

From 2008 to 2018, there were 43,872,185 live births. Of these, 38,011,843 births were included in the study sample. Cohort derivation was described in the supplement (eFigure 1). In the study sample, 53.1% were white, 14.4% were black, and 24.3% were Hispanic (Table 1). Black and Hispanic mothers were twice more likely than white mothers to be adolescent, unmarried, and receive Medicaid and WIC (the special supplemental nutrition program for women, infants, and children). Black and Hispanic mothers had lower education levels and lived in large central metro areas. The percentage of cesarean delivery was 32.4% and slightly higher among black infants than among white and Hispanic infants (Table 1). Percentages of VLBW and LBW were two times higher among black infants compared with white and Hispanic infants.

Trends for Crude NICU Admission Rates by Race/Ethnicity

Overall crude NICU admission rates increased from 6.62% (95% CI 6.59-6.65) in 2008 to 9.07% (95% CI 9.04-9.10) in 2018, a 37% growth. Increases were observed regardless of race/ethnicity: 6.58% (95% CI 6.54-6.62) to 8.50% (95% CI 8.46-8.53) among white infants, 9.09% (95% CI 8.99-9.18) to 12.03% (95% CI 11.94-12.11) among black infants, and 5.70% (95% CI 5.65-5.75) to 8.63% (95% CI 8.57-8.69) among Hispanic infants (Figure 1 and eTable 1-4). NICU admission rates were the highest among black infants across all years. Among Hispanic infants, the NICU admission rate was the lowest in 2008, but it increased the most with the largest percent change (51.4%) compared with white (29.1%) and black (32.4%) infants.

In the birth weight-stratified analysis, white infants had higher NICU admission rates in the VLBW and MLBW groups, whereas black infants had higher NICU admission rates in the NHBW group (Figure 1). The differences in NICU admission rates among the highest risk group (VLBW) were prominent between white and Hispanic infants in 2008, but greatly decreased. In the MBLW group, the differences in NICU admission rates between white and black infants remained persistent over the study period. Figure 1.E shows how racial/ethnic differences of NICU admission rates across birth weights changed between 2008 and 2018. Similar trends emerged in the gestational age-stratified analysis. White infants had higher NICU admission rates in lower gestational age groups (≤ 36 wks), whereas black infants had higher NICU admission rates in higher gestational age groups (> 36 wks) (eFigure 2).

Trends for NICU Admission Rate Ratios by Race/Ethnicity

Table 2 shows trends for rate ratios of NICU admission between black and white infants and between Hispanic and white infants overall and by birth weight groups. Black infants had an approximately 40% higher rate of NICU admission than white infants over the study period, whereas Hispanic infants had a 12% lower NICU admission rate than white infants in 2008 but reached the same rate by 2015. Overall risk-adjusted rate ratios remained close to 1 for both black and Hispanic infants. However, birth weight stratified analyses showed different trends. Between black and white infants, adjusted rate ratios remained close to 1 in the VLBW group, slightly lower in the MLBW group but higher in the NHBW group. Between Hispanic and white infants, adjusted rate ratios were lower than 1 but increased over the years in the VLBW and MLBW groups but continued to be higher than 1 in the NHBW group.

Contribution of Birth Weight to the Overall increase in NICU Admission by Race/Ethnicity

The change in the birth weight distribution was small (percentage changes: VLBW -1.7%, MLBW 4.1% and NHBW -0.3%) while the increase in NICU admission rates was observed across all birth weight groups (percentage changes: VLBW 9.8%, MLBW 21.6% and NHBW 54.4%). Overall increase of 2.48 percentage points was decomposed into 0.08 (3.4%) attributed to changes in the birth weight distribution and 2.37 (96.6%) attributed to changes in the birth weight-specific NICU admission rate (Table 3). Analyses by race/ethnicity revealed different patterns. Among white infants, the proportions of VLBW and MLBW infants decreased by 11.6% and 2.1%, negating the effect of increasing birth weight-specific NICU admission rates (- .15 of 2.06). Among black infants, the increase in NICU admission rates was mostly driven by the growth in birth weight-specific NICU admission rates, but a slight increase in the proportion

of MLBW also contributed to a positive increase in NICU admission. The contribution of birth weight distribution changes to increasing NICU admission was most noticeable among Hispanic infants as their proportions of VLBW and MLBW infants increased by 5.2% and 7.9%, respectively. Figure 2 shows that VLBW, MLBW and NHBW groups contributed 3.2%, 26.4% and 70.4%, respectively to the overall NICU admission rate increase. The relative contribution of NHBW group to the increasing trend of NICU admissions was much larger among white infants (82.8%) than black (60.3%) or Hispanic (66.5%) infants.

Sensitivity Analysis

Maternal and neonatal characteristics were similar between births recorded with the revised version of birth certificate and total births, suggesting that our study population represented national trends in NICU admission (eTable 5). When we limited our analysis to births in the U.S. states where the 2003 revision had been used throughout the entire study period, we found that trends in NICU admission overall and by race/ethnicity were consistent (eTable 6).

Discussion

Overall NICU admission rates increased by 37% from 2008 to 2018, and the increasing trends were observed among all racial and ethnic groups. The absolute and percent increases were the smallest among white infants as their birth outcomes improved during the study period, reducing the need for NICU admissions. On the other hand, NICU admission rates remained highest among black infants reflecting high rates of preterm birth and low birth weight. Hispanic infants had lowest NICU admission rates in early study years but reached rates similar to those of white infants in later years. Partitioning the changes in NICU admission rates into the effect of birth

weight distribution and the effect of birth weight-specific rate, we found that changes in birth weight-specific NICU admission rates were the main contributor to the overall increasing trend in rates among all race/ethnicity. Analyses by race/ethnicity revealed that infants in the NHBW group made the greatest relative contributions to NICU admission rate increase, especially among white infants.

Most differences in overall NICU admission by race/ethnicity disappeared after the risk adjustment. This could indicate that crude racial/ethnic rate differences were justified by different risks or needs. These average findings, however, obscure important differences revealed in stratified analyses. In the VLBW and MLBW groups, compared to white infants, black and Hispanic infants had lower risk-adjusted NICU admission rates that were catching up in recent years. This may reflect improved access to timely appropriate NICU care among high-risk infants through increasing health care coverage coupled with growing NICU supply.³⁷⁻⁴¹ Higher rates of NICU admissions with little racial/ethnic differences among high risk infants, especially VLBW infants who are recommended to be admitted to a NICU according to the AAP guideline, are encouraging trends in perinatal care.

In contrast, black and Hispanic infants maintained higher risk-adjusted NICU admission rates in the NHBW group. The higher use of NICUs in this low risk group may indicate overutilization of NICUs. The growth in NICU bed supply has outpaced measured need³⁷, and the greater availability of NICU beds is known to be associated with greater utilization. Freeman demonstrated that available NICU beds increased additional NICU utilization among those less ill or in the range of birth weights in which admission decisions are likely to be more

discretionary.⁴² Shulman et al found that among infants born at GA of 34 weeks or more, inborn admission rates for specific GA strata correlated strongly with overall inborn admission rates and did not significantly correlate with percentage of admissions with high illness acuity.⁷ Similarly, Ziegler et al found significant between-hospital variation in NICU admission rates that cannot be explained by infant health condition among infants born 35 to 42 weeks' gestation.¹⁰ Harrison et al found that non-VLBW infants were more likely to be admitted to a NICU in regions with the highest NICU bed supply, indicating possible overuse.¹¹ In our study population, almost 50% of the black and Hispanic mothers compared with 28% of white mothers resided in a large central metro area where they were likely to be close to large hospitals with NICU beds.^{40,41,43} Increased capacity, payments that reward NICU care, perhaps disproportionately to its value in lower risk newborns, and weak state regulation may cause potential overuse of NICU among NHBW infants.⁴⁴ The U.S. has significantly greater neonatal clinicians and NICU beds per capita than other developed countries with provision of neonatal intensive care extended beyond regional or academic centers.^{45,46} Yet, there lacks of clear criteria for designating levels of risk-appropriate neonatal care and capability across states.⁴⁴

Strengths and Limitations

This study is one of few that compares NICU utilization by race/ethnicity and the first study to evaluate the effect of race/ethnicity on NICU admission rate as a primary interest across all birth weights.^{24,40,41} The literature is rich in evaluating the quality of care across providers or hospital characteristics, but it is often limited to VLBW or VPT infants. When race/ethnicity is included, it is usually as a covariate in statistical modeling rather than as a primary study exposure.^{47,48}

Understanding racial/ethnic differences in NICU admission is particularly relevant given that racial/ethnic differences in birth outcomes are persistent.^{49,50}

This study has some limitations. First, even though the birth certificate form defines NICU admissions, differences in coding may have occurred across states and hospitals. A 2012 policy statement by the AAP defines a NICU as a level III and IV facilities, where ongoing assisted ventilation for 24 hours or more is available,⁴ but there is a wide variation among states in the definition and criteria of a NICU and accuracy of coding may improve over the years.⁵¹

However, increasing NICU admission trends were observed also in hospital discharge data⁴² and validation studies on the accuracy of birth certificate data report a good agreement on NICU admission between birth certificates compared to hospital medical records.⁵² Second, our study may have underestimated NICU admissions since birth certificates are required to be filed within 5 days of the date of birth.^{53,54}

Conclusions

From 2008 to 2018, there was little difference in overall risk-adjusted NICU admission rates by race/ethnicity. However, birth weight-stratified analysis revealed that racial/ethnic differences diminished in the VLBW and MLBW groups while risk-adjusted NICU admission rates remained higher among black and Hispanic infants in the NHBW group. The decline in infants of VLBW and MLBW mitigated the overall increase in NICU admission rates among white infants. Improvement of birth weight among black and Hispanic, who currently have higher VLBW and MLBW rates, will slow the increases in NICU use. Increasing NICU admission rates

in the NHBW group contributed the most to overall NICU admission increase and further study is needed to identify the reasons for this trend and prevent possible overuse of NICU care.

Tables and Figures

Table 1. Maternal and Neonatal Characteristics of Live Births: United States, 2008-2018

	Births, No. (%)				
Mother's race/ethnicity	All	White	Black	Hispanic	Other
No. of births	38,011,843	20,202,011	5,484,266	9,233,196	3,092,370
% of births	100.0	53.1	14.4	24.3	8.1
Maternal Characteristics, %					
Age category, y					
<20	7.1	5.2	10.9	10.6	3.0
20-24	22.2	19.8	29.9	26.0	12.2
25-29	28.7	30.0	27.3	27.5	26.6
30-34	26.2	28.9	19.5	21.6	34.3
35-39	12.8	13.2	9.9	11.5	19.2
40-54	3.0	2.9	2.6	2.9	4.8
Payment source ^a					
Medicaid	43.0	31.2	65.1	59.7	31.5
Private Insurance	47.5	61.0	26.8	26.4	57.8
Self-Pay	4.1	2.9	2.9	7.3	5.0
Other	4.4	4.0	4.1	5.5	4.7
Unknown	1.1	1.0	1.0	1.2	1.1
WIC received ^a	42.4	29.0	61.5	64.8	29.9
Unmarried ^b	40.4	29.2	71.0	52.6	22.8
Educational attainment					
Less than high school	16.1	8.5	17.3	34.1	9.8
High school	25.1	21.9	33.4	30.4	16.3
Some college	20.5	21.1	26.4	18.0	13.4
Associate or Bachelor's degree	26.5	34.1	16.8	13.1	33.6
Master's or higher degree	10.6	13.9	5.1	3.1	20.9
Unknown	1.2	0.5	0.9	1.3	6.0
Urban-Rural classification ^c					
Large central metro	38.4	28.4	47.2	49.5	55.5
Large fringe metro	19.5	21.0	20.5	16.4	17.8
Medium metro	22.4	24.3	19.1	22.6	14.7
Small metro	9.9	12.9	7.6	6.2	5.6
Micropolitan	7.7	10.5	4.6	4.4	4.7
Noncore	2.1	3.0	1.0	0.9	1.8
Neonatal Characteristics, %					
Female	48.8	48.7	49.2	49.0	48.5
Multiple gestations	3.4	3.7	3.9	2.4	3.2
Cesarean delivery	32.4	31.6	35.7	32.0	32.7
Birthweight category, g					
<1500	1.2	1.0	2.5	1.1	1.1
1500-2499	6.7	5.9	10.5	5.9	7.2
2500-3999	84.3	83.6	82.7	85.9	86.3
≥4000	7.8	9.5	4.4	7.1	5.5
Gestational age, wk					
<32	1.4	1.1	2.6	1.3	1.2
32-36	8.2	7.8	10.5	7.8	7.8
37-38	26.3	24.7	28.6	27.9	28.0

39-40	57.5	59.0	52.7	57.1	57.1
≥41	6.7	7.4	5.6	6.0	5.9
5-Minute Apgar score					
<7	1.8	1.8	3.0	1.3	1.4
7-8	12.6	13.6	14.2	10.1	10.8
9-10	85.5	84.5	82.8	88.6	87.8

^a Information was restricted to births since 2009 when they started to be collected.

^b Births occurring in or to residents of California in 2017-2018 were excluded due to state statutory restrictions.

^c The National Center for Health Statistics' (NCHS) Urban–Rural Classification Scheme for Counties was used.

Figure 1. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Birth Weight and Race/Ethnicity

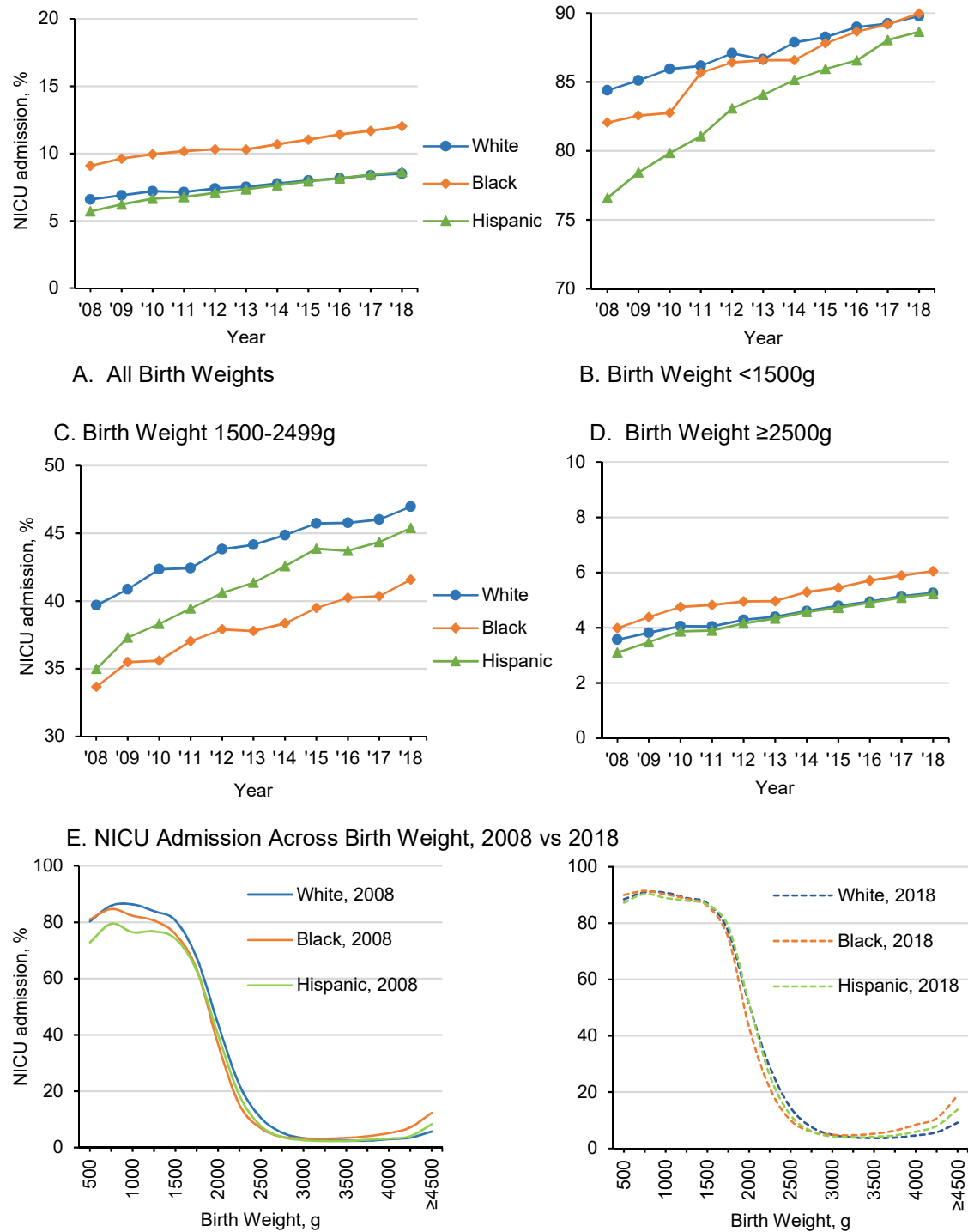


Table 2. Trends for Crude and Adjusted Rate Ratios for NICU Admission among Black and Hispanic Infants Compared with White Infants, 2008-2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NICU, All	6.62	7.02	7.43	7.48	7.74	7.90	8.17	8.44	8.66	8.90	9.07
Black RR	1.38 (1.36-1.40)	1.40 (1.38-1.41)	1.38 (1.37-1.40)	1.42 (1.41-1.44)	1.39 (1.38-1.41)	1.37 (1.36-1.38)	1.37 (1.36-1.39)	1.38 (1.37-1.39)	1.40 (1.39-1.41)	1.40 (1.38-1.41)	1.42 (1.40-1.43)
Hispanic RR	0.88 (0.86-0.88)	0.91 (0.89-0.91)	0.93 (0.91-0.93)	0.96 (0.94-0.96)	0.96 (0.95-0.96)	0.99 (0.97-0.99)	0.99 (0.97-0.99)	1.00 (0.98-1.00)	1.01 (0.99-1.01)	1.01 (1.00-1.01)	1.02 (1.01-1.02)
Black ARR	1.03 (1.03-1.04)	1.03 (1.03-1.04)	1.04 (1.03-1.04)	1.04 (1.03-1.04)	1.04 (1.04-1.04)	1.04 (1.04-1.04)	1.04 (1.04-1.05)	1.05 (1.04-1.05)	1.05 (1.04-1.05)	1.05 (1.05-1.05)	1.05 (1.05-1.06)
Hispanic ARR	0.98 (0.98-0.99)	0.99 (0.98-0.99)	0.99 (0.99-1.00)	1.00 (1.00-1.00)	1.01 (1.01-1.01)	1.02 (1.01-1.02)	1.02 (1.02-1.02)	1.03 (1.03-1.03)	1.04 (1.03-1.04)	1.04 (1.04-1.05)	1.05 (1.05-1.05)
NICU, VLBW	81.44	82.53	83.47	84.59	85.75	85.97	86.60	87.54	88.33	88.86	89.42
Black RR	0.97 (0.96-0.98)	0.97 (0.96-0.98)	0.96 (0.95-0.97)	0.99 (0.98-1.00)	0.99 (0.98-1.00)	1.00 (0.99-1.01)	0.99 (0.98-0.99)	0.99 (0.99-1.00)	1.00 (0.99-1.00)	1.00 (0.99-1.01)	1.00 (0.99-1.01)
Hispanic RR	0.91 (0.89-0.92)	0.92 (0.91-0.93)	0.93 (0.92-0.94)	0.94 (0.93-0.95)	0.95 (0.94-0.96)	0.97 (0.96-0.98)	0.97 (0.96-0.98)	0.97 (0.96-0.98)	0.97 (0.96-0.98)	0.99 (0.98-1.00)	0.99 (0.98-1.00)
Black ARR	0.98 (0.97-0.98)	0.98 (0.98-0.99)	0.98 (0.98-0.99)	0.99 (0.98-0.99)	0.99 (0.99-0.99)	0.99 (0.99-1.00)	0.99 (0.99-1.00)	1.00 (0.99-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.01)
Hispanic ARR	0.92 (0.91-0.93)	0.93 (0.92-0.94)	0.94 (0.93-0.94)	0.95 (0.94-0.95)	0.96 (0.95-0.96)	0.96 (0.96-0.97)	0.97 (0.97-0.97)	0.98 (0.97-0.98)	0.98 (0.98-0.99)	0.99 (0.98-0.99)	0.99 (0.99-1.00)
NICU, MLBW	36.74	38.29	39.39	40.04	41.14	41.49	42.29	43.26	43.49	43.76	44.67
Black RR	0.85 (0.83-0.86)	0.87 (0.85-0.88)	0.84 (0.83-0.85)	0.87 (0.86-0.88)	0.87 (0.85-0.88)	0.86 (0.84-0.87)	0.85 (0.84-0.87)	0.86 (0.85-0.87)	0.88 (0.87-0.89)	0.88 (0.87-0.89)	0.89 (0.88-0.89)
Hispanic RR	0.88 (0.87-0.89)	0.91 (0.90-0.93)	0.90 (0.89-0.92)	0.93 (0.92-0.94)	0.93 (0.91-0.94)	0.94 (0.93-0.95)	0.95 (0.94-0.96)	0.96 (0.95-0.97)	0.95 (0.94-0.97)	0.96 (0.95-0.97)	0.97 (0.96-0.98)
Black ARR	0.96 (0.95-0.97)	0.96 (0.96-0.97)	0.96 (0.96-0.97)	0.97 (0.96-0.97)	0.97 (0.96-0.97)	0.97 (0.97-0.97)	0.97 (0.97-0.97)	0.97 (0.97-0.98)	0.98 (0.97-0.98)	0.98 (0.97-0.98)	0.98 (0.97-0.98)
Hispanic ARR	0.95 (0.94-0.96)	0.96 (0.95-0.96)	0.96 (0.96-0.97)	0.97 (0.96-0.97)	0.97 (0.97-0.98)	0.98 (0.98-0.98)	0.98 (0.98-0.99)	0.99 (0.99-0.99)	0.99 (0.99-1.00)	1.00 (0.99-1.00)	1.00 (1.00-1.01)
NICU, NHBW	3.47	3.79	4.10	4.12	4.35	4.47	4.70	4.88	5.05	5.23	5.36
Black RR	1.12 (1.09-1.14)	1.15 (1.13-1.17)	1.17 (1.15-1.19)	1.19 (1.17-1.21)	1.16 (1.14-1.17)	1.13 (1.11-1.15)	1.15 (1.13-1.17)	1.14 (1.12-1.15)	1.15 (1.14-1.17)	1.15 (1.13-1.16)	1.15 (1.14-1.16)
Hispanic RR	0.87 (0.86-0.88)	0.91 (0.90-0.93)	0.95 (0.94-0.97)	0.96 (0.95-0.98)	0.97 (0.96-0.98)	0.99 (0.97-1.00)	0.99 (0.98-1.01)	0.99 (0.98-1.00)	0.99 (0.98-1.00)	0.99 (0.98-1.00)	0.99 (0.98-1.00)
Black ARR	1.08	1.08	1.08	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.07

	(1.07-1.09)	(1.07-1.09)	(1.07-1.08)	(1.07-1.08)	(1.07-1.08)	(1.07-1.08)	(1.07-1.08)	(1.07-1.08)	(1.07-1.08)	(1.06-1.08)	(1.06-1.08)
Hispanic ARR	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.07	1.07	1.08	1.09
	(1.01-1.03)	(1.02-1.03)	(1.03-1.04)	(1.04-1.05)	(1.04-1.05)	(1.05-1.06)	(1.06-1.06)	(1.06-1.07)	(1.07-1.08)	(1.08-1.09)	(1.08-1.09)

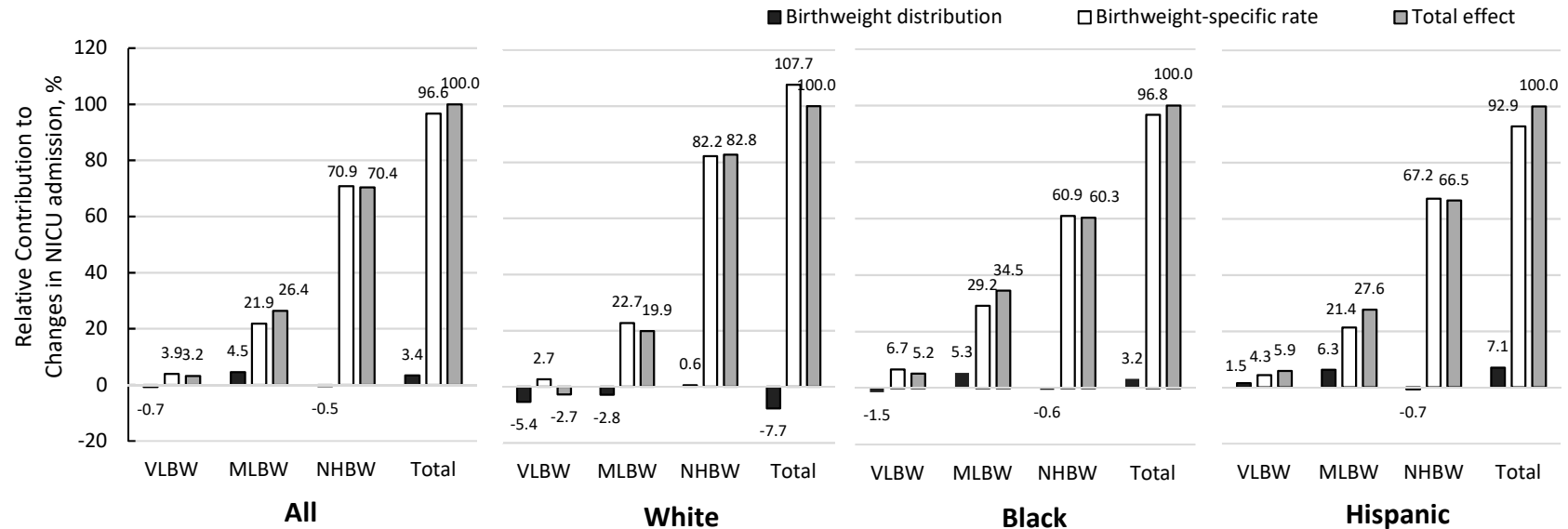
Abbreviations: NICU, neonatal intensive care unit; RR, rate ratio; ARR, adjusted rate ratio; VLBW, very low birth weight (<1500g); MLBW, moderately low birth weight (1500-2499g); NHBW, normal to high birth weight (≥2500g).

Table 3. Contributions of Changes in the Birth Weight Distribution and Birth Weight-Specific NICU admission to Temporal Changes in NICU Admission Rates by Race/Ethnicity between 2008 and 2018

BW, g	% of Distribution			BW-Specific NICU Rate			Rate Change Components		
	2008	2018	Percentage Change	2008	2018	Percentage Change	BW Distribution	BW-Specific Rate	Total Effect
All Race/Ethnicity									
<1500	1.22	1.20	-1.72	81.44	89.42	9.80	-0.02	0.10	0.08
1500-2499	6.62	6.89	4.14	36.74	44.67	21.57	0.11	0.54	0.65
≥2500	92.16	91.91	-0.27	3.47	5.36	54.39	-0.01	1.74	1.73
Total	100.00	100.00	NA	6.62	9.07	37.02	0.08	2.37	2.45
White									
<1500	1.03	0.91	-11.57	84.39	89.77	6.38	-0.10	0.05	-0.05
1500-2499	6.03	5.91	-2.07	39.68	46.97	18.38	-0.05	0.44	0.38
≥2500	92.94	93.19	0.26	3.57	5.26	47.35	0.01	1.57	1.59
Total	100.00	100.00	NA	6.58	8.50	29.10	-0.15	2.06	1.91
Black									
<1500	2.50	2.45	-2.02	82.05	89.98	9.66	-0.04	0.20	0.15
1500-2499	10.62	11.04	3.93	33.66	41.58	23.54	0.16	0.86	1.01
≥2500	86.88	86.52	-0.42	3.99	6.06	51.86	-0.02	1.79	1.77
Total	100.00	100.00	NA	9.09	12.03	32.38	0.10	2.85	2.94
Hispanic									
<1500	1.03	1.08	5.21	76.58	88.64	15.75	0.04	0.13	0.17
1500-2499	5.78	6.24	7.92	34.98	45.39	29.76	0.18	0.63	0.81
≥2500	93.19	92.68	-0.55	3.11	5.22	68.22	-0.02	1.97	1.95
Total	100.00	100.00	NA	5.70	8.63	51.35	0.21	2.72	2.93

Abbreviation: BW, birth weight.

Figure 2. Relative Contributions of Birth Weight Distribution and Birth Weight-Specific Rate to Changes in NICU Admission Rate from 2008 to 2018



Abbreviations: NICU, neonatal intensive care unit; VLBW, very low birth weight (<1500g); MLBW, moderately low birth weight (1500-2499g); NHBW, normal to high birth weight (≥ 2500 g).

Appendix

Modeling Strategy for Risk Adjustment

We selected potential risk factors mainly from four well-known risk adjustment scores that have been widely used in the United States and United Kingdom and included factors beyond physiologic variables, which were not available on the birth certificate.¹⁻⁵ When the updated or improved version of risk adjustment score model was available, it was used (SNAP-PE II and CRIB II).

Comparison of Data Components in Mortality Risk Adjustment Scores for Neonatal

Intensive Care Unit Settings

NICU Mortality Risk Adjustment Scores				
	SNAP-PE II	CRIB II	VON-RA	NICHD 2008
Population				
All NICU patients	+	+	+	
<1500 g birth weight				
22 to 25 wk gestation				+
Excludes lethal anomalies				+
<31 wk gestation				
<32 wk gestation		+		
Birth characteristics				
Birth weight	+	+		+
Small for gestational age	+		+	
Apgar score	+		+	
Gestational age		+	+	+
Birth defects			+	
Gender		+	+	+
Plurality			+	+
Antenatal steroids				+
Transfer			+	
Mode of delivery			+	
Clinical characteristics	+	+		

We excluded birth defect and transfer status because of their infrequency or unreliability. The definition of birth defect was inconsistent, and its infrequency was not expected to add

discrimination because almost all the infants were without a birth defect. Transfer was merely a proxy for NICU admission and was also not expected to add discrimination because almost all infants were inborn. Gestational age was in completed weeks, and small for gestational age (SGA, Yes or No) and large for gestational age (LGA, Yes or NO) were defined as below the 10th percentile and above the 97 percentiles for birth weight respectively, given the infant's gestational age, race/ethnicity and gender based on the United States 2008-2018 natality data.

Univariable logistic regressions for each of the candidate risk factors versus NICU admission were conducted, and area under receiver operator characteristic (ROC) curve was assessed.

Within each variable, adjacent risk categories were consolidated if their area under ROCs did not differ significantly.

Univariable Logistic Regression for Potential Risk Factors

	Coeff.	Std. Err.	z	p-value	95% CI	
Gestational Age				<0.0001 ^a		
<32	5.194	0.004	1266.36	<0.0001	5.186	5.202
32	4.986	0.006	789.24	<0.0001	4.974	4.999
33	4.826	0.005	949.18	<0.0001	4.816	4.836
34	4.365	0.003	1273.03	<0.0001	4.358	4.371
35	2.989	0.003	1112.58	<0.0001	2.984	2.994
36	1.896	0.002	766.53	<0.0001	1.892	1.901
37	0.964	0.002	410.37	<0.0001	0.959	0.968
38	0.270	0.002	117.14	<0.0001	0.266	0.275
39-40	Reference					
>=41	0.299	0.003	89.16	<0.0001	0.292	0.305
5-min Apgar Score				<0.0001 ^a		
<7	2.964	0.003	1176.95	<0.0001	2.959	2.969
7-8	1.538	0.001	1116.5	<0.0001	1.535	1.541
9-10	Reference					
Cesarean Delivery	1.038	0.001	859.4	<0.0001	1.036	1.041
Plurality	2.126	0.002	1103.62	<0.0001	2.122	2.130
SGA	0.497	0.002	289.47	<0.0001	0.494	0.501

Female Sex	-0.170	0.001	-142	<0.0001	-0.173	-0.168
LGA	0.284	0.003	90.02	<0.0001	0.278	0.290

^aFactor p-value for overall significance.

Area under the ROC from Univariable Regressions

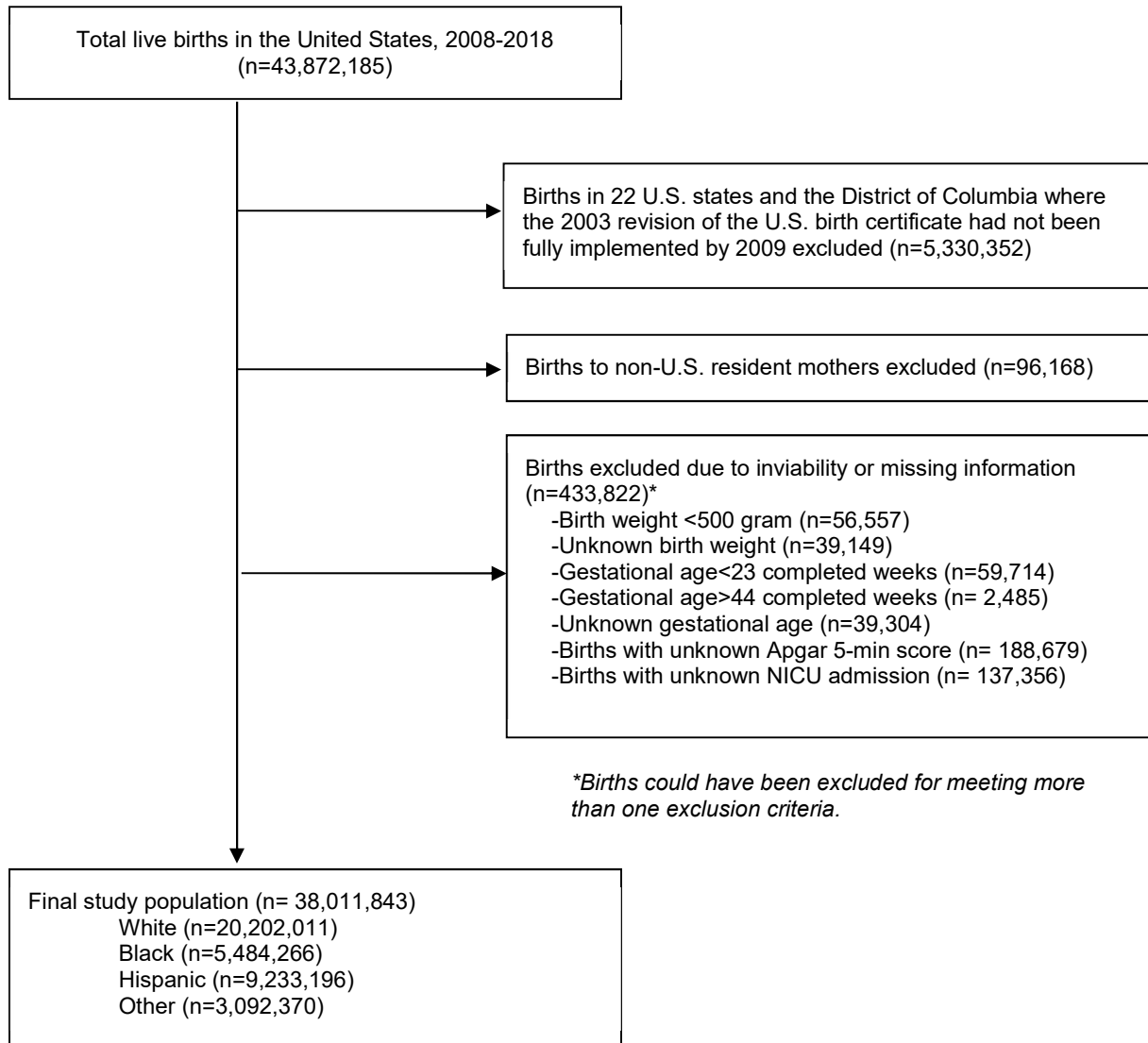
	Area Under ROC curve	Std. Err.	95% CI	
Gestational Age	0.7932	0.0002	0.79288	0.79352
5-min Apgar Score	0.6659	0.0001	0.66564	0.66622
Cesarean Delivery	0.6242	0.0001	0.62387	0.62445
Plurality	0.5697	0.0001	0.56952	0.56993
SGA	0.5260	0.0001	0.5258	0.52621
Female Sex	0.5212	0.0001	0.52091	0.52149
LGA	0.5046	0.0001	0.50446	0.50469

We built multivariable models by starting with gestational age and adding a risk factor in the model one by one based on the area under ROC from univariable regressions. We compared models for predictive performance using the area under ROC. Our final model included gestational age, 5-min Apgar score, cesarean delivery, plurality, SGA, female sex and LGA. The area under ROC was 0.8581, which was considered excellent discrimination.⁶

Multivariable Logistic Regressions

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
Gestational Age	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
<32	5.194	0.004	4.585	0.004	4.435	0.004	4.387	0.004	4.448	0.004	4.449	0.004	4.447	0.004
32	4.986	0.006	4.756	0.006	4.625	0.007	4.570	0.007	4.630	0.007	4.628	0.007	4.628	0.007
33	4.826	0.005	4.685	0.005	4.579	0.005	4.526	0.005	4.583	0.005	4.581	0.005	4.582	0.005
34	4.365	0.003	4.279	0.004	4.197	0.004	4.148	0.004	4.199	0.004	4.198	0.004	4.199	0.004
35	2.989	0.003	2.878	0.003	2.797	0.003	2.750	0.003	2.785	0.003	2.783	0.003	2.783	0.003
36	1.896	0.002	1.795	0.003	1.722	0.003	1.684	0.003	1.706	0.003	1.703	0.003	1.703	0.003
37	0.964	0.002	0.906	0.002	0.862	0.002	0.841	0.002	0.849	0.002	0.847	0.002	0.846	0.002
38	0.270	0.002	0.262	0.002	0.255	0.002	0.247	0.002	0.247	0.002	0.245	0.002	0.244	0.002
39-40	reference		reference		reference		reference		reference		reference		reference	
≥41	0.299	0.003	0.239	0.003	0.271	0.003	0.270	0.003	0.270	0.003	0.269	0.003	0.269	0.003
5-min Apgar														
<7			2.406	0.003	2.358	0.003	2.363	0.003	2.341	0.003	2.336	0.003	2.332	0.003
7-8			1.143	0.002	1.120	0.002	1.121	0.002	1.117	0.002	1.117	0.002	1.115	0.002
9-10			reference		reference		reference		reference		reference		reference	
C-section					0.634	0.001	0.613	0.002	0.605	0.002	0.604	0.002	0.595	0.002
Plurality							0.216	0.003	0.143	0.003	0.149	0.003	0.164	0.003
SGA									0.661	0.002	0.660	0.002	0.675	0.002
Female Sex											-0.164	0.002	-0.164	0.002
LGA													0.359	0.004
Area Under ROC	0.7932		0.8415		0.8528		0.8529		0.8558		0.8571		0.8581	
(95% CI)	(0.7929-0.7935)		(0.8412-0.8418)		(0.8525-0.8531)		(0.8527-0.8532)		(0.8555-0.8560)		(0.8569-0.8574)		(0.8578-0.8583)	

eFigure 1. Cohort Derivation



eTable 1. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Race/Ethnicity, All Birth Weights

Year	NICU admission, % (95% CI)			
	All	White	Black	Hispanic
2008	6.62 (6.59-6.65)	6.58 (6.54-6.62)	9.09 (8.99-9.18)	5.70 (5.65-5.75)
2009	7.02 (6.99-7.05)	6.89 (6.84-6.93)	9.62 (9.53-9.72)	6.21 (6.15-6.26)
2010	7.43 (7.40-7.45)	7.19 (7.15-7.23)	9.96 (9.87-10.05)	6.64 (6.59-6.70)
2011	7.48 (7.45-7.51)	7.14 (7.10-7.18)	10.17 (10.09-10.26)	6.77 (6.72-6.83)
2012	7.74 (7.71-7.77)	7.40 (7.36-7.44)	10.32 (10.23-10.40)	7.07 (7.02-7.13)
2013	7.90 (7.87-7.92)	7.52 (7.48-7.55)	10.29 (10.21-10.37)	7.34 (7.28-7.40)
2014	8.17 (8.14-8.20)	7.78 (7.74-7.81)	10.68 (10.60-10.76)	7.64 (7.58-7.69)
2015	8.44 (8.41-8.47)	7.99 (7.95-8.02)	11.03 (10.95-11.11)	7.93 (7.87-7.98)
2016	8.66 (8.63-8.68)	8.16 (8.12-8.20)	11.42 (11.33-11.50)	8.15 (8.09-8.20)
2017	8.90 (8.87-8.93)	8.37 (8.33-8.41)	11.68 (11.60-11.76)	8.42 (8.36-8.48)
2018	9.07 (9.04-9.10)	8.50 (8.46-8.53)	12.03 (11.94-12.11)	8.63 (8.57-8.69)

eTable 2. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Race/Ethnicity, Birth Weight <1500g

Year	NICU Admission, % (95% CI)			
	All	White	Black	Hispanic
2008	81.44 (81.01-81.86)	84.39 (83.78-84.98)	82.05 (81.23-82.86)	76.58 (75.63-77.50)
2009	82.53 (82.12-82.93)	85.11 (84.52-85.69)	82.55 (81.75-83.33)	78.44 (77.51-79.34)
2010	83.47 (83.09-83.84)	85.94 (85.40-86.47)	82.76 (82.03-83.48)	79.84 (78.96-80.70)
2011	84.59 (84.24-84.94)	86.16 (85.65-86.66)	85.66 (85.02-86.28)	81.06 (80.20-81.90)
2012	85.75 (85.41-86.08)	87.07 (86.58-87.56)	86.42 (85.81-87.03)	83.07 (82.26-83.86)
2013	85.97 (85.64-86.30)	86.64 (86.14-87.12)	86.58 (85.98-87.17)	84.06 (83.27-84.84)
2014	86.60 (86.28-86.91)	87.89 (87.43-88.33)	86.58 (85.99-87.15)	85.15 (84.40-85.87)
2015	87.54 (87.24-87.84)	88.25 (87.80-88.69)	87.81 (87.25-88.35)	85.95 (85.23-86.64)
2016	88.33 (88.04-88.62)	88.98 (88.53-89.41)	88.65 (88.12-89.17)	86.56 (85.87-87.23)
2017	88.86 (88.57-89.14)	89.23 (88.78-89.67)	89.17 (88.65-89.68)	88.05 (87.39-88.69)
2018	89.42 (89.13-89.70)	89.77 (89.32-90.21)	89.98 (89.47-90.47)	88.64 (87.98-89.27)

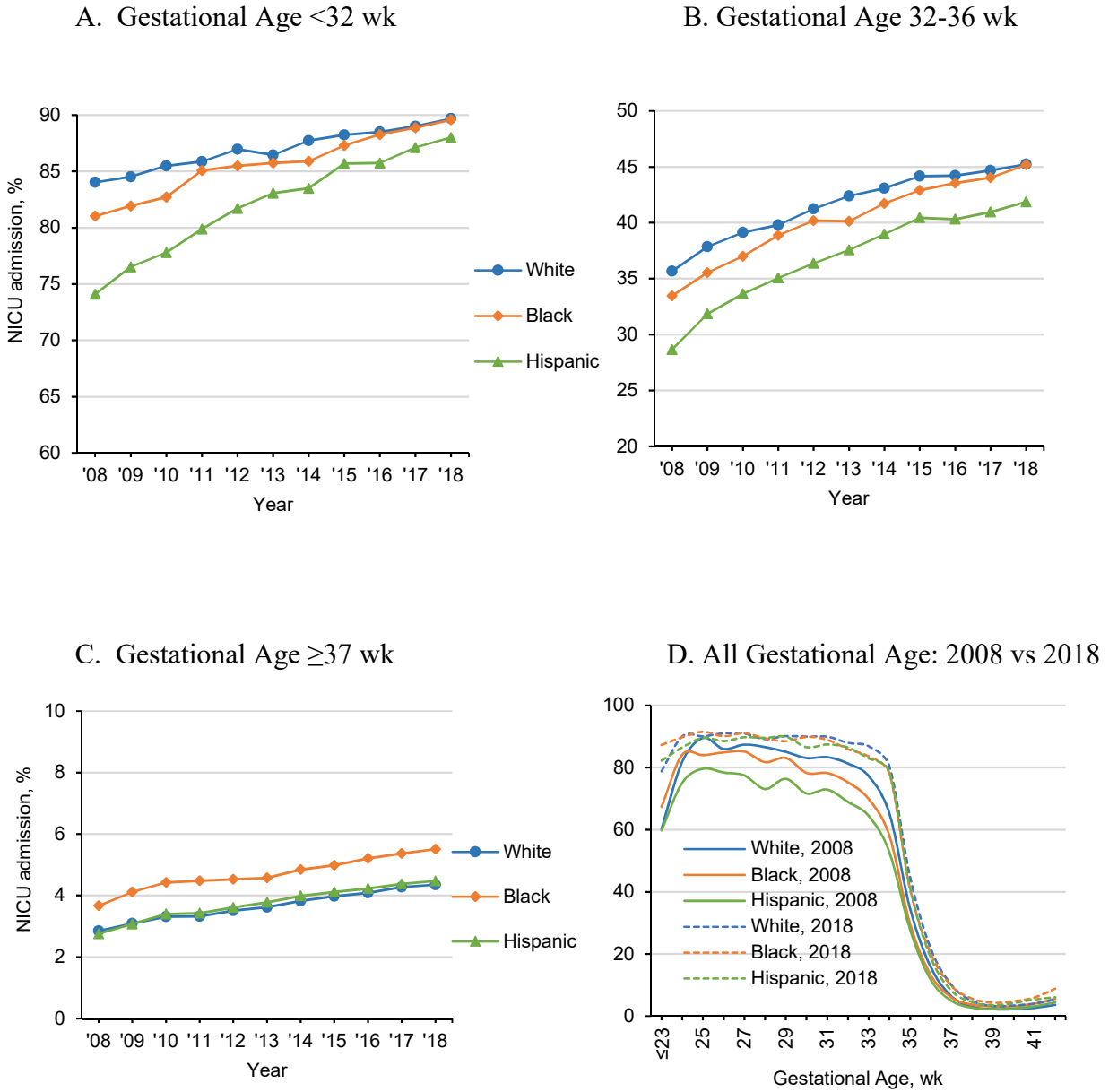
eTable 3. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Race/Ethnicity, Birth Weight 1500-2499g

Year	NICU Admission, % (95% CI)			
	All	White	Black	Hispanic
2008	36.74 (36.52-36.97)	39.68 (39.35-40.01)	33.66 (33.17-34.14)	34.98 (34.54-35.42)
2009	38.29 (38.07-38.51)	40.86 (40.53-41.19)	35.49 (35.01-35.98)	37.29 (36.84-37.74)
2010	39.39 (39.18-39.61)	42.35 (42.04-42.66)	35.60 (35.15-36.05)	38.30 (37.86-38.75)
2011	40.04 (39.83-40.24)	42.42 (42.13-42.72)	37.02 (36.60-37.45)	39.44 (39.00-39.88)
2012	41.14 (40.93-41.34)	43.82 (43.53-44.12)	37.91 (37.49-38.34)	40.61 (40.16-41.06)
2013	41.49 (41.29-41.69)	44.15 (43.85-44.44)	37.78 (37.36-38.19)	41.36 (40.92-41.81)
2014	42.29 (42.10-42.48)	44.86 (44.58-45.14)	38.35 (37.95-38.75)	42.58 (42.15-43.01)
2015	43.26 (43.07-43.46)	45.73 (45.45-46.01)	39.48 (39.09-39.87)	43.88 (43.46-44.30)
2016	43.49 (43.30-43.68)	45.78 (45.50-46.06)	40.23 (39.85-40.62)	43.72 (43.30-44.13)
2017	43.76 (43.57-43.95)	46.02 (45.74-46.30)	40.35 (39.97-40.73)	44.35 (43.93-44.77)
2018	44.67 (44.48-44.86)	46.97 (46.69-47.26)	41.58 (41.19-41.96)	45.39 (44.97-45.81)

eTable 4. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Race/Ethnicity, Birth Weight ≥ 2500 g

Year	NICU Admission, % (95% CI)			
	All	White	Black	Hispanic
2008	3.47 (3.45-3.49)	3.57 (3.54-3.61)	3.99 (3.92-4.06)	3.11 (3.07-3.15)
2009	3.79 (3.76-3.81)	3.83 (3.79-3.86)	4.39 (4.32-4.47)	3.49 (3.45-3.53)
2010	4.10 (4.08-4.12)	4.06 (4.03-4.09)	4.76 (4.69-4.83)	3.87 (3.83-3.91)
2011	4.12 (4.10-4.14)	4.05 (4.02-4.08)	4.83 (4.76-4.90)	3.90 (3.86-3.94)
2012	4.35 (4.32-4.37)	4.29 (4.26-4.32)	4.96 (4.89-5.02)	4.16 (4.11-4.20)
2013	4.47 (4.45-4.49)	4.40 (4.37-4.43)	4.97 (4.91-5.03)	4.34 (4.29-4.39)
2014	4.70 (4.67-4.72)	4.61 (4.58-4.64)	5.30 (5.24-5.36)	4.58 (4.53-4.62)
2015	4.88 (4.86-4.90)	4.80 (4.77-4.83)	5.45 (5.39-5.52)	4.73 (4.68-4.78)
2016	5.05 (5.03-5.07)	4.95 (4.92-4.98)	5.71 (5.64-5.77)	4.91 (4.87-4.96)
2017	5.23 (5.21-5.26)	5.14 (5.11-5.18)	5.89 (5.83-5.96)	5.10 (5.05-5.14)
2018	5.36 (5.33-5.38)	5.26 (5.23-5.30)	6.06 (5.99-6.12)	5.22 (5.18-5.27)

eFigure 2. Temporal Trends for NICU Admission by Gestational Age and Race/Ethnicity for 2008-2018



eTable 5. Comparison of the Study Population and Total U.S. Birth Cohorts for 2008-2015*

	Study Population	United States
No. of Births	26,912,694	32,249,785
Maternal Characteristics, %		
Race/Ethnicity		
White	53.1	53.8
Black	14.3	14.7
Hispanic	24.8	23.6
Other	7.9	7.9
Maternal Age, yr		
<20	8.0	8.2
20-24	23.2	23.2
25-29	28.6	28.5
30-34	25.3	25.1
35-39	12.1	12.1
40-54	2.9	2.9
Unmarried	40.6	40.6
Neonatal Characteristics, %		
Female	48.8	48.8
Multiple gestations	3.4	3.5
Cesarean delivery	32.5	32.5
Birthweight category, g		
<1500	1.4	1.4
1500-2499	6.6	6.7
2500-3999	84.1	84.0
≥4000	7.8	7.8
Gestational age, wk		
<32	1.6	1.6
32-36	8.2	8.2
37-38	26.3	26.4
39-40	57.1	56.9
≥41	6.7	6.7
5-Minute Apgar score		
<7	2.0	1.9
7-8	12.9	12.0
9-10	84.6	85.6

*Because most of the excluded infants had birth information recorded using the earlier 1989 version of the U.S. birth certificate (up to 2015), we assessed the representativeness of our study cohort by comparing birth cohorts recorded with the 2003 revision to total U.S. birth cohorts for 2008-2015. Starting with 2016, the 2003 revision had been implemented in all U.S. states and the District of Columbia.

eTable 6. Temporal Trends for Crude NICU Admission Rates for 2008-2018 by Race/Ethnicity, All Birth Weights Limited to 27 States*

Year	NICU Admission, % (95% CI)			
	All	White	Black	Hispanic
2008	6.62 (6.59-6.65)	6.58 (6.54-6.62)	9.09 (8.99-9.18)	5.70 (5.65-5.75)
2009	7.03 (7.00-7.06)	6.85 (6.80-6.89)	9.74 (9.65-9.84)	6.22 (6.16-6.27)
2010	7.36 (7.33-7.39)	7.11 (7.07-7.15)	10.21 (10.11-10.31)	6.56 (6.50-6.62)
2011	7.43 (7.40-7.46)	7.12 (7.07-7.16)	10.28 (10.18-10.39)	6.72 (6.66-6.78)
2012	7.75 (7.71-7.78)	7.42 (7.38-7.47)	10.65 (10.54-10.75)	7.07 (7.01-7.13)
2013	7.96 (7.93-7.99)	7.65 (7.60-7.69)	10.63 (10.52-10.73)	7.33 (7.27-7.39)
2014	8.27 (8.24-8.31)	7.92 (7.87-7.96)	11.07 (10.97-11.18)	7.67 (7.60-7.73)
2015	8.49 (8.46-8.52)	8.12 (8.07-8.16)	11.30 (11.20-11.41)	7.92 (7.85-7.98)
2016	8.71 (8.67-8.74)	8.31 (8.26-8.35)	11.72 (11.61-11.82)	8.09 (8.02-8.15)
2017	8.97 (8.93-9.00)	8.52 (8.47-8.57)	12.04 (11.94-12.15)	8.39 (8.32-8.45)
2018	9.17 (9.13-9.20)	8.65 (8.60-8.70)	12.35 (12.24-12.46)	8.67 (8.60-8.74)

*The 27 states that had implemented the revised birth certificate as of January 1, 2008, were the following: California, Colorado, Delaware, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Michigan, Montana, Nebraska, New Hampshire, New Mexico, New York (including New York City), North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Vermont, Washington, and Wyoming. These states represent 65 % of the births to U.S. residents in 2008.

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JOURNAL ARTICLE 2

Racial/Ethnic Differences in Factors Associated with Neonatal Intensive Care Unit Admission Growth in the U.S. 2009-2018

Journal of Perinatology

Abstract

IMPORTANCE: Neonatal intensive care unit (NICU) admissions have increased for all birth weights, particularly in larger and less premature newborns. However, little is known about what drives the growth of NICU admission rates. Given the racial/ethnic differences in birth outcomes and access to care, the role of factors associated with increasing NICU admission rates may differ by race/ethnicity.

OBJECTIVES: To decompose the NICU admission growth between 2009 and 2018 into contributing factors and to determine whether the relative association of the drivers differ by race/ethnicity.

DESIGN, SETTING, AND PARTICIPANTS: In this population-based retrospective study, we used data from restricted natality files provided by the National Center for Health Statistics (NCHS) at the U.S. Centers for Disease Control and Prevention (CDC) to assess the growth of NICU admission rates. We included births in 2009 and 2018 to residents of 28 U.S. states where the latest version (2003) of the U.S. birth certificate had been fully implemented by 2009 (N= 4,990,195).

MAIN OUTCOMES AND MEASURES: Changes in NICU admission rates between 2009 and 2018 overall and stratified by race/ethnicity. The Oaxaca-Blinder decomposition analysis was conducted to quantify the contribution of infant health risk, NICU bed supply, and maternal socioeconomic characteristics to the growth of NICU admission rates.

RESULTS: NICU admission rate increased by 1.78, 2.61, and 2.46 per 100 infants, respectively for white, black, and Hispanic infants. Changes in infant health risk contributed 0.87 and 0.47 of NICU admission rate increase per 100 infants among black and Hispanic infants respectively, while it mitigated the increase by 0.14 among white infants. Increased NICU bed supply contributed 0.48, 0.04, and 0.28 per 100 infants among white, black, and Hispanic infants, respectively. Maternal socioeconomic characteristics did not change but changes in their association with NICU admission contributed most to the NICU admission increase among all race/ethnic groups (1.05, 1.01, and 0.72 per 100 infants for white, black, and Hispanic infants respectively).

CONCLUSIONS AND RELEVANCE: The contributions of the factors affecting NICU admission growth substantially differed by race/ethnicity. Improvement in infant health mitigated the growth of NICU admission among white infants while changes in the association of maternal socioeconomic characteristics contributed most among all race/ethnic groups.

Introduction

Neonatal intensive care has significantly improved the mortality of premature and sick newborns.¹ In the U.S., the number of neonatal deaths per 1000 live births dropped from 18.73 in 1960 to 3.78 in 2018 and most of the reduction is attributed to neonatal intensive care.^{2,3} The delivery of very low birth weight or very preterm infants at hospitals with a Level III/IV neonatal intensive care unit (NICU) is now a standard of care.⁴⁻⁷ Although specialized care provided at NICUs improves the health of infants, it is expensive and can put infants at hospital-associated health risk and disrupt family dynamics.^{8,9} Therefore, the benefits of a NICU admission should be weighed against possible adverse consequences.

Studies show that NICU admission rates have recently increased greatly across all birth weights, particularly in larger and less premature newborns.⁷ However, little is known about what factors drive the growth of NICU admission rates and how they differ by race and ethnicity that are important when assessing health risk and access to health care.¹⁰ We hypothesized that the effects of contributing factors may differ by race/ethnicity. Understanding the differences in determinants for NICU admissions can be crucial for policymakers in assessing the relative importance of contributing factors and for developing policies to ensure risk-appropriate care.

Based on Andersen's Behavioral Model for determinants of health care utilization,¹¹ we included infant health risk, regional availability of NICU bed supply, and maternal socioeconomic characteristics as potential factors affecting NICU admission. Infant health risk determines the need for NICU admission and increasing NICU admission rates for high-risk infants can be desirable because those infants can benefit most. However, the growth of admissions among near

term or normal weight may, on average, be less beneficial suggesting unnecessary or unwarranted use. The growth in NICU bed supply has outpaced the need^{12,13} and some studies underscore the association between NICU bed supply and additional NICU utilization¹⁴⁻¹⁶ similar to the association of inpatient care with bed capacity among the adult population. Traditional socioeconomic determinants for health care access and utilization, such as insurance status and maternal education attainment, can also affect the likelihood of NICU admission.^{17,18}

In this study, we analyze potential drivers of the growth in NICU admission and quantify their relative contributions using the Oaxaca Blinder (OB) decomposition for each of white, black, and Hispanic infant groups.^{19,20} The classic OB decomposition focusing on group differences of the mean of primary outcome is suitable for studying changes in primary outcome over different periods. Using this method, we decomposed the growth of NICU admission rates between 2009 and 2018 into two components; one that is explained by differences in the distribution of the determinants, and another component that is explained by differences in the effect of the determinant on the NICU admissions.

Methods

Data Source and Study Population

This is a population-based study using restricted natality files provided by the National Center for Health Statistics (NCHS) at the U.S. Centers for Disease Control and Prevention (CDC).

Among births occurred in the U.S. in 2009 and 2018 (7,939,370), we included births occurred in 28 U.S. states where the 2003 revision of the U.S. birth certificate had been fully implemented by 2009 (n=5,268,456). Information on NICU admissions began with the 2003 revision and

some of the socioeconomic variables for analysis became available since 2009-year data. Therefore, states, where the 2003 version of the birth certificate had not been fully implemented by 2009, were excluded as they were not comparably present for both years (n=2,670,914). We then excluded births to mothers whose state of residence was not U.S. states or the District of Columbia (n=13,804). We further excluded those weighing less than 500 grams or born before 23 completed weeks of gestational age as they are not considered viable with current technology,^{18,20,21} and those with missing information on NICU information, birthweight, gestational age, Apgar score, payment source of delivery, maternal education and receipt of the special supplemental nutrition program for women, infants, and children (WIC). To assess whether excluding infants due to missing information could affect the NICU admission rates or not, we ran a sensitivity analysis without applying these exclusions except NICU information and gestational age. The final study cohort contained 4,990,195 births: 2,562,926 births for 2009 and 2,427,269 births for 2018 (Figure1).

NICU Admission by Race/Ethnicity

The outcome of interest was the difference in NICU admission rates between 2009 and 2018. NICU admission was defined as “admission into a facility or unit staffed and equipped to provide continuous mechanical ventilator support for a newborn” according to the CDC’s guideline.²¹ This definition of NICU care is comparable to Levels III and IV of neonatal care as established by the American Academy of Pediatrics (AAP).⁴ NICU admission rates were measured as NICU admissions per 100 live births. Since the birth certificate is required to be filed within 5 days of the birth,²² any NICU admission beyond this 5-day period was not

included. We also assumed infants with the record of NICU admission were fully admitted to a NICU as the CDC's guideline states not to include the infants who were taken to the NICU for observation only.²¹ We examined changes in NICU admission rates for each race/ethnic group. Race/ethnicity was identified by combining the bridged race that included more than one race and Hispanic ethnicity and was categorized into non-Hispanic white ("white"), non-Hispanic black ("black"), Hispanic, and other.

Contributing Factors

Factors potentially affecting NICU admissions were categorized into infant health risk, regional availability of NICU beds, and maternal socioeconomic characteristics. Infant health risk included gestational age, 5-min Apgar score, multiple births, cesarean delivery, small for gestational age (SGA), large for gestational age (LGA), and male sex. These are traditional risk factors for neonatal mortality that are relevant to NICU admission as well.^{7,23-28} Regional availability of NICU was measured as available NICU beds per 1000 births. We divided the number of NICU beds by the sum of births in the county in a given year. Then, we categorized year-specific county-level NICU bed supply per 1000 births into quartiles, sorted them from lowest to highest using pooled two years of data. A county assigned as quartile 2 in 2009 can be assigned as a higher quartile if the number of NICU beds per 1000 births increased in 2018 or vice versa. The information on the number of NICU beds at the county level was available from the area health resources files (AHRF), previously known as the area resource files (ARF). The AHRF is publicly available to download at the Health Resources and Services Administration (HRSA) website (<https://data.hrsa.gov/>). The AHRF data used the hospital-level data from the American Hospital Association (AHA) Annual Survey Database and aggregated to the county level. Maternal

socioeconomic characteristics included maternal education attainment, health insurance status, and receipt of WIC (the special supplemental nutrition program for women, infants, and children) from the natality file.

Contributing factors were compared between 2009 and 2018 and their changes were examined in two parts, changes in the distribution of contributing factors and changes in their associations with NICU admission measured as the coefficient estimates from the regression analysis. The relative and absolute contributions by each of contributing factors to changes in NICU admission rates were quantified using the decomposition analysis explained in the following section.

Statistical Analysis

We used the Oaxaca Blinder (OB) decomposition that has been widely used in the study of labor market discrimination.^{19,20} It was developed by Ronald Oaxaca and Alan Blinder to decompose racial and sex wage differentials into a component attributable to differences in individual characteristics (“endowments”) and a component attributable to differences in the estimated effects of individual characteristics (“coefficients”).^{19,20} In health care, several studies have used this approach to quantify the contribution of different factors in explaining differences in disease prevalence,²⁹⁻³¹ health outcomes,³² and healthcare utilization across different sub-groups of the population.^{33,34} Multivariable decomposition uses the output from regression models to partition the components of a group difference in outcomes. When the outcome, Y is a function of a linear combination of predictors and regression coefficients,

$$Y=F(X\beta)$$

where Y is a dependent variable vector, X is a matrix of independent variables, and β is a vector of coefficients. The mean difference in Y between groups A and B can be decomposed as³⁵

$$\begin{aligned}\bar{Y}_A - \bar{Y}_B &= \overline{F(X_A \hat{\beta}_A)} - \overline{F(X_B \hat{\beta}_B)} \\ &= \underbrace{\left\{ \overline{F(X_A \hat{\beta}_A)} - \overline{F(X_B \hat{\beta}_A)} \right\}}_E + \underbrace{\left\{ \overline{F(X_B \hat{\beta}_A)} - \overline{F(X_B \hat{\beta}_B)} \right\}}_C\end{aligned}$$

The endowment component (E) represents the part of the differential attributable to differences in a set of predictors and reflects a counterfactual comparison of the difference if group A were given group B's distribution of predictors. The coefficients component (C) refers to the part of the differential attributable to differences in coefficients of predictors weighted by group B's distribution of predictors.

The outcome interest, NICU admission is a binary variable and we conducted multivariable logistic regressions using Stata command Oaxaca developed by Jann for nonlinear regression.³⁶ This command provides the detailed decomposition into contributions of individual drivers.³⁶ Using this method, we decomposed the growth of NICU admissions between 2009 (treated as Group B) and 2018 (treated as Group A) into two components; one that is explained by differences in the distribution of infant health risk, regional availability of NICU bed supply, and maternal socioeconomic status, and another component that is explained by differences in the effect of these determinants on the NICU admissions. The detailed decomposition further decomposes E and C components into the unique contribution of each driver. This allows us to quantify the contribution of each driver to the growth in NICU admissions, thus identify which factors contribute most to the growth between the two time periods.^{19,20}

The study protocol was reviewed and approved by the Committee for the Protection of Human Subjects (CPHS) at the University of Texas Health Science Center at Houston and all statistical analyses were performed using Stata, version 16.0 (StataCorp LLC., College Station, TX).

Results

Characteristics of Live Births in 2009 and 2018 by Race/Ethnicity

Neonatal characteristics indicating infant health risk slightly improved between 2009 and 2018, but changes differed by race/ethnicity (Table 1). Percentages of multiple births and cesarean delivery decreased among white infants but increased among black infants. Percentages of premature birth before 37 weeks of gestation and low birth weight (<2500g) increased among Hispanic infants while decreasing slightly among white infants. Very preterm birth (<32wk) and very low birth weight (<1500g) rates remained twice as high among black infants compared to white and Hispanic infants. NICU beds per 1000 births increased from 4.2 to 4.9 (Table 1). The changes in maternal characteristics were similar across race/ethnicity.

NICU Admission Growths by Race/Ethnicity and Gestational Age between 2009 and 2018

From 2009 to 2018, NICU admission rates per 100 infants increased by 30% from 7.0 to 9.2 (Table 2). The increase was smallest among white infants (1.8 per 100 infants) and largest among black infants (2.6 per 100 infants). The increase was observed across all gestational categories. Admissions increased to about 90 per 100 infants among those infants born before 32 weeks of gestation. Hispanic infants in that category had considerably lower NICU admission rates in 2009 compared to white and black infants, but by 2018, this difference disappeared.

Relative changes from 2009 to 2018 were larger among infants in gestational age ≥ 32 weeks, in particular in the 37-38 weeks category regardless of race/ethnicity. We conducted a sensitivity analysis including infants excluded due to missing information other than NICU admission and gestation age, which accounted for about 5% of the final study population, and found consistent results.

Changes in Characteristics Contributing to NICU Admission between 2009 and 2018

Table 3 shows distributional changes in observed characteristics contributing to NICU admission between 2009 and 2018 for each race/ethnic group. Overall infant health risk reduced among white infants while it remained relatively unchanged among black infants and slightly increased among Hispanic infants. Among white infants, percentages of premature births, multiple gestations, cesarean delivery, and SGA decreased. Among black infants, percentages of early-term or late-term births decreased while percentages of infants with multiple gestations and cesarean delivery increased. Among Hispanic infants, premature birth rates and multiple gestations increased but the percentage of infants with cesarean delivery decreased. The percentage of births occurred in higher quartile increased regardless of race/ethnicity. Maternal insurance status and education improved more among Hispanic compared to white and black infants.

Changes in Coefficient (Odds Ratio (OR)) Estimates between 2009 and 2018

Table 4 presents coefficient estimates reporting in odds ratios from multivariable logistic regression models in 2009 and 2018. Among white infants, odds of being admitted to a NICU according to gestational age in reference to full-term did not differ between 2009 and 2018

except 37-38 weeks of gestational age. Odds of being admitted to a NICU admission for early-term birth (37-38wk) was 1.75 times that of full-term birth in 2009 and it increased to 1.90 in 2018. Among black and Hispanic infants, coefficient estimates substantially increased for less than 32-week gestational age (OR 65.8 in 2009 vs OR 85.2 in 2018 among black infants and OR 59.9 in 2009 vs OR 86.3 in 2018 among Hispanic infants). The associations of other infant health factors with NICU admission increased also for lower 5-min Apgar and LGA in all racial/ethnic groups. Higher quartiles were associated with higher NICU admission compared to quartile 1 (OR>1 for NICU bed supply quartile 2 or higher). It is noticeable that there was little to no incremental increase in ORs across quartile 2, 3, and 4 among white and black infants. These odds ratios remained similar between 2009 and 2018 among white and black infants but increased among Hispanic infants. Being insured was not significantly associated with NICU admission in 2009 but was associated with higher NICU admission in 2018 among white infants. Among black infants, being insured was associated with lower NICU admission in 2009 but this association became insignificant in 2018. Among Hispanic infants, being insured was associated with higher NICU admission and the association increased in 2018 (OR 1.09 in 2009 and OR 1.17 in 2018). Higher maternal education was associated with lower NICU admission rates in 2009 among white infants and this inverse association became larger in 2018. Among black infants, maternal education levels were not significantly associated with NICU admission in 2009 but it became inversely associated in 2018. Among Hispanic infants, high school graduate or higher education was associated with higher NICU admission in 2009 but the association became insignificant in 2018. Receiving WIC was associated with higher NICU admission among white infants in both 2009 and 2018 but it was only significantly associated with high NICU admission in 2018 among black and Hispanic infants.

Decomposition of NICU Growth between 2009 and 2018

The growth was decomposed into the component attributable to the changes in the distribution of characteristics and the component attributable to the changes in the association of characteristics with NICU admission. Therefore, each factor has two components.

Table 5 shows the detailed decomposition analysis at the level of individual factors. The first part of the detailed decomposition showed the changes in NICU admission rates associated with the differences in characteristics. Among white infants, the contributions due to changes in infant health characteristics were mostly negative indicating improvement of infant health status would have reduced the NICU admission rate in 2018 if other conditions had remained the same.

Among black infants, the contribution of infant health risk to the growth NICU admission rates was negative but small indicating little improvement in health status. Among Hispanic infants, the contribution of infant health risk was also small but positive indicating slightly worsening health status. The contribution of changes in NICU bed supply was a primary driver among white and Hispanic infants but not among black infants. The second part of the detailed decomposition shows the changes in NICU admission rates attributable to changes in the associations of contributing factors with NICU admission reported in odds ratios from logistic regressions. The contribution by changes in the association of infant health risk factors with NICU admission was largest among black infants while the contribution by changes in the association of NICU bed supply with NICU supply was largest among Hispanic infants. The contributions by changes in the association of maternal socioeconomic characteristics were a primary driver among all racial/ethnic groups.

Figure 2 shows decomposition analysis by two components at the aggregated subset of factors to infant health risk, NICU bed supply, and maternal socioeconomic characteristics across race/ethnicity. Among white infants, NICU bed supply and maternal socioeconomic characteristics were responsible for 0.60 (33.5%), and 0.96 (53.6%) respectively out of 1.78 NICU admission rate increase per 100 infants. Among them, infant health risk contributed negatively by 0.14 (-8.0%) meaning that NICU admission rate would have reduced by 0.14 per 100 infants if there were no other changes in NICU supply and maternal education between 2009 and 2018. The remaining portion (0.37, 20.9%) of the increase was absorbed as a constant term and indicate the contribution of unobservable factors. Among black infants, infant health risk and maternal socioeconomic characteristics were responsible for 0.87 (33.2%) and 1.00 (38.3%) out of 2.61, respectively. Among Hispanic infants, infant health risk, NICU bed supply, and maternal socioeconomic characteristics respectively contributed by 0.47 (19.0%), 0.67 (27.2%), and 0.86 (35.1%) out of 2.46.

Discussion

In this study, we examined the factors associated with the growth of NICU admissions and assessed their contributions by race/ethnicity. We found different patterns across the race/ethnic groups that could imply potential racial/ethnic disparities.

Infant health status improved substantially among white infants but little among black infants and slightly worsened among Hispanic infants. As a result, the change in infant health status mitigated the growth of NICU admission rates among white infants while it minimally affected NICU admission rates among black and Hispanic infants. On the other hand, changes in the

associations of health risk factors with NICU admission contributed to the growth of NICU admission most among black infants and least among white infants.

The contribution of NICU bed supply to NICU admission growth was largest among Hispanic infants and smallest among black infants. We found that as NICU bed supply increased from 2nd to 3rd quartile or 3rd to 4th quartile, there were no significant changes in the association between NICU bed supply and NICU admission among white and black infants. Previous studies found that regional variation exists in NICU care not explained by infant health condition^{15,37-40} and that greater bed supply is associated with high NICU admissions, particularly among low-risk newborns.^{15,16,37} A recent study found geographic segregation and inequality in NICU care by race and ethnicity.⁴¹ Our study suggests that greater bed supply may be associated with high NICU admissions only up to a certain extent and this association may differ by racial/ethnic community.

The contribution attributable to changes in maternal socioeconomic characteristics was minimal among all race/ethnic groups. Most of the contribution was from the changes in the association of maternal socioeconomic characteristics with NICU admission, especially among white infants. This may imply that the growth of NICU admission rates could be less justified and may be driven in part by potential overutilization.

Our study had limitations. First, our NICU admission rates could underestimate actual rates compared to measures based on hospital discharge data capturing admissions during the entire length of newborn hospitalization. Second, there could be an improvement in the data quality in

the later year of data as the states gained more experience. Third, our study population was limited to 28 U.S. states which represented about 63% of total U.S. births in 2009 and 2018. However, our study has strengths. First, this is one of a few studies investigating NICU admission rates across the entire range of newborn risk groups. Second, even though our study cohort was limited to 28 U.S. states, our previous study confirmed that characteristics of births were representative for the entire U.S. birth cohort. Third, as far as we know, our study is the first study that decomposed and quantified the effect of potential drivers to NICU growth by race/ethnicity.

Our findings provide several policy and clinical implications. We found that improved infant health mitigated the growth of NICU admission rates among white infants. Given the persistently higher premature births and VLBW rates among black infants and the evidence of worsening health among Hispanic infants, promoting maternal and perinatal health and reducing racial/ethnic disparities in birth outcomes could substantially lower NICU admissions. We found that the increased association of infant health risk factors with NICU admission contributed to the growth of NICU admission rates among all infants but especially among black infants. This could indicate improved risk-appropriate care among higher risk infants. Alternatively, a lower risk threshold for initiating NICU care could indicate unnecessary NICU admissions. We also found that among white infants and black infants, distributional changes across higher quartiles of NICU bed supply did not contribute to the NICU admission growth. This could mean that the incremental effect of NICU bed supply diminished beyond a certain level. Further research requires to understand that the patterns of distributional changes in NICU bed supply and its effect on the NICU admission growth by race/ethnicity.

Conclusion

Between 2009 and 2018, the NICU admission rate per 100 infants increased by 30%. The contributions of the drivers substantially differed by race/ethnicity. Improvement in infant health mitigated the growth of NICU admission among white infants while maternal socioeconomic characteristics contributed most among all race/ethnic groups. Our findings can be used to develop policies to ensure risk-appropriate care and reduce unnecessary care by race/ethnicity.

Tables and Figures

Figure 1. Cohort Derivation

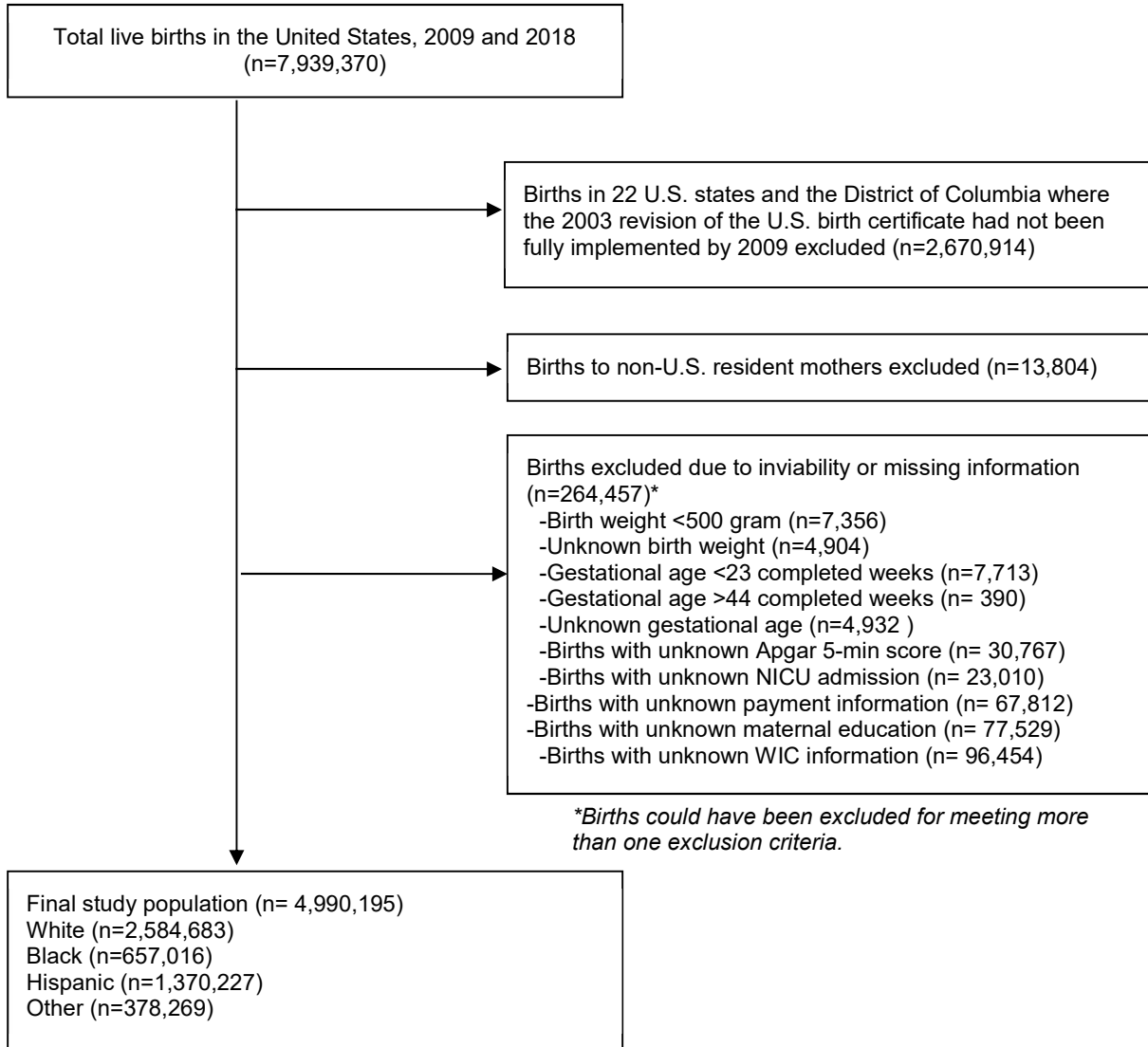


Table 1. Characteristics of Live Births: 28 U.S. States^a, 2009 and 2018

Year	Total		White		Black		Hispanic	
	2009	2018	2009	2018	2009	2018	2009	2018
No. of Infants	2,562,926	2,427,269	1,335,744	1,248,939	326,393	330,623	722,139	648,088
Neonatal Characteristics, %								
Male	51.1	51.1	51.2	51.2	50.8	50.7	51.0	50.9
Multiple gestations	3.3	3.2	3.8	3.5	3.8	4.1	2.3	2.5
Cesarean delivery	33.1	32.1	32.6	30.7	35.9	36.3	32.7	32.4
Gestational age, wk								
<32	1.4	1.3	1.2	1.1	2.7	2.6	1.2	1.3
32-36	8.3	8.3	8.1	7.8	10.8	10.8	7.8	8.3
37-38	28.7	26.6	27.4	24.7	30.2	29.6	30.3	28.3
39-40	54.9	57.6	56.3	59.4	50.4	52.1	54.3	56.9
≥41	6.7	6.2	7.1	7.2	5.9	5.0	6.5	5.3
Birthweight category, g								
<1500	1.2	1.2	1.0	0.9	2.5	2.4	1.0	1.1
1500-2499	6.6	6.8	6.0	5.9	10.4	10.8	5.8	6.2
2500-3999	84.7	84.4	84.0	83.9	82.9	82.4	86.2	85.8
≥4000	7.6	7.7	9.0	9.4	4.1	4.4	7.0	6.9
5-Minute Apgar score								
<7	1.7	1.8	1.8	1.8	2.9	2.7	1.2	1.3
7-8	12.6	11.8	14.0	12.9	15.1	13.2	9.6	9.6
9-10	85.7	86.4	84.2	85.3	82.0	84.1	89.2	89.1
NICU Supply								
NICU Beds per 1000 births	4.2	4.9	NA	NA	NA	NA	NA	NA
Maternal Characteristics, %								
Age category, y								
<20	10.1	4.8	7.3	3.4	16.1	7.0	14.1	7.4
20-24	24.5	19.3	22.7	17.1	31.5	25.0	27.6	23.7
25-29	28.3	29.2	30.0	29.8	25.4	30.2	26.9	28.9
30-34	22.9	28.6	25.1	31.4	16.4	22.4	19.4	23.5
35-39	11.4	14.9	12.0	15.2	8.4	12.2	9.8	13.1
40-54	2.7	3.4	2.9	3.0	2.2	3.2	2.3	3.5
Health Insurance								
Medicaid	44.3	42.9	32.4	30.9	64.1	64.5	60.3	59.2
Private Insurance	46.1	48.5	60.3	61.8	27.5	28.3	24.8	29.5
Self-Pay	4.6	4.3	3.0	3.4	3.5	3.1	8.6	6.1
Other	5.0	4.3	4.3	3.9	4.9	4.1	6.3	5.3
WIC received	48.5	37.4	33.5	24.6	67.5	54.6	71.6	57.1
Unmarried ^b	40.9	39.7	29.4	29.5	72.4	68.8	52.4	51.2
Educational attainment								
Less than high school	21.1	13.0	10.7	7.4	22.6	13.4	41.8	25.2
High school	26.4	26.2	23.9	21.9	33.9	35.5	29.6	33.1
Some college	20.1	20.2	21.9	19.8	25.3	25.5	15.8	20.4
Associate or Bachelor's degree	23.9	28.9	31.9	35.9	14.4	19.7	10.5	17.2
Master's or higher degree	8.6	11.7	11.7	15.1	3.9	6.0	2.4	4.1
Urban-Rural classification ^c								
Large central metro	40.7	40.4	29.2	30.3	51.5	49.4	52.1	49.0
Large fringe metro	17.2	18.0	19.0	18.9	18.4	20.0	13.8	15.6

Medium metro	23.1	23.2	25.5	25.4	19.2	19.3	23.0	24.0
Small metro	9.2	9.6	12.3	12.5	6.6	7.4	5.6	6.4
Micropolitan/Noncore	9.9	8.9	14.1	13.0	4.4	3.8	5.5	4.9

Abbreviations: NICU, neonatal intensive care unit; NA, not applicable; WIC, the special supplemental nutrition program for women, infants, and children.

^aBy 2009, the 2003 revision of U.S. Birth Certificates had been implemented in 28 U.S. states including CA, CO, DE, FL, GA, IA, ID, IN, KS, KY, MI, MT, ND, NE, NH, NM, NY, OH, OR, PA, SC, SD, TN, TX, UT, VT, WA, and WY.

^bBirths occurring in or to residents of California in 2018 were excluded due to state statutory restrictions.

^cThe National Center for Health Statistics' (NCHS) Urban–Rural Classification Scheme for Counties was used.

Table 2. NICU Admission Growth by Race/Ethnicity and Gestational Age Group: 28 U.S. States^a, 2009 and 2018

	NICU Admissions per 100 infants (95% CI)			
	2009	2018	Absolute Diff. ^b	Relative Ratio ^b
Total	7.0 (7.0-7.1)	9.2 (9.1-9.2)	2.1 (2.1-2.2)	1.30 (1.29-1.31)
GA <32	82.3 (81.9-82.7)	89.6 (89.3-89.9)	7.3 (6.8-7.9)	1.09 (1.08-1.10)
32-36	36.0 (35.8-36.2)	45.1 (44.9-45.3)	9.1 (8.8-9.4)	1.25 (1.24-1.26)
37-38	4.3 (4.3-4.4)	6.7 (6.7-6.8)	2.4 (2.3-2.5)	1.55 (1.53-1.57)
39-40	2.6 (2.6-2.7)	3.8 (3.7-3.8)	1.1 (1.1-1.2)	1.43 (1.41-1.44)
≥41	3.5 (3.4-3.6)	5.0 (4.8-5.1)	1.4 (1.3-1.6)	1.41 (1.37-1.46)
White	6.9 (6.9-6.9)	8.7 (8.6-8.7)	1.8 (1.7-1.8)	1.26 (1.25-1.27)
GA, wk <32	85.2 (84.7-85.8)	90.1 (89.6-90.6)	4.8 (4.1-5.6)	1.06 (1.05-1.07)
32-36	38.2 (37.9-38.5)	46.5 (46.1-46.8)	8.3 (7.8-8.7)	1.22 (1.20-1.23)
37-38	4.5 (4.4-4.6)	7.2 (7.1-7.3)	2.6 (2.5-2.8)	1.59 (1.56-1.62)
39-40	2.4 (2.4-2.5)	3.5 (3.4-3.5)	1.0 (1.0-1.1)	1.43 (1.40-1.46)
≥41	3.0 (2.9-3.1)	4.3 (4.1-4.4)	1.3 (1.1-1.5)	1.43 (1.36-1.50)
Black	9.7 (9.6-9.8)	12.3 (12.2-12.5)	2.6 (2.5-2.8)	1.27 (1.25-1.29)
GA, wk <32	83.0 (82.3-83.8)	90.4 (89.8-91.0)	7.4 (6.4-8.4)	1.09 (1.08-1.10)
32-36	36.1 (35.6-36.6)	46.5 (46.0-47.1)	10.4 (9.7-11.2)	1.29 (1.27-1.31)
37-38	5.1 (5.0-5.3)	7.6 (7.4-7.7)	2.5 (2.2-2.7)	1.48 (1.43-1.53)
39-40	3.5 (3.4-3.6)	4.7 (4.6-4.8)	1.2 (1.1-1.3)	1.34 (1.30-1.39)
≥41	4.9 (4.5-5.2)	6.3 (5.9-6.7)	1.4 (1.0-1.9)	1.30 (1.18-1.41)
Hispanic	6.2 (6.2-6.3)	8.7 (8.6-8.8)	2.5 (2.4-2.5)	1.39 (1.38-1.41)
GA, wk <32	77.1 (76.2-78.0)	88.4 (87.7-89.1)	11.2 (10.1-12.4)	1.15 (1.13-1.16)
32-36	32.2 (31.8-32.6)	42.2 (41.8-42.7)	10.0 (9.4-10.6)	1.31 (1.29-1.33)
37-38	3.8 (3.7-3.9)	5.8 (5.7-5.9)	2.0 (1.9-2.2)	1.53 (1.49-1.57)
39-40	2.6 (2.5-2.6)	3.8 (3.7-3.8)	1.2 (1.1-1.2)	1.45 (1.41-1.49)
≥41	3.8 (3.6-3.9)	5.7 (5.4-5.9)	1.9 (1.6-2.2)	1.50 (1.40-1.59)

Abbreviations: NICU, neonatal intensive care unit; CI, confidence interval; GA, gestational age.

^aBy 2009, the 2003 revision of U.S. Birth Certificates had been implemented in 28 U.S. states including CA, CO, DE, FL, GA, IA, ID, IN, KS, KY, MI, MT, ND, NE, NH, NM, NY, OH, OR, PA, SC, SD, TN, TX, UT, VT, WA, and WY.

^bAll estimates were significant at $p < 0.05$.

Table 3. Changes in Characteristics Contributing to NICU Admission between 2009 and 2018 by Race/Ethnicity

Year	White			Black			Hispanic		
	2009	2018	p- value	2009	2018	p- value	2009	2018	p- value
<u>Infant Health Risk, %</u>									
Gestational Age									
<32wk	1.2	1.1	<0.001	2.7	2.5	<0.001	1.2	1.3	<0.001
32-36wk	8.1	7.7		10.8	10.8		7.8	8.3	
37-38wk	27.4	24.6		30.2	29.6		30.3	28.3	
39-40wk	56.3	59.4		50.4	52.1		54.3	56.9	
≥41wk	7.0	7.2		5.9	5.0		6.4	5.3	
5-min Apgar									
<7	1.8	1.8	<0.001	2.9	2.7	<0.001	1.2	1.3	<0.001
7-8	14.0	12.9		15.1	13.2		9.6	9.6	
9-10	84.2	85.3		82.0	84.1		89.2	89.1	
Plurality	3.8	3.5	<0.001	3.8	4.1	<0.001	2.3	2.5	<0.001
Cesarean delivery	32.6	30.7	<0.001	35.9	36.3	0.001	32.7	32.4	0.003
SGA	10.0	9.7	<0.001	9.7	9.6	0.099	9.9	9.7	0.002
LGA	2.9	2.9	0.034	2.9	3.0	<0.001	3.0	2.9	0.018
Male	51.2	51.2	0.719	50.8	50.7	0.245	51.0	50.9	0.14
<u>NICU bed supply, %</u>									
Quartile 1 (low)	35.0	28.6	<0.001	19.1	16.6	<0.001	19.3	15.1	<0.001
Quartile 2	23.5	21.1		30.3	18.9		31.6	23.3	
Quartile 3	18.4	19.4		28.7	32.9		30.8	36.1	
Quartile 4 (high)	23.1	30.9		21.9	31.6		18.3	25.5	
<u>Maternal SES, %</u>									
Insured	97.0	96.6	<0.001	96.5	96.9	<0.001	91.4	93.9	<0.001
Education									
Less than high school	10.7	7.4	<0.001	22.5	13.3	<0.001	41.8	25.2	<0.001
High school	23.9	21.9		33.9	35.5		29.6	33.1	
Some college	21.9	19.8		25.3	25.5		15.8	20.4	
Associate or Bachelor	31.9	35.9		14.4	19.7		10.5	17.2	
Master's or higher	11.7	15.1		3.9	6.0		2.4	4.1	
WIC received	33.5	24.5	<0.001	67.5	54.6	<0.001	71.6	57.1	<0.001

Abbreviations: NICU, neonatal intensive care unit; SGA, small for gestational age; LGA, large for gestational age; SES, socioeconomic status; WIC, the special supplemental nutrition program for women, infants, and children.

Table 4. Changes in Coefficient (Odds Ratio (OR)) Estimates between 2009 and 2018 by Race/Ethnicity

Year	White		Black		Hispanic	
	2009 OR (95% CI)	2018 OR (95% CI)	2009 OR (95% CI)	2018 OR (95% CI)	2009 OR (95% CI)	2018 OR (95% CI)
<u>Infant Health Risk</u>						
Gestational Age						
<32wk	98.17 (93.40-103.19)	102.66 (96.48-109.22)	65.82 (61.63-70.29)	85.18 (78.62-92.30)	59.94 (56.57-63.52)	86.34 (80.20-92.95)
32-36wk	18.37 (17.99-18.77)	17.92 (17.57-18.29)	12.77 (12.31-13.25)	14.44 (13.96-14.94)	14.20 (13.80-14.61)	15.51 (15.11-15.93)
37-38wk	1.75 (1.71-1.79)	1.90 (1.86-1.93)	1.42 (1.36-1.47)	1.55 (1.50-1.60)	1.39 (1.35-1.43)	1.49 (1.45-1.53)
39-40wk	Reference	Reference	Reference	Reference	Reference	Reference
≥41wk	1.22 (1.17-1.28)	1.20 (1.15-1.24)	1.32 (1.23-1.42)	1.25 (1.17-1.34)	1.44 (1.37-1.52)	1.47 (1.40-1.55)
5-min Apgar						
<7	9.30 (8.97-9.65)	15.90 (15.36-16.46)	7.11 (6.71-7.55)	13.68 (12.89-14.51)	7.49 (7.05-7.96)	15.98 (15.10-16.92)
7-8	2.88 (2.83-2.93)	3.99 (3.92-4.06)	2.56 (2.48-2.64)	3.62 (3.51-3.73)	2.97 (2.88-3.05)	4.04 (3.93-4.14)
9-10	Reference	Reference	Reference	Reference	Reference	Reference
Plurality	1.42 (1.39-1.46)	1.32 (1.28-1.36)	1.44 (1.37-1.51)	1.35 (1.28-1.41)	1.59 (1.52-1.66)	1.39 (1.33-1.45)
Cesarean delivery	1.89 (1.86-1.92)	1.85 (1.82-1.87)	2.02 (1.97-2.08)	1.99 (1.94-2.05)	1.85 (1.81-1.89)	1.82 (1.79-1.86)
SGA	1.78 (1.74-1.82)	1.77 (1.73-1.81)	2.09 (2.00-2.18)	2.07 (2.00-2.16)	2.00 (1.93-2.06)	1.88 (1.83-1.94)
LGA	1.09 (1.04-1.14)	1.44 (1.38-1.50)	1.31 (1.21-1.41)	1.76 (1.65-1.87)	1.28 (1.20-1.35)	1.73 (1.64-1.82)
Male	1.24 (1.22-1.26)	1.24 (1.22-1.26)	1.08 (1.05-1.11)	1.11 (1.08-1.14)	1.13 (1.10-1.15)	1.13 (1.11-1.16)
<u>NICU bed supply</u>						
Quartile 1 (low)	Reference	Reference	Reference	Reference	Reference	Reference
Quartile 2	2.00 (1.95-2.05)	2.15 (2.10-2.20)	1.60 (1.53-1.68)	1.62 (1.55-1.70)	1.35 (1.30-1.40)	1.48 (1.42-1.53)
Quartile 3	2.03 (1.98-2.09)	2.03 (1.98-2.08)	1.56 (1.49-1.64)	1.52 (1.46-1.59)	1.40 (1.35-1.45)	1.57 (1.52-1.63)
Quartile 4 (high)	2.21 (2.16-2.26)	2.25 (2.20-2.30)	1.61 (1.53-1.69)	1.50 (1.44-1.57)	1.72 (1.65-1.78)	1.73 (1.66-1.79)
<u>Maternal SES</u>						
Insured	0.99 (0.94-1.05)	1.21 (1.16-1.28)	0.85 (0.79-0.91)	0.94 (0.87-1.01)	1.09 (1.05-1.13)	1.17 (1.12-1.23)
Education						
Less than high school	Reference	Reference	Reference	Reference	Reference	Reference
High school	0.95 (0.92-0.98)	0.94 (0.91-0.97)	0.97 (0.93-1.01)	0.91 (0.87-0.95)	1.04 (1.01-1.07)	0.97 (0.95-1.00)
Some college	0.98 (0.95-1.01)	0.91 (0.88-0.94)	0.96 (0.92-1.00)	0.88 (0.84-0.92)	1.12 (1.08-1.16)	0.99 (0.96-1.02)
Associate or Bachelor	0.90 (0.88-0.93)	0.82 (0.79-0.84)	1.00 (0.95-1.05)	0.85 (0.81-0.89)	1.09 (1.05-1.13)	0.97 (0.93-1.00)
Master's or higher	0.90 (0.87-0.93)	0.82 (0.79-0.85)	0.92 (0.85-1.00)	0.79 (0.74-0.85)	1.07 (1.00-1.16)	0.97 (0.92-1.03)
WIC received	1.05 (1.03-1.07)	1.05 (1.03-1.07)	1.01 (0.97-1.04)	1.05 (1.02-1.08)	1.00 (0.97-1.02)	1.06 (1.04-1.09)

Abbreviations: NICU, neonatal intensive care unit; OR, odds ratio; CI, confidence interval; SGA, small for gestational age; LGA, large for gestational age; SES, socioeconomic status; WIC, the special supplemental nutrition program for women, infants, and children.

Table 5. Decomposition of NICU Admissions Growths between 2009 and 2018 by Race/Ethnicity

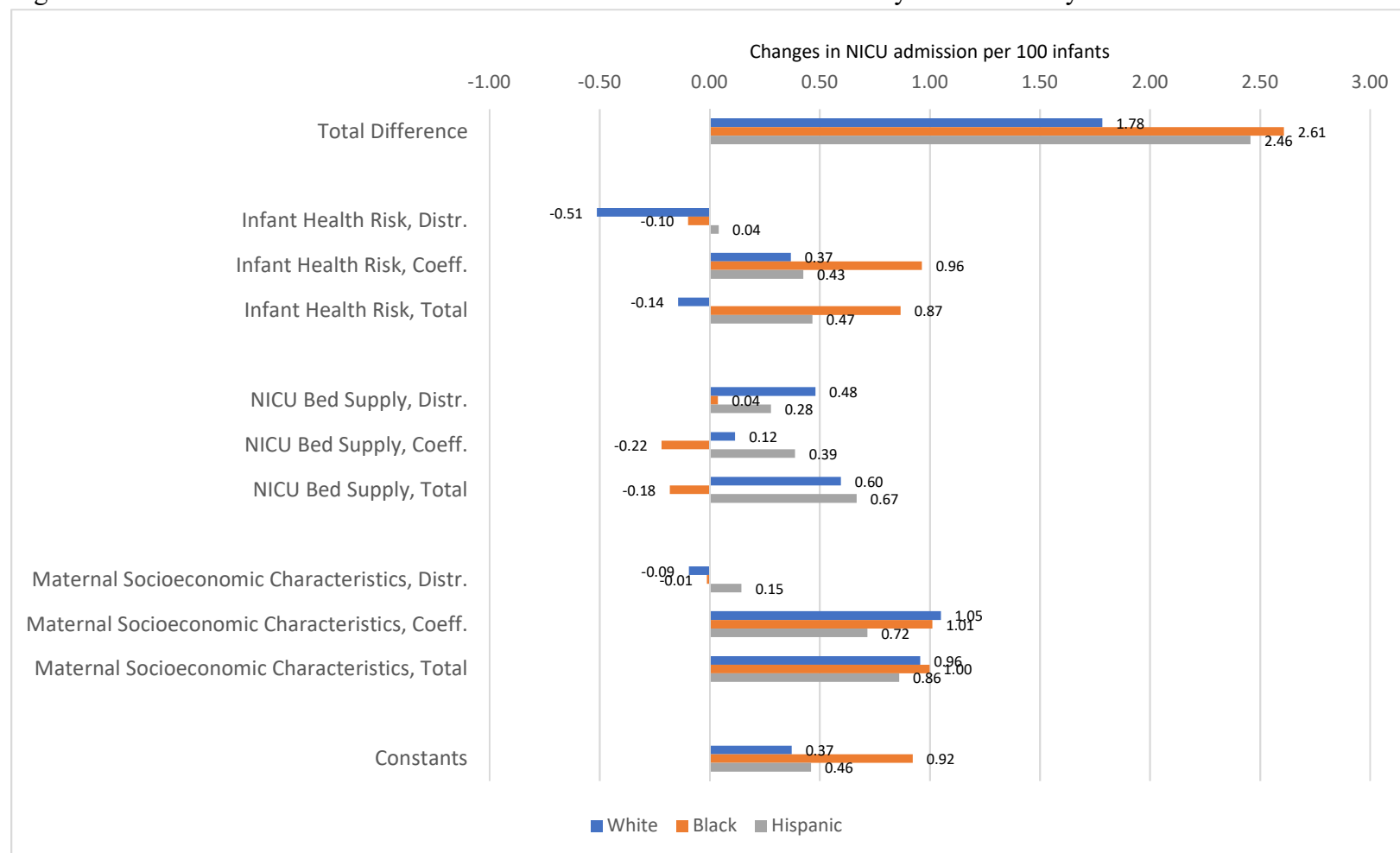
	White		Black		Hispanic	
	Est. (95% CI)	Share, %	Est. (95% CI)	Share, %	Est. (95% CI)	Share, %
NICU admission per 100						
Year 2018	8.687 (8.644-8.729)		12.341 (12.246-12.436)		8.696 (8.636-8.756)	
Year 2009	6.903 (6.867-6.940)		9.732 (9.645-9.819)		6.239 (6.189-6.288)	
Total difference	1.783 (1.727-1.839)	100.00	2.609 (2.480-2.738)	100.00	2.457 (2.380-2.535)	100.00
Detailed Decomposition						
Diff. due to diff. in characteristics						
<u>Infant Health Risk</u>	-0.512 (-0.574--0.450)	-28.70	-0.097 (-0.147--0.047)	-3.73	0.042 (0.010-0.074)	1.70
Gestational age	-0.281 (-0.315--0.246)	-15.73	-0.035 (-0.059--0.010)	-1.33	0.041 (0.017-0.065)	1.68
5-min Apgar	-0.098 (-0.113--0.084)	-5.52	-0.073 (-0.101--0.044)	-2.78	0.019 (0.008-0.030)	0.77
Plurality	-0.010 (-0.012--0.008)	-0.58	0.003 (0.001-0.004)	0.11	0.007 (0.005-0.009)	0.28
Cesarean delivery	-0.111 (-0.128--0.094)	-6.23	0.009 (0.004-0.015)	0.35	-0.013 (-0.022--0.004)	-0.53
SGA	-0.012 (-0.016--0.008)	-0.68	-0.003 (-0.007-0.001)	-0.11	-0.010 (-0.016--0.003)	-0.39
LGA	0.000 (0.000-0.001)	0.02	0.001 (0.000-0.002)	0.05	-0.001 (-0.003-0.000)	-0.06
Male	0.000 (-0.002-0.003)	0.03	0.000 (-0.001-0.000)	-0.01	-0.001 (-0.003-0.000)	-0.05
<u>NICU bed supply</u>	0.480 (0.395-0.566)	26.94	0.038 (0.025-0.052)	1.47	0.279 (0.254-0.304)	11.35
<u>Maternal SES</u>	-0.095 (-0.112--0.078)	-5.30	-0.012 (-0.031-0.007)	-0.45	0.145 (0.109-0.181)	5.90
Insured	0.000 (-0.002-0.003)	0.02	-0.002 (-0.003--0.001)	-0.08	0.018 (0.010-0.027)	0.75
Education	-0.057 (-0.072--0.041)	-3.18	-0.007 (-0.021-0.007)	-0.28	0.120 (0.084-0.156)	4.89
WIC received	-0.038 (-0.054--0.022)	-2.15	-0.003 (-0.017-0.011)	-0.10	0.006 (-0.027-0.040)	0.26
Diff. due to diff. in coefficients						
<u>Infant Health Risk</u>	0.369 (0.263-0.475)	20.71	0.965 (0.672-1.257)	36.97	0.426 (0.269-0.582)	17.33
Gestational age	0.093 (0.033-0.154)	5.24	0.349 (0.170-0.527)	13.37	0.201 (0.106-0.296)	8.17
5-min Apgar	0.295 (0.270-0.320)	16.52	0.505 (0.438-0.571)	19.34	0.241 (0.212-0.270)	9.80
Plurality	-0.015 (-0.023--0.007)	-0.84	-0.021 (-0.043-0.002)	-0.80	-0.020 (-0.030--0.011)	-0.83
Cesarean delivery	-0.039 (-0.079-0.000)	-2.20	-0.042 (-0.156-0.072)	-1.62	-0.029 (-0.091-0.032)	-1.19
SGA	-0.001 (-0.020-0.017)	-0.08	-0.005 (-0.048-0.039)	-0.18	-0.034 (-0.060--0.009)	-1.40

LGA	0.046 (0.036-0.056)	2.59	0.071 (0.047-0.095)	2.72	0.053 (0.039-0.067)	2.17
Male	-0.009 (-0.074-0.056)	-0.51	0.108 (-0.048-0.265)	4.15	0.015 (-0.080-0.109)	0.60
<u>NICU bed supply</u>	0.116 (0.003-0.229)	6.52	-0.219 (-0.591-0.154)	-8.38	0.388 (0.151-0.626)	15.81
<u>Maternal SES</u>	1.051 (0.658-1.444)	58.94	1.012 (0.201-1.823)	38.77	0.716 (0.345-1.088)	29.15
Insured	1.111 (0.716-1.507)	62.32	0.766 (-0.032-1.565)	29.37	0.423 (0.072-0.774)	17.21
Education	-0.067 (-0.101--0.033)	-3.76	0.060 (-0.057-0.176)	2.28	0.060 (-0.030-0.151)	2.46
WIC received	0.007 (-0.032-0.045)	0.37	0.186 (0.002-0.369)	7.12	0.233 (0.112-0.354)	9.49
Constant ^a	0.372 (-0.061-0.806)	20.89	0.922 (-0.051-1.895)	35.35	0.461 (-0.030-0.952)	18.76

Abbreviations: NICU, neonatal intensive care unit; CI, confidence interval; SGA, small for gestational age; LGA, large for gestational age; SES, socioeconomic status; WIC, the special supplemental nutrition program for women, infants, and children.

^aConstant term contains contributions of unobservable factors.

Figure 2. Contributions to NICU Admission Growths between 2009 and 2018 by Race/Ethnicity



Abbreviations: NICU, neonatal intensive care unit; Distr., distribution; Coeff., coefficient; SES, socioeconomic status. Note: Infant health risk include gestation age, 5-min Apgar score, plurality, cesarean delivery, small for gestational age, large for gestational age and male sex. Maternal SES includes maternal insurance status, education level and WIC receipt. P values are <0.05 except constants.

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CONCLUSION

Overall NICU admission rates increased by 37% from 2008 to 2018, and the increasing trends were observed among all racial and ethnic groups. There was little difference in overall risk-adjusted NICU admission rates by race/ethnicity. However, birth weight-stratified analyses revealed that racial/ethnic differences diminished in the VLBW and MLBW groups while risk-adjusted NICU admission rates remained higher among black and Hispanic infants in the NHBW group. Increasing NICU admission rates in the NHBW group contributed the most to overall NICU admission rate growth and further study is needed to identify the reasons for this trend and prevent possible overuse of NICU care among this low-risk group.

The contributions of the drivers to the growth of NICU admission rates substantially differed by race/ethnicity. Among white infants, the contribution due to changes in infant health characteristics was negative indicating improvement of infant health status would have reduced the NICU admission rate in 2018 if other conditions had remained the same. The contribution of changes in the NICU bed supply was one of the primary drivers among white and Hispanic infants but not among black infants. The contributions by changes in the effect of maternal socioeconomic characteristics were a primary driver among all racial/ethnic groups.

This study has some limitations. First, even though the birth certificate form defines NICU admissions, differences in coding may have occurred across states and hospitals. A 2012 policy statement by the AAP defines a NICU as a level III and IV facilities, where ongoing assisted ventilation for 24 hours or more is available,⁸ but there is a wide variation among states

in the definition and criteria of a NICU and the accuracy of coding may improve over the years.⁹⁹ However, increasing NICU admission trends were observed also in hospital discharge data¹⁹ and validation studies on the accuracy of birth certificate data report a good agreement on NICU admission between birth certificates compared to hospital medical records.⁵⁶ Second, our study may have underestimated NICU admission rates since birth certificates are required to be filed within 5 days of the date of birth.^{57,100} Third, since the study excluded births recorded not using the 2003 revision of U.S. Standard Certificate of Live Birth, the largest exclusion occurred in earlier years in particular states where the statewide implementation had not been completed during part of the study period. However, we found the population characteristics between two birth cohorts, one recorded with the 1989 version and another with the 2003 version were similar. Additionally, sensitivity analysis limiting to births occurred in states where the 2003 revision had been used throughout the entire study period found consistent trends.

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