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A Population-Based Assessment of Severe Maternal Morbidity Among Non-Hispanic Black Women in the United States

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A POPULATION-BASED ASSESSMENT OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

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HEALTH EDUCATION / PROMOTION

ABSTRACT

Non-Hispanic Black women (Black women) are disproportionately affected by adverse maternal health outcomes as compared to women of other races. Little is known about the distribution of adverse maternal health outcomes among Black women. Using the 2014 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ), a nationally representative sample of hospital discharges in the United States (U.S.) from January 1 through December 31, 2014, we examined severe maternal morbidity (SMM) experienced during delivery hospitalization among Black women. We conducted population-based, cross-sectional studies to examine the distribution of SMM prevalence; assess within-race variability based on sociodemographic, geographic, and clinical characteristics; and identify exposures associated with SMM among Black women in the U.S.

We identified 454,760 discharge records with an indication of inpatient delivery of which 13,100 had an indication of SMM. There were significant differences between women with and without SMM across sociodemographic characteristics, clinical factors, and hospital characteristics. There was also geographic variability, by census region and census division, among those who experienced SMM. Factors associated with experiencing SMM during inpatient delivery included sociodemographic characteristics

(age, primary payer, rurality, median household income for zip code), clinical factors (length of stay, number of chronic conditions, discharge disposition), and hospital characteristics (hospital control/ownership, census region, census division.)

Keywords: surveillance, severe maternal morbidity, disparities, geographic distribution, United States, Black women

DEDICATION

This dissertation is dedicated to my grandmother, Dorothy Louise Jones, who always stressed the importance of education. With a limited formal education, due to racial segregation, my grandmother often told me "Get your lesson" and reminded me that education was one of the few things no one could ever take away. "Get your lesson" guided my educational path.

Grandma, I got my lesson!

TABLE OF CONTENTS

Page

LIST OF TABLES

Table *Page*

PREVALENCE OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

GEOGRAPHIC DISTRIBUTION OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

LIST OF TABLES

Table *Page*

SEVERE MATERNAL MORBIDITY RISK AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

LIST OF FIGURES

Table *Page*

PREVALENCE OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

GEOGRAPHIC DISTRIBUTION OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

INTRODUCTION

Disparities in maternal health-related behaviors and outcomes between Black and White women in the United States (U.S.) are well-documented in the literature. Black women experience pregnancy-related mortality (Tucker et al., 2007), births resulting in pre-term delivery and low birthweight infants (Berg et al., 2001; McGrady et al., 1992; Shiono et al., 1997), and infant mortality (Schoendorf et al., 1992) at higher rates than White women even when controlling for sociodemographic characteristics and risk factors for adverse health outcomes. These disparities have persisted for decades.

A lower proportion of Black women initiate prenatal care in the first trimester and a higher proportion of Black women receive late or no prenatal care during pregnancy as compared to White women (Martin et al., 2018). Black women are 3.4 times more likely to experience pregnancy-related death than White women (Creanga et al., 2017), and racial disparities in maternal adverse birth outcomes persist after controlling for socioeconomic differences (Singh, 2010) and other patient characteristics such as age, body mass index, cigarette use, insurance status, comorbidities and risk factors, and hospital characteristics (Grobman et al., 2015). In 2015, the rates of severe maternal morbidity (SMM) and in-hospital mortality were 112% and 193% higher, respectively, for Black women as compared to White women (Fingar et al., 2018). Among all live births in 2020, 14.4% of births to non-Hispanic Black women and 9.1% of births to non-Hispanic White women occurred before 37 weeks of gestation, resulting in pre-term birth (Centers for Disease Control and Prevention, n.d.).

From 1993 through 2014, the Centers for Disease Control and Prevention (CDC) reported an upward trend in the rate of SMM per 10,000 delivery hospitalizations. The CDC defines SMM as the occurrence of at least one of twenty-one diagnoses or procedures, SMM indicators, which are listed in Appendix 1 with their corresponding International Classification of Diseases, Ninth Revision (ICD-9-CM) codes (Centers for Disease Control and Prevention, n.d.). In the overall population, increased rates per 10,000 delivery hospitalizations were observed in fourteen of the twenty-one SMM indicators (blood transfusions, acute myocardial infarction, aneurysm, acute renal failure, adult respiratory distress syndrome, cardiac arrest, fibrillation/conversion of cardiac rhythm, shock, ventilation, temporary tracheostomy, sepsis, hysterectomy, disseminated intravascular coagulation, and air and thrombotic embolism) (Centers for Disease Control and Prevention, n.d.). Somer et al. reviewed epidemiological literature addressing each SMM indicator and found increased rates for African American women for nineteen of the twenty-one indicators (Somer et al., 2017).

The Agency for Healthcare Research and Quality (AHRQ) examined SMM experienced during delivery hospitalizations from 2005 through 2015 and found non-Hispanic Black women were 110 percent more likely to experience SMM as compared to non-Hispanic White women in the cohort (Fingar et al., 2018). In 2018, the national rate was 76.7 per 10,000 hospital deliveries, excluding blood products transfusion as an SMM indicator. This rate was 111.8 per 10,000 deliveries for Black women and 63.2 for White women (HCUPnet, n.d.).

While maternal health-related racial and ethnic disparities in the U.S. are well-documented in the literature, we found no published studies that examined the

distribution of maternal health-related morbidity and mortality among Black women in the U.S. using a nationally representative sample. For this dissertation we conducted population-based, cross-sectional studies to examine the distribution of SMM prevalence among Black women; explore differences based on clinical and sociodemographic characteristics, including geographic variation; and assess exposure risks associated with SMM using a nationally representative sample of hospital discharges from January 1, 2014 through December 31, 2014. In the first paper, we described the sociodemographic and clinical characteristics of Black women with an inpatient delivery in 2014, and we tested the hypotheses that differences exist between women with and without an indication of SMM based on individual-level sociodemographic and clinical characteristics. In the second paper, we described the geographic distribution of SMM among women in the sample, and we hypothesized geographical variation in SMM prevalence based on census region and census division. In the third paper, we identified variables that associated with experiencing SMM during delivery hospitalization.

PREVALENCE OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

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Format adapted for dissertation

ABSTRACT

Background and Objective: Racial and ethnic disparities in maternal health behaviors and outcomes are well-documented in the literature. In the United States (U.S.), non-Hispanic Black women (Black women) bear a disproportionate burden of adverse maternal health outcomes, and little is known about the distribution of adverse outcomes among Black women. This study aimed to describe the prevalence of severe maternal morbidity (SMM) experienced during the inpatient delivery stay among Black women, using a U.S. population sample, and assess differences based on sociodemographic, clinical, and hospital characteristics between women with and without an indication of SMM.

Methods: The 2014 National Inpatient Sample (NIS), a nationally representative sample of hospital discharges from January 1, 2014 to December 31, 2014, was queried for this descriptive, population-based, cross-sectional study. Discharge records for Black women with an indication of birth delivery were included in the analyses. SMM, coded to a binary variable, was the primary outcome. Independent variables included sociodemographic factors (age, median household income, primary payer, rurality) and clinical characteristics (chronic conditions, comorbidities, discharge disposition, length of stay). Chi-square, Wilcoxon rank sum, and independent t-tests were conducted to compare variables by SMM status.

Results: There were 454,760 weighted discharges for delivering Black women of which 13,100 had an indication of SMM. For the overall sample, the average age was 26.9±6.8 years. The majority of the women had Medicaid (65%); resided in a zip code with a median household income ≤$39,999 (49%); resided in a central county of a metropolitan

area with a population ≥1 million (44%); delivered at a private, non-profit (71%) and urban teaching (75%) hospital; and were discharged to home (98%). The most frequent SMM indicators were blood products transfusion (61.6%), disseminated intravascular coagulation (9.3%), acute renal failure (4.7%), adult respiratory distress syndrome (3.6%), and hysterectomy (3.5%). SMM status is reported with and without blood products transfusion, a common procedure at delivery in the U.S. Women who experienced SMM during inpatient delivery were older (27.7 ± 7.3 years vs 26.9 ± 6.8 years), experienced longer hospital stays (4 days (interquartile range, 3-5) vs 3 days (interquartile range, 2-3)) and had more chronic conditions (2 (interquartile range, 1-3) vs 0 (interquartile range, 0-1)) as compared to women who did not experience SMM. The groups also significantly differed by median household income ($p=0.011$), patient location as an indicator of rurality ($p<0.001$), primary payer ($p<0.001$), discharge disposition ($p<0.001$), hospital ownership ($p=0.026$), and hospital location/teaching status ($p=0.043$). When blood products transfusion was excluded as an SMM indicator (n=3,530), the statistically significant differences between the groups remained, with the exception of hospital ownership ($p=0.149$).

Conclusion: National data show statistically significant differences in sociodemographic, clinical, and hospital characteristics between Black women who did and did not experience SMM during inpatient delivery. Further analyses could be conducted to determine if the differences are due to the effects of a large sample size.

INTRODUCTION

Severe maternal morbidity (SMM) prevalence continues to rise in the United States (U.S.). (Callaghan et al., 2012; Centers for Disease Control and Prevention, n.d.; Kuklina et al., 2009; Luke et al., 2021). The rate of SMM during delivery hospitalization increased from 49.5 per 10,000 deliveries in 1993 to 144 per 10,000 in 2014 (Centers for Disease Control and Prevention, n.d.). Variability in the rate of SMM during in-hospital delivery is observed at multiple levels of socioecological influence. For Black women, the SMM rate per 10,000 deliveries in 2015 was 241 compared to 114 for White women (Fingar, et al., 2018). Patients with Medicaid or Medicare as the primary payer experience SMM at a higher rate (88 per 10,000 deliveries) compared to those with private insurance (67 per 10,000 deliveries). Patients delivering at publicly owned hospitals experience SMM at a higher rate (96 per 10,000 deliveries) compared to those who deliver at privately owned hospitals (74 per 10,000 deliveries). And patients residing in zip codes with a median income in the lowest quartile experience SMM at a higher rate (87 per 10,000 deliveries) compared to those in the highest quartile (71 per 10,000 deliveries) (Agency for Healthcare Research and Quality, n.d.).

While disparities in SMM prevalence are addressed in the literature, studies on racial and ethnic disparities primarily focus on between-race differences. Using aggregated data from 2012 through 2015, Admon et al. examined SMM incidence and found the SMM rate per 10,000 delivery hospitalizations for non-Hispanic Black women almost twice the rate for non-Hispanic White women (Admon et al., 2018). This disparity persisted through 2017 (Luke et al., 2021). Howell et al. demonstrated the racial disparity in SMM rates between Black and White women persisted after controlling

for patient characteristics, hospital characteristics, and site of care (Howell et al., 2016). These racial disparities are observed across stages of pregnancy with Black women experiencing a higher proportion of SMM during the antepartum, intrapartum, and postpartum periods as compared to White women (Liese et al., 2019).

Little is known about within-race differences in SMM prevalence among Black women, a group that is disproportionately affected by SMM. However, studies examining variability within a Black or African American population have been used to identify subpopulations for targeted and culturally relevant interventions (Chandler et al., 2020; Consedine et al., 2004; Forney-Gorman and Kozhimannil, 2016; Odedina et al., 2011; Quinn et al., 2017). This study provides new insight into within-race disparities in SMM by describing the distribution of SMM prevalence and examining variability among Black women using a nationally representative sample. We hypothesized differences in sociodemographic characteristics (age, median household income, primary payer, rurality), clinical factors (chronic conditions, comorbidities, length of stay, discharge disposition), and hospital characteristics (hospital control/ownership, hospital location/teaching status) between Black women who did and did not experience SMM during delivery hospitalization.

METHODS

Study Design and Data Source

For this population-based, descriptive, cross-sectional study, we queried the 2014 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ), a nationally representative sample of hospital discharges in the US from January 1, 2014 through December 31, 2014, containing demographic, clinical, and administrative data for approximately 7 million unweighted and 35 million weighted hospital discharges covering approximately 96% of the US population (HCUP National Inpatient Sample, n.d.). The 2014 NIS dataset is the last annual dataset that reports clinical diagnoses and procedures solely using the International Classification of Diseases, Ninth Revision (ICD-9), and the algorithm used to identify in-hospital deliveries within the discharge records uses a validated list of ICD-9 and diagnosis-related group (DRG) codes (Kuklina et al., 2008).

NIS datasets include sampling weights for data analyses to allow generalization to the overall population, and we used weighted data to ensure our findings are more representative of what is occurring in the population (Korn & Graubard, 1995). These data have been used to provide population estimates for the distribution of maternal morbidity and adverse maternal outcomes (Admon et al., 2018; Callaghan et al., 2012; Kuklina et al., 2009; Liese et al., 2019; Shen et al., 2005).

Inclusion Criteria

Records with discharge dates from January 1, 2014 to December 31, 2014 for Black women with an indication of birth delivery were included. Inpatient deliveries were identified using a published composite of ICD-9 and DRG codes that was validated utilizing NIS data (Kuklina et al., 2008).

Outcome Variable

The primary outcome was SMM, a binary composite variable, defined as the presence or absence of at least one of twenty-one CDC-defined SMM indicators consisting of diagnoses (acute myocardial infarction; aneurysm; acute renal failure; adult respiratory distress syndrome; amniotic fluid embolism; cardiac arrest, ventricular fibrillation, ventricular flutter; disseminated intravascular coagulation; eclampsia; heart failure, arrest during surgery or procedure; puerperal cerebrovascular disorders; pulmonary edema, acute heart failure; severe anesthesia complications; sepsis; shock; sickle cell disease with crisis; air and thrombotic embolism) and procedures (conversion of cardiac rhythm, blood products transfusion, hysterectomy, temporary tracheostomy, ventilation) (Centers for Disease Control and Prevention, n.d.).

Accounting for most SMM cases, the rate of blood product transfusions per 10,000 delivery hospitalizations increased almost 400% from 1993 to 2014. In 2014, the SMM rates per 10,000 delivery hospitalizations with and without blood transfusions were 144 and 35 respectively. (Centers for Disease Control and Prevention, n.d.). To account for the impact of blood transfusions on the overall rate of SMM, we report SMM with and without blood products transfusion as an indicator.

Statistical Methods

Univariate analyses were conducted for all continuous and categorical variables to describe the sample. Mean (standard deviation) or median (interquartile range) was reported for continuous variables; frequency (proportion) was reported for categorical variables. Missing data were reported. Chi-square, Wilcoxon rank sum tests, and independent t-tests were conducted to compare variables by SMM status. Reported p-values were 2-tailed with statistical significance set at $p<0.05$. All analyses were conducted using Survey version 4.1-1, Jtools version 2.1.4, and R version 4.0.3 software (R Project for Statistical Computing, Vienna, Austria).

Use of Human Subjects

The University of Alabama at Birmingham (UAB) Institutional Review Board for Human Use (IRB) deemed this research study non-human subject research.

RESULTS

Sample

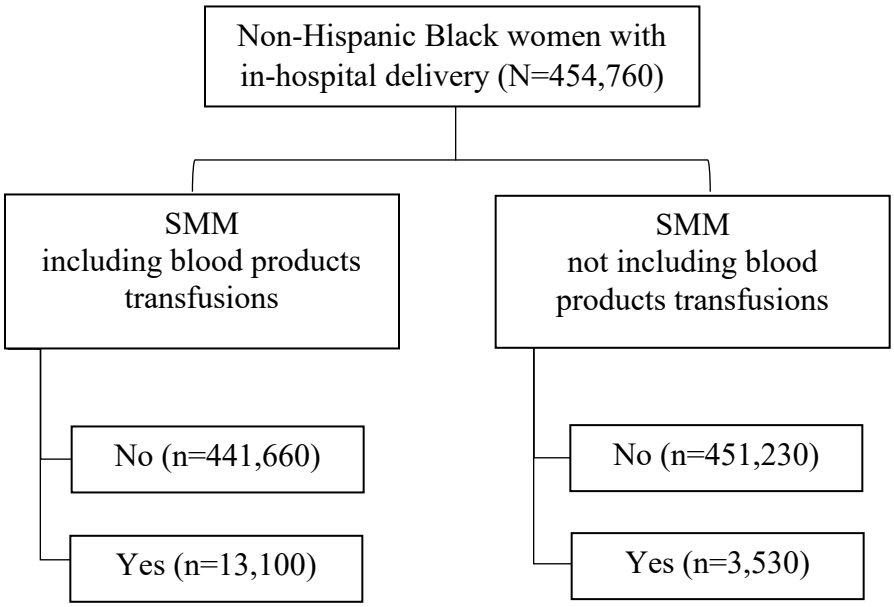
The 2014 NIS dataset contained 90,952 unweighted (N=454,760 weighted) discharge records for Black women with an indication of inpatient delivery (Table 1). The mean age was 26.9 ± 6.8 years, and most women were discharged to home (97.5%). Medicaid was the most frequent primary payer (64.6%), and 49.2% of the women resided in a zip code with a median household income ≤$39,999. Approximately, 44% of the women resided in a central county of a metropolitan area with a population ≥1 million.

The average length of stay for all delivery hospitalizations in the sample was 3 days (IQR, 3-2) with most women delivering at private nonprofit (70.9%) and urban teaching (75.1%) hospitals. The five most reported comorbidities were chronic blood loss anemia (20.1%), deficiency anemias (15.7%), obesity (11.4%), chronic pulmonary disease (6.7%), and hypertension (4.8%) (Table 2).

Severe Maternal Morbidity Prevalence

Of the total records in the analytic cohort, 13,100 contained at least one of the 21 CDC-defined SMM indicators (Figure 1). Blood products transfusion was the most common SMM indicator, appearing on 61.6% of the records (Table 3). When blood products transfusion was excluded from the SMM composite variable, the number of SMM cases decreased to 3,530.

Figure 1. Analytic cohort (N=454,760)



Descriptive Data

Severe Maternal Morbidity: Including Blood Products Transfusion

The most frequently occurring SMM indicators were blood products transfusion (61.6%), disseminated intravascular coagulation (9.3%), acute renal failure (4.7%), adult respiratory distress syndrome (3.6%), and hysterectomy (3.5%) (Table 3). The five most frequently occurring comorbidities were chronic blood loss anemia (64.4%), deficiency anemias (35.6%), coagulopathy (16.6%), obesity (14.2%), and hypertension (11.2%) (Table 2).

Women with SMM were older (27.7 years ± 7.3 vs 26.9 years ± 6.8, $p<0.001$), had more chronic conditions (2 (IQR, 3-1) vs 0 (IQR, 1-0), $p<0.001$), and experienced longer lengths of stay (4 days (IQR 5-3) vs 3 days (IQR 3-2), $p<0.001$) compared to women who did not experience SMM during delivery hospitalization. There were significant differences between the groups by expected payer ($p<0.001$), rurality of

patient location (p<0.001), median household income for patient's zip code (p=0.011) discharge disposition (p<0.001), hospital ownership (p=0.026), and hospital location/teaching status (p=0.043) (Table 4).

Severe Maternal Morbidity: Not Including Blood Products Transfusion

When blood products transfusion was excluded from the SMM composite variable, the most frequently occurring SMM indicators were disseminated intravascular coagulation (24.2%), acute renal failure (12.3%), adult respiratory distress syndrome (9.4%), hysterectomy (9.2%), and eclampsia (8.4%) (Table 3). Significant differences in sociodemographic and clinical characteristics remained between the two groups. Women with SMM were older (28.2 years ± 7.6 vs 26.9 years ± 6.8, p <0.001), had a history of more chronic conditions (2 (IQR, 3-1) vs 0 (IQR, 1-0), p<0.001), and had longer lengths of stay (4 days (IQR, 6-3) vs 3 days (IQR, 3-2), p<0.001 (Table 5). The groups also differed by primary payer (p<0.001), rurality of patient location (p=0.042), median household income for patient's zip code (p=0.043), discharge disposition (p<0.001), and hospital location/teaching status (p<0.001). There was no significant difference based on hospital ownership (p=0.149).

DISCUSSION

Racial and ethnic disparities in SMM prevalence persist in the U.S. (AHRQ, n.d.), and Black women experience higher rates of SMM as compared to White women. The rate of SMM during in-hospital delivery in our analytic cohort was 288 per 10,000 deliveries, including blood products transfusion as an SMM indicator, and 78 per 10,000 deliveries, excluding blood product transfusion. The national rates, in 2014, with and without blood product transfusion were 144 per 10,000 and 35 per 10,000, respectively (Centers for Disease Control and Prevention, n.d.).

As hypothesized, there were significant differences in sociodemographic characteristics (age, primary payer, rurality, median household income), clinical factors (length of stay, number of chronic conditions, discharge disposition), and hospital characteristics (hospital control/ownership, hospital location/teaching status) between those with and without SMM during delivery hospitalization. Differences were observed for all variables of interest, except for hospital ownership which did not differ when blood products transfusion was excluded from the SMM composite variable. However, due to the large sample size, these significant findings should be interpreted with caution.

This study has some limitations. First, the NIS, an administrative dataset, relies on accurate ICD-9-CM coding to identify SMM cases, chronic conditions, and comorbidities in the discharge records. Inaccurate coding of events during hospital stays affects the size of the analytic cohort and the distribution of SMM across sociodemographic, clinical, and hospital characteristics. Second, for null hypothesis significance testing, the reported p-value is an indicator of statistical significance. The chance of finding a significant p-value increases with a larger sample size (Khalilzadeh &

Tasci, 2017). We should repeat the analyses with a smaller, random sample from the larger sample.

Table 1. Characteristics of non-Hispanic Black women in the United States with a hospital discharge for inpatient delivery, 2014 (N=454,760)

Age (years), mean ± SD	26.9±6.8	
Length of Stay (days), median (IQR)	3 (3-2)	
Number of Chronic Conditions, median (IQR)	0 (1-0)	
	n	%
Primary Payer		
Medicare	6,005	1.32
Medicaid	294,025	64.65
Private Insurance	134,735	29.63
Self-Pay	9,730	2.14
No Charge	370	0.08
Other (including other government programs)	9,140	2.01
Missing	755	0.17
Patient Location (rurality)		
Central county of metro area of ≥1M population	198,620	43.68
Fringe county of metro area of ≥1M population	108,615	23.88
County in metro area of 250,000-999,999 population	81,570	17.94
County in metro area of 50,000-249,999 population	33,305	7.32
Micropolitan county	18,835	4.14
Not metropolitan or micropolitan county	13,015	2.86
Missing	800	0.18
Median Household Income		
≤ $39,999	223,745	49.20
$40,000-$50,999	106,685	23.46
$51,000-$65,999	71,990	15.83
≥$66,000	44,820	9.86
Missing	7,520	1.65
Discharge Disposition		
Routine	443,530	97.53
Transfer to short-term hospital	290	0.06
Transfer other	345	0.08
Home health care	9,790	2.15
Against medical advice	715	0.16
Died in hospital	45	0.01
Missing	45	0.01

Delivering Hospital Control/Ownership		
Government, nonfederal	63,685	14.00
Private, non-profit	322,245	70.86
Private, investor-owned	68,830	15.14
Missing	0	0.00
Delivering Hospital Location/Teaching Status		
Rural	22,450	4.94
Urban nonteaching	90,755	19.96
Urban Teaching	341,555	75.11
Missing	0	0.00

Table 2. Comorbidities among delivering non-Hispanic Black women in the United States, 2014

	SMM (n=13,100)		No SMM (n=441,660)		Total (N=454,760)	
	%	Rank	%	Rank	%	Rank
Chronic Blood Loss Anemia	64.4	1	18.8	1	20.1	1
Deficiency Anemias	35.6	2	15.1	2	15.7	2
Coagulopathy	16.6	3	1.7	8	2.2	7
Obesity	14.2	4	11.3	3	11.4	3
Hypertension	11.2	5	4.6	5	4.8	5
Chronic Pulmonary Disease	10.2	6	6.6	4	6.7	4
Fluid and Electrolyte Disorders	9.5	7	-	-	-	-
Drug Abuse	4.1	8	3.0	6	3.0	6
Depression	3.7	9	1.9	7	2.0	8
Diabetes, Uncomplicated	2.8	10	1.4	9	1.4	9
Psychoses	-	-	1.3	10	1.3	10

Note: SMM=Severe Maternal Morbidity

Table 3. Severe maternal morbidity indicators among delivering non-Hispanic Black women in the United States, 2014

	With BPT (n=18,220) %	Without BPT (n=6,995) %
Diagnoses		
Disseminated intravascular coagulation	9.28	24.16
Acute renal failure	4.72	12.29
Adult respiratory distress syndrome	3.62	9.44
Eclampsia	3.24	8.43
Sepsis	3.05	7.93
Pulmonary edema/acute heart failure	2.61	6.79
shock	1.78	4.65
Sickle cell disease with crisis	1.65	4.29
Puerperal cerebrovascular disorders	1.10	2.86
Air and thrombotic embolism	0.71	1.86
Heart failure/arrest during surgery or procedure	0.49	1.29
Severe anesthesia complications	0.44	1.14
Cardiac arrest/ventricular fibrillation/ventricular flutter	0.33	0.86
Acute myocardial infarction	0.11	0.29
Amniotic fluid embolism	0.08	0.21
Procedures		
Blood products transfusion	61.61	-
Hysterectomy	3.54	9.22
Ventilation	1.10	2.86
Conversion of cardiac rhythm	0.44	1.14
Temporary tracheostomy	0.11	0.29

Note: BPT=Blood Products Transfusion

Table 4. Characteristics of delivering non-Hispanic Black Women in the United States by severe maternal morbidity status, 2014 (N=454,760)

	No SMM (n=441,660)		SMM (n=13,100)		p-value
Age (years), mean±SD	26.9±6.8		27.7±7.3		<0.001
Length of Stay (days), median (IQR)	3 (2 ,3)		4 (3, 5)		<0.001
Number of Chronic Conditions, median (IQR)	0 (0, 1)		2 (1, 3)		<0.001
	n	%	n	%	
Primary Payer					<0.001
Medicare	5,555	1.26	450	3.44	
Medicaid	285,405	64.62	8,620	65.80	
Private Insurance	131,260	29.72	3,475	26.53	
Self-Pay	9,410	2.13	320	2.44	
No Charge	360	0.08	10	0.08	
Other (including other government programs)	8,940	2.02	200	1.53	
Missing	730	0.17	25	0.19	
Patient Location (rurality)					<0.001
Central county of metro area of ≥1M population	192,305	43.54	6,315	48.21	
Fringe county of metro area of ≥1M population	105,525	23.89	3,090	23.59	
County in metro area of 250,000-999,999 population	79,765	18.06	1,805	13.78	
County in metro area of 50,000-249,999 population	32,350	7.32	955	7.29	
Micropolitan county	18,230	4.13	605	4.62	
Not metropolitan or micropolitan county	12,700	2.88	315	2.40	
Missing	785	0.18	15	0.11	

Median Household Income					
≤ $39,999	217,035	49.14	6,710	51.22	0.011
$40,000-$50,999	103,785	23.50	2,900	22.14	
$51,000-$65,999	70,090	15.87	1,900	14.50	
≥$66,000	43,515	9.85	1,305	9.96	
Missing	7,235	1.64	285	2.18	
Discharge Disposition					<0.001
Routine	431,240	97.64	12,290	93.82	
Transfer to short-term hospital	230	0.05	60	0.46	
Transfer other	295	0.07	50	0.38	
Home health care	9,210	2.09	580	4.43	
Against medical advice	635	0.14	80	0.61	
Died in hospital	5	0.001	40	0.31	
Missing	45	0.01	0	0.00	
Hospital Control/Ownership					0.026
Government, nonfederal	61,475	13.92	2,210	16.87	
Private, non-profit	313,150	70.90	9,095	69.43	
Private, investor-owned	67,035	15.18	1,795	13.70	
Hospital Location/Teaching Status					0.043
Rural	21,845	4.95	605	4.62	
Urban nonteaching	88,445	20.03	2,310	17.63	
Urban teaching	331,370	75.03	10,185	77.75	

Table 5. Characteristics of delivering non-Hispanic Black Women in the United States by severe maternal morbidity status, excluding blood products transfusion, 2014 (N=454,760)

	No SMM (n=451,230)		SMM (n=3,530)		p-value
Age (years), mean±SD	26.9±6.8		28.2±7.6		<0.001
Length of Stay (days), median (IQR)	3 (2 ,3)		4 (3, 6)		<0.001
Number of Chronic Conditions, median (IQR)	0 (0, 1)		2 (1, 3)		<0.001
	n	%	n	%	
Primary Payer					<0.001
Medicare	5,825	1.29	180	5.10	
Medicaid	291,725	64.65	2,300	65.16	
Private Insurance	133,805	29.65	930	26.35	
Self-Pay	9,685	2.15	45	1.27	
No Charge	365	0.08	5	0.14	
Other (including other government programs)	9,085	2.01	55	1.56	
Missing	740	0.16	15	0.42	
Patient Location (rurality)					0.042
Central county of metro area of ≥1M population	196,950	43.65	1,670	47.31	
Fringe county of metro area of ≥1M population	107,830	23.90	785	22.24	
County in metro area of 250,000-999,999 population	80,975	17.95	595	16.86	
County in metro area of 50,000-249,999 population	33,000	7.31	305	8.64	
Micropolitan county	18,750	4.16	85	2.41	
Not metropolitan or micropolitan county	12,930	2.87	85	2.41	
Missing	795	0.18	5	0.14	

Median Household Income					0.043
≤ $39,999	221,895	49.18	1,850	52.41	
$40,000-$50,999	105,930	23.48	755	21.39	
$51,000-$65,999	71,460	15.84	530	15.01	
≥$66,000	44,485	9.86	335	9.49	
Missing	7,460	1.65	60	1.70	
Discharge Disposition					
Routine	440,250	97.57	3,280	92.92	<0.001
Transfer to short-term hospital	270	0.06	20	0.57	
Transfer other	330	0.07	15	0.42	
Home health care	9,615	2.13	175	4.96	
Against medical advice	690	0.15	25	0.71	
Died in hospital	30	0.01	15	0.42	
Missing	45	0.01	0	0.00	
Hospital Control/Ownership					0.149
Government, nonfederal	63,115	13.99	570	16.15	
Private, non-profit	319,745	70.86	2,500	70.82	
Private, investor-owned	68,370	15.15	460	13.03	
Hospital Location/Teaching Status					<0.001
Rural	22,380	4.96	70	1.98	
Urban nonteaching	90,215	19.99	540	15.30	
Urban teaching	338,635	75.05	2,920	82.72	

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GEOGRAPHIC DISTRIBUTION OF SEVERE MATERNAL MORBIDITY AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

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ABSTRACT

Background and Objective: In the United States (U.S.), geographic variability is observed in healthcare resources, including the distribution of healthcare professionals, healthcare spending, and disease rates. This study aimed to describe the geographic distribution of the prevalence of severe maternal morbidity (SMM) experienced during inpatient delivery among non-Hispanic Black women (Black women), using a U.S. population sample, and assess differences based on U.S. census regions and divisions by SMM status.

Methods: A descriptive, population-based, cross-sectional study was conducted utilizing the 2014 National Inpatient Sample (NIS), a nationally representative sample of hospital discharges from January 1 - December 31, 2014. The analyses included all discharge records for Black women who delivered during the inpatient stay. SMM was the primary outcome variable. The independent variables, U.S. census region (Northeast, Midwest, South, West) and U.S. census division (New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific), represented the geographic characteristics of the delivering hospitals. Frequencies and percentages were calculated to describe the variables, and chi-square tests were conducted to compare variables by SMM status.

Results: The 2014 NIS contained 454,760 weighted discharges for Black women with an indication of inpatient delivery. There were 13,100 SMM cases, including blood products transfusion, and 3,530 SMM cases not including blood products transfusion. Of the total deliveries, the proportion of SMM cases by region ranged from 2.5%-3.8% and 0.7%-1.0% with and without blood products transfusion respectively. The proportion of

SMM cases by division ranged from 2.1%-4.0% and 0.6%-1.0% with and without blood transfusions products respectively. Variability in SMM rates were observed by census region (p=0.008 and p=0.005, with and without blood products transfusion respectively) and division (p=0.030 and p=0.027, with and without blood products transfusion respectively). The Northeast region and the Middle Atlantic Division had statistically higher SMM rates with and without blood products transfusion.

Conclusion: National data show geographic variability in SMM prevalence among Black women.

INTRODUCTION

Geographic variation in healthcare resources and morbidity and mortality rates across medical conditions in the United States (U.S.) is well-documented in the literature. Health outcomes can be viewed as a function of the interaction of race, sociodemographic characteristics, and place or geographic location (Adler & Rehkopf, 2008). Thus, it can be difficult to tease out the factor driving the disparity. Baicker et al. posit that because racial health disparities can be hard to measure, researchers should instead focus on geographic variation in quality of health care. Improving overall quality of care will in turn decrease population-based health disparities (Baicker et al., 2005). Research conducted by Horev et al. focused on the geographic variation of healthcare resources in the U.S. and found significant differences in the distribution of physicians, hospital beds, and health care quality indicators – all of which influence health outcomes (Horev et al., 2004).

Geographic variations or trends across diverse medical conditions and populations are also found in the literature. Wang and Beydoun examined geographic and urban/rural differences in obesity prevalence in the U.S. using a population-based sample (Wang & Beydon, 2007). Forte et al. and Skinner et al. used Medicare administrative claims data to examine geographic variability in hip fracture and knee arthroplasty treatments (Forte et al., 2008; Skinner et al., 2003). Voeks et al. assessed geographic variability in diabetes prevalence in a population-based cohort (Voeks et al., 2008).

Specific to the scope of this research inquiry, the effect of neighborhood-level characteristics, or geographic variations, on maternal health and outcomes is also addressed in the literature. Nidley et al. found an association between geographic rurality

and perinatal depression risk (Nidley, et al., 2020). Shannon et al. found an association between local violent crime and perceived stress during pregnancy (Shannon et al., 2020). Researchers also found an association between adverse birth outcomes and neighborhood-level factors such as area racism, racial segregation, and poverty (Kane et al., 2017; Suplee et al., 2018; Chae et al., 2018), and residential segregation was found to result in a higher risk of pre-term birth for Black women with no adverse effect on White women (Mehra et al., 2017). In addition to the association with pre-term birth, Janevic et al., Ma et al, and Ncube et al. also found an association between neighborhood disadvantage and low birthweight (Janevic et al., 2010; Ma et al., 2015; Ncube et al., 2016).

This study aimed to describe the geographic distribution of severe maternal morbidity (SMM) prevalence among non-Hispanic Black women (Black women) in the U.S. using a nationally representative sample of hospital discharges. Given geographic variation in factors associated with birth outcomes, such as public health funding, hospital quality, and access to prenatal care, (Holcomb et al., 2021; Howell et al., 2016; Mays & Smith, 2009; Yin, 2019) we hypothesized geographic variation, or differences, in SMM prevalence by U.S. census regions and divisions.

METHODS

Study Design

A population-based, cross-sectional study was conducted utilizing a nationally representative sample of U.S. hospital discharges from January 1 – December 31, 2014. The institutional review board of the University of Alabama at Birmingham deemed this study non-human subject research.

Study Participants

Discharge records were included for Black women with an indication of in-hospital birth delivery. Deliveries were identified on discharge records using the algorithm developed by Kuklina et al. which consists of International Classification of Diseases, Ninth Revision (ICD-9) and diagnosis-related group (DRG) procedure codes for delivery, vaginal delivery, and cesarean section (Kuklina et al., 2008).

Data Source

The 2014 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ), a nationally representative sample of inpatient hospital stays was queried. The 2014 NIS includes data from approximately 4,400 hospitals, representing approximately 7 million unweighted and 35 million weighted discharges covering about 96% of the U.S. population (HCUP, n.d.). Data are geographically stratified by U.S. census division, geographic areas of U.S. census regions (Figure 1; Figure 2; Table 1).

A major limitation of this study is the reliance upon secondary data as the accurate identification of deliveries and the reporting of SMM prevalence depends on the accurate coding of medical events on the health record.

Variables

Severe Maternal Morbidity (SMM) was the primary outcome variable. SMM, a composite, binary variable, indicated the presence of at least one CDC-defined SMM indicators (acute myocardial infarction; aneurysm; acute renal failure; adult respiratory distress syndrome; amniotic fluid embolism; cardiac arrest, ventricular fibrillation, ventricular flutter; disseminated intravascular coagulation; eclampsia; heart failure, arrest during surgery or procedure; puerperal cerebrovascular disorders; pulmonary edema, acute heart failure; severe anesthesia complications; sepsis; shock; sickle cell disease with crisis; air and thrombotic embolism; conversion of cardiac rhythm; blood products transfusion; hysterectomy; temporary tracheostomy; ventilation) on the discharge record (Centers for Disease Control and Prevention, n.d.). As frequently reported in the literature, SMM is reported both including and excluding blood products transfusion, a frequently occurring procedure during delivery. The independent variables describe geographic characteristics, census region and census division, of the delivery hospitals.

Statistical Methods

Univariate analyses were conducted to describe the geographic distribution of the inpatient deliveries for the sample. Frequency (percentage) was reported by U.S. census region and division. The geographic distribution of SMM, including and excluding blood

products transfusion as an SMM indicator, was described by U.S. census region and division. Frequency (percentage) was reported for the categorical variables. Chi-square tests were conducted to assess between-group differences by SMM status based on census region and division. Statistical significance was set at $p<0.05$. Analyses were conducted utilizing Survey Version 4.1-1, Jtools version 2.1.4, and R version 4.0.3 software (R Project for Statistical Computing, Vienna, Austria).

RESULTS

In the 2014 NIS dataset, 454,760 discharge records were identified for non-Hispanic Black women with an indication of inpatient delivery. The majority of the discharge records were from delivering hospitals in the South region (58%) of the U.S. with the South Atlantic division (36.9%) comprising most of the records (Table 2). The West region had the least number of records (9.1%) in the sample. Table 2 describes the geographic distribution of the discharge records with an indication of SMM with (n=13,100) and without (n=3,530) blood products transfusion (BPT) as an SMM indicator. The South region was the only region with slightly more SMM with BPT (53.7%) than without BPT (49.7%). This trend is also noted in the East South Central (5.9% compared to 5.0%) and South Atlantic divisions (34.0% compared to 30.7%) but not in the West South Central division of the South region. All the other regions had more SMM cases without BPT; however, when examining the division level there were several divisions with more SMM cases with BPT than without BPT: West North Central division of the Midwest region (2.8% compared to 2.4%) and the Middle Atlantic division of the Northeast region (18.2 compared to 17.8%).

SMM cases, with and without BPT, differed significantly by Census region (p=.008 and p=0.005 respectively) (Table 3). The proportion of SMM cases of the total deliveries by region, with and without BPT, ranged from 2.5%-3.8% and 0.7%-1.0% respectively with the Northeast region having the highest proportion of SMM cases with BPT (3.8%) and of No BPT (1.0%). The lowest proportion of SMM cases was observed in the West region (2.5%) when including BPT and in the South region (0.7%) when BPT was not included as an SMM indicator.

Variability in the proportion of SMM cases is also observed among the divisions (Table 4). The proportion of SMM cases of the total deliveries by division, with and

without BPT ranged from 2.1%-4.0% and 0.6%-1.0% respectively and was statistically significant (p=0.030 and p=0.027 respectively.) The Middle Atlantic division of the Northeast region had the highest proportion of SMM cases with BPT (4.0%) and without BPT (1.0%). The Mountain division of the West region had the lowest proportion of SMM with BPT (2.1%) while the West North Central division of the Midwest and the South Atlantic along with the East South Central divisions of the South region had the lowest proportion of SMM without BPT (0.6%).

DISCUSSION

The prevalence of severe maternal morbidity experienced during inpatient delivery among Black women in the U.S. was found to vary geographically by census region and census division. The majority (58.0%) of the sample represented births at delivering hospitals in the South region. Correspondingly, the majority of the SMM cases in the sample occurred in the South, 53.7% and 49.7%, with and without blood products transfusion as an SMM indicator respectively. When examined as a proportion of the deliveries in the region, however, the Northeast region had the highest proportion of SMM cases, 3.8% and 1.0% with and without blood products transfusion as an SMM indicator respectively.

Literature addressing the national geographic distribution of SMM among Black women is lacking. Recent literature addresses geographic variation in SMM rates in the U.S. using national data but does not examine within-race variation. Using NIS data, Kozhimannil et al. found geographic variation in SMM distribution based on urban and rural differences (Kozhimannil, 2019). Chen et al. also used NIS data and found geographic variation in SMM experienced during inpatient delivery and during the postpartum period after delivery discharge based on census region (Chen et al., 2021).

To further elucidate the geographic variation in SMM prevalence among Black women, geographic variation in the sociodemographic and clinical characteristics of the sample could be explored. These findings could be used to inform policy-level interventions aimed at decreasing overall racial health disparities in this area.

Figure 1. U.S. Census Regions

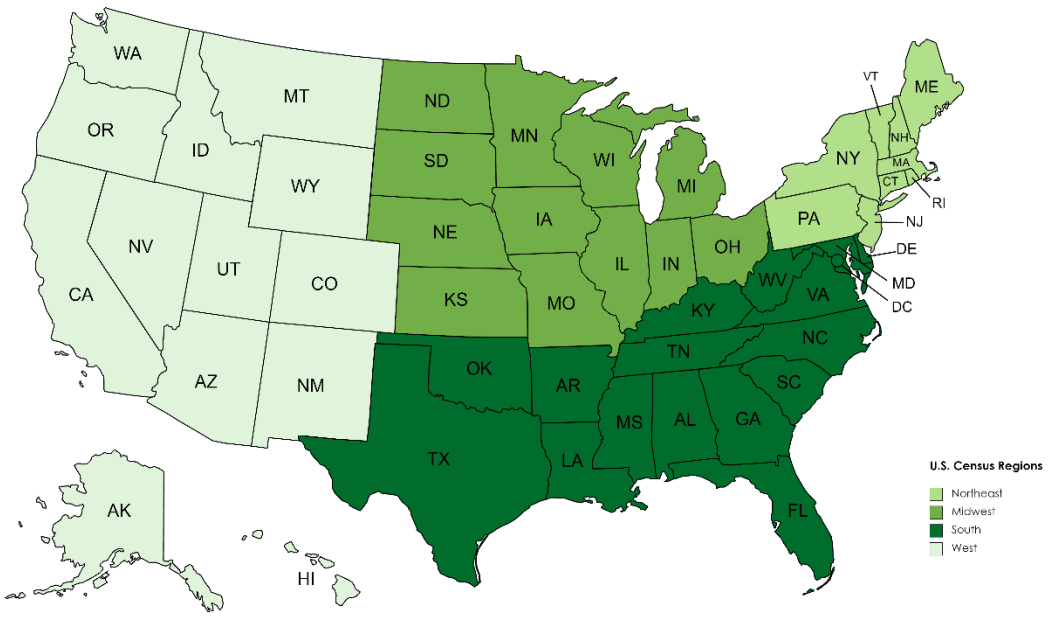

Figure 2. U.S. Census Divisions

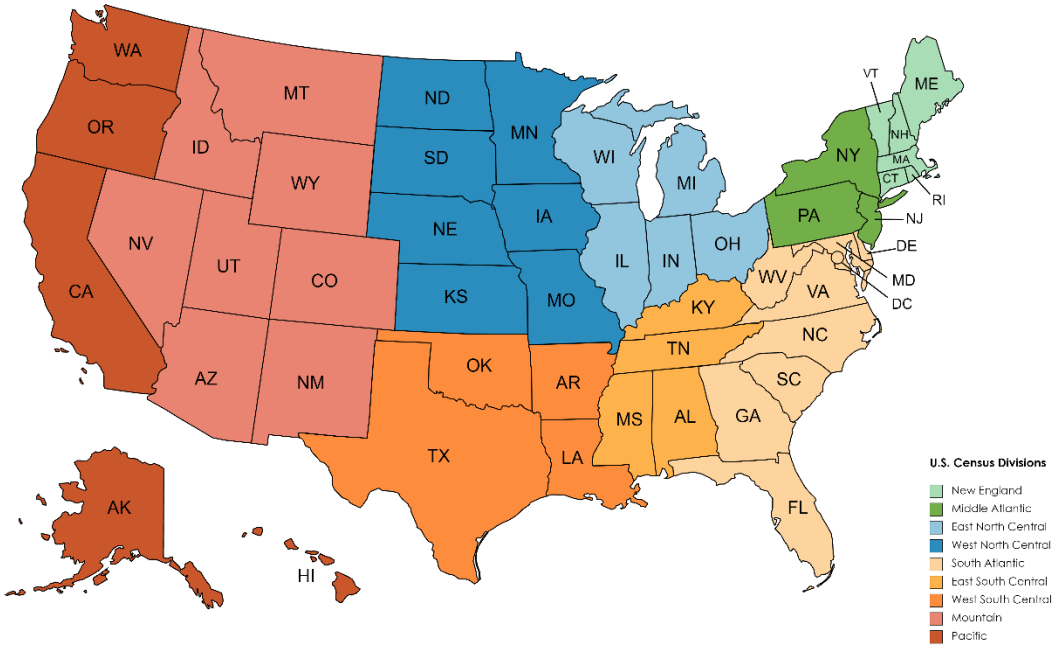

Table 1. 2014 National Inpatient Sample by U.S. Census Region and Division

Census Region	Census Division	Unweighted Discharges (n=7,071,762) n	%	Weighted Discharges (n=35,358,818) n	%
Northeast	New England	325,338	4.60%	1,626,694	4.60%
	Middle Atlantic	999,401	14.13%	4,997,003	14.13%
		1,324,739	18.73%	6,623,697	18.73%
Midwest	East North Central	1,098,380	15.53%	5,491,899	15.53%
	West North Central	490,204	6.93%	2,451,014	6.93%
		1,588,584	22.46%	7,942,913	22.46%
South	South Atlantic	1,442,211	20.39%	7,211,065	20.39%
	East South Central	484,683	6.85%	2,423,423	6.85%
	West South Central	827,952	11.71%	4,139,760	11.71%
		2,754,846	38.96%	13,774,248	38.96%
West	Mountain	437,135	6.18%	2,185,671	6.18%
	Pacific	966,458	13.67%	4,832,289	13.67%
		1,403,593	19.85%	7,017,960	19.85%

Table 2. Geographic Distribution of Severe Maternal Morbidity Among non-Hispanic Black Women by U.S., 2014

	Study Population		SMM including BPT		SMM not including BPT	
	N=454,760	%	n=13,100	%	n=3,530	%
Region: Midwest	**79,420**	**17.5%**	**2,385**	**18.2%**	**690**	**19.5%**
Division: East North Central	65,780	14.5%	2,020	15.4%	605	17.1%
Division: West North Central	13,640	3.0%	365	2.8%	85	2.4%
Region: Northeast	**70,030**	**15.4%**	**2,630**	**20.1%**	**720**	**20.4%**
Division: Middle Atlantic	60,325	13.3%	2,390	18.2%	630	17.8%
Division: New England	9,705	2.1%	240	1.8%	90	2.5%
Region: South	**263,730**	**58.0%**	**7,030**	**53.7%**	**1,755**	**49.7%**
Division: East South Central	30,805	6.8%	775	5.9%	175	5.0%
Division: South Atlantic	167,780	36.9%	4,450	34.0%	1,085	30.7%
Division: West South Central	65,145	14.3%	1,805	13.8%	495	14.0%
Region: West	**41,580**	**9.1%**	**1,055**	**8.1%**	**365**	**10.3%**
Division: Mountain	10,530	2.3%	220	1.7%	75	2.1%
Division: Pacific	31,050	6.8%	835	6.4%	290	8.2%

BPT=Blood Products Transfusion

Table 3. Comparing the Geographic Distribution of Severe Maternal Morbidity Among non-Hispanic Black Women by U.S. Census Region, 2014

	Including Blood Products Transfusion					Not Including Blood Products Transfusion				
	SMM (n=13,100)		No SMM (n=441,660)			SMM (n=3,530)		No SMM (n=451,230)		
	n	%	n	%	p-value	n	%	n	%	p-value
Census Region					0.008					0.005
Midwest	2,385	3.0%	77,035	97.0%		690	0.9%	78,730	99.1%	
Northeast	2,630	3.8%	67,400	96.2%		720	1.0%	69,310	99.0%	
South	7,030	2.7%	256,700	97.3%		1,755	0.7%	261,975	99.3%	
West	1,055	2.5%	40,525	97.5%		365	0.9%	41,215	99.1%	

Table 4. Comparing the Geographic Distribution of Severe Maternal Morbidity Among non-Hispanic Black Women by U.S. Census Division, 2014

	Including Blood Products Transfusion					Not Including Blood Products Transfusion				
	SMM (n=13,100)		No SMM (n=441,660)			SMM (n=3,530)		No SMM (n=451,230)		
	n	%	n	%	p-value	n	%	n	%	p-value
Census Division					0.030					0.027
New England	240	2.5	9,465	97.5		90	0.9	9,615	99.1	
Middle Atlantic	2,390	4.0	57,935	96.0		630	1.0	59,695	99.0	
East North Central	2,020	3.1	63,760	96.9		605	0.9	65,175	99.1	
West North Central	365	2.7	13,275	97.3		85	0.6	13,555	99.4	
South Atlantic	4,450	2.7	163,330	97.3		1,085	0.6	166,695	99.4	
East South Central	775	2.5	30,030	97.5		175	0.6	30,630	99.4	
West South Central	1,805	2.8	63,340	97.2		495	0.8	64,650	99.2	
Mountain	220	2.1	10,310	97.9		75	0.7	10,455	99.3	
Pacific	835	2.7	30,215	97.3		290	0.9	30,760	99.1	

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SEVERE MATERNAL MORBIDITY RISK AMONG NON-HISPANIC BLACK WOMEN IN THE UNITED STATES

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ABSTRACT

Background and Objective: Modifiable and unmodifiable risk factors for conditions are often identified to elucidate cause and plan for appropriate intervention. This study aimed to identify and describe risk factors for severe maternal morbidity (SMM) experienced during inpatient delivery among non-Hispanic Black women (Black women), using a national, population-based sample.

Methods: A retrospective, cross-sectional study was conducted utilizing the 2014 National Inpatient Sample (NIS), a nationally representative sample of hospital discharges from January 1 - December 31, 2014. SMM was the primary outcome variable. Predicctor variables included sociodemographic characteristics (age, primary payer, rurality, median household income), clinical factors (length of stay, number of chronic conditions, discharge disposition), and hospital characteristics (hospital control/ownership, hospital location/teaching status, census region, census division.) Mean (SD), median (IQR), and frequencies (%) were calculated to describe the variables. Bivariate analyses included Wilcoxon rank sum tests and chi-square tests. Simple logistic regressions were performed to provide crude odds ratios (cOR). Statistical significance was set at <0.05.

Results: In the 2014 NIS, 13,100 SMM cases were identified among delivering Black women. The sociodemographic characteristics, clinical factors, and hospital characteristics that were associated with experiencing SMM during inpatient delivery included age, length of stay, number of chronic conditions, primary payer, rurality, discharge disposition, hospital control/ownership, Census region, and Census division. Clinically, the number of chronic conditions was a significant predictor as there was a

61% increase in the likelihood of experiencing SMM for each additional chronic condition reported (cOR=1.61, 95% CI 1.57-1.65).

Conclusion: For Black women in the U.S., sociodemographic characteristics, clinical factors, and hospital characteristics are associated with the likelihood of experiencing SMM during inpatient delivery.

INTRODUCTION

The prevalence of severe maternal morbidity (SMM) continues to rise in the United States (U.S.), and racial disparities persist (Callaghan et al., 2012; Kuklina et al., 2009; Luke et al., 2021). Black women are disproportionately affected by SMM as compared to White women. Risk factors for adverse maternal health outcomes, including SMM, have been examined using national and regional data. Sociodemographic characteristics, clinical factors, and hospital characteristics were found to predict adverse maternal health outcomes.

Race is associated with maternal morbidity with Black women having a higher likelihood of experiencing maternal morbidity and pregnancy-related comorbidities as compared to White women (Brown et al., 2020; Bryant et al., 2010; Chen et al., 2021; Gray et al., 2012). Gray et al. (2012) also found women with pre-existing medical conditions had a higher risk of experiencing SMM. However, Chen et al. (2021) found that risk factors varied with the timing of SMM, distinguishing between SMM experienced during the delivery hospitalization and SMM experienced during postpartum hospitalization.

METHODS

Study Design

A retrospective, cross-sectional study of risk factors for SMM during inpatient delivery was conducted utilizing a nationally representative sample of U.S. hospital discharges.

Study Population

All discharge records for Black women with an indication of inpatient delivery were included in the analyses. A published algorithm consisting of International Classification of Diseases, Ninth Revision (ICD-9) and diagnosis-related group (DRG) procedure codes for delivery was used to identify inpatient deliveries (Kuklina et al., 2008).

Data Source

The 2014 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ), a nationally representative sample of hospital discharges from January 1, 2014 through December 31, 2014 was utilized for this study. The institutional review board of the University of Alabama at Birmingham deemed research utilizing NIS data non-human subject research.

Primary Outcome Variable

SMM was the primary outcome variable. Coded to a composite, binary variable, SMM indicated the presence of at least one of the twenty-one CDC-defined diagnoses and procedures that indicate SMM (Centers for Disease Control and Prevention, n.d.).

Predictor Variables

Predictor variables included sociodemographic characteristics (age, primary payer, rurality, median household income), clinical factors (length of stay, number of chronic conditions, discharge disposition), and hospital characteristics (hospital control/ ownership, hospital location/teaching status, census region, census division.)

Statistical Methods

Univariate analyses were conducted to describe SMM prevalence by sociodemographic characteristics, clinical factors, and hospital characteristics. Mean (SD) or median (IQR) were reported for the continuous variables. Frequency (percentage) was reported for the categorical variables. Bivariate analyses for SMM were conducted using chi-square and Wilcoxon rank sum tests. Simple logistic regressions were performed univariately. Crude odds ratios (cOR) and 95% confidence intervals (CI) were reported. Statistical significance was set at $p<0.05$. All analyses were conducted using Survey version 4.1-1, Jtools version 2.1.4, and R version 4.0.3 software (R Project for Statistical Computing, Vienna, Austria).

RESULTS

Study Population

The analytic cohort for this study consisted of 454,760 discharge records of which 13,100 had at least one SMM indicator. Participants' sociodemographic characteristics, clinical factors, and hospital characteristics are described in Table 1.

Predictors of SMM

Simple logistic regression was conducted to assess independent predictors of SMM. Table 2 summarizes the variables associated with SMM: sociodemographic characteristics (age, primary payer, rurality), clinical factors (length of stay, number of chronic conditions, discharge disposition), and hospital characteristics (hospital ownership, census, regions, census division.) Median household income and hospital location/teaching status were not statistically significant predictors.

Sociodemographic Characteristics

For each 1-year increase in age, there was an associated 2% increase in the likelihood of experiencing SMM during the inpatient delivery hospitalization (cOR=1.02, 95% CI 1.01-1.03). As compared to participants with Medicare, those with private insurance had the highest likelihood of not experiencing SMM during delivery hospitalization (cOR=.32, 95% CI 0.25-0.40). Residing in a county metro area with a population of 250,000-999,999 was more protective as compared to residing in a central county metro area of ≥1 million population (cOR=0.70, 95% CI 0.59-0.82).

Clinical Factors

Each additional day of hospitalization was associated with a 10% increase in the odds of experiencing SMM (cOR=1.10, 95% CI 1.09-1.12). The number of chronic conditions reported on the discharge record was also associated with SMM as the odds increased 61% for each additional chronic condition reported (cOR=1.61, 95% CI 1.57-1.65). As compared to women who were routinely discharged to home, women who were discharged with home health care were 2.3 times more likely to have experienced inpatient SMM (cOR=2.32, 95% CI 1.80-2.99) while women who died during the inpatient stay were 282.6 times more likely (cOR=282.57, 95% CI 35.35-2258.46).

Hospital Characteristics

Women who delivered at private, investor-owned hospitals were 24% less likely to experience SMM during delivery hospitalization (cOR=0.76, 95% CI 0.61-0.94) as compared to those who delivered at government, nonfederal hospitals. The geographic location of the delivering hospital was also a significant factor associated with SMM. Women who delivered at hospitals in the West census region were 33% less likely to experience SMM (cOR=0.67, 95% CI 0.52-0.87) as compared to those who delivered in the Northeast region. Women who delivered at hospitals in the Mountain census division were 17% less likely to experience SMM (cOR=0.83, 95% CI 0.53-1.32) as compared to those who delivered in the New England division, while those who delivered in the Middle Atlantic division were 1.57 (cOR=1.57, 95% CI 1.08-2.30) times more likely to experience SMM.

DISCUSSION

We sought to identify factors associated with experiencing SMM during inpatient delivery. Significant univariate associations included age, length of stay, number of chronic conditions, primary payer, rurality, discharge disposition, hospital control/ownership, Census region, and Census division. Age slightly increased the likelihood of experiencing SMM (cOR=1.02, 95% CI 1.01-1.03) while the number of chronic conditions reported significantly increased the likelihood (cOR=1.61, 95% CI 1.57-1.65). Hospital control/ownership of the delivering hospital also impacted the likelihood of experiencing SMM as women who delivered at private, non-profit and private, investor-owned hospitals were less likely to experience SMM as compared to those who delivered at government, nonfederal hospitals (17% and 24% respectively).

Limitations of this study include the reliance upon accurate administrative data to identify diagnoses and procedures on the discharge records which determined the analytic cohort and SMM subgroups. Also, the large sample size could be driving the statistical significance of variables found to be associated with SMM as the likelihood of finding significance increases with the sample size.

Table 1. Severe maternal morbidity among non-Hispanic Black women in the United States, 2014 (N=454,760)

	No SMM (n=441,660)		SMM (n=13,100)		p-value
Age (years), mean±SD	26.9±6.8		27.7±7.3		<0.001
Length of Stay (days), median (IQR)	3 (2 ,3)		4 (3, 5)		<0.001
Number of Chronic Conditions, median (IQR)	0 (0, 1)		2 (1, 3)		<0.001
	n	%	n	%	
Primary Payer					<0.001
Medicare	5,555	1.26	450	3.44	
Medicaid	285,405	64.62	8,620	65.80	
Private Insurance	131,260	29.72	3,475	26.53	
Self-Pay	9,410	2.13	320	2.44	
No Charge	360	0.08	10	0.08	
Other (including other government programs)	8,940	2.02	200	1.53	
Missing	730	0.17	25	0.19	
Patient Location (rurality)					<0.001
Central county of metro area of ≥1M pop	192,305	43.54	6,315	48.21	
Fringe county of metro area of ≥1M pop	105,525	23.89	3,090	23.59	
County in metro area of 250,000-999,999 pop	79,765	18.06	1,805	13.78	
County in metro area of 50,000-249,999 pop	32,350	7.32	955	7.29	
Micropolitan county	18,230	4.13	605	4.62	
Not metropolitan or micropolitan county	12,700	2.88	315	2.40	
Missing	785	0.18	15	0.11	

Median Household Income					0.011
≤ $39,999	217,035	49.14	6,710	51.22	
$40,000-$50,999	103,785	23.50	2,900	22.14	
$51,000-$65,999	70,090	15.87	1,900	14.50	
≥$66,000	43,515	9.85	1,305	9.96	
Missing	7,235	1.64	285	2.18	
Discharge Disposition					<0.001
Routine	431,240	97.64	12,290	93.82	
Transfer to short-term hospital	230	0.05	60	0.46	
Transfer other	295	0.07	50	0.38	
Home health care	9,210	2.09	580	4.43	
Against medical advice	635	0.14	80	0.61	
Died in hospital	5	0.001	40	0.31	
Missing	45	0.01	0	0.00	
Hospital Control/Ownership					0.026
Government, nonfederal	61,475	13.92	2,210	16.87	
Private, non-profit	313,150	70.90	9,095	69.43	
Private, investor-owned	67,035	15.18	1,795	13.70	
Hospital Location/Teaching Status					0.043
Rural	21,845	4.95	605	4.62	
Urban nonteaching	88,445	20.03	2,310	17.63	
Urban teaching	331,370	75.03	10,185	77.75	

Census Region					0.008
Midwest	77,035	17.44	2,385	18.21	
Northeast	67,400	15.26	2,630	20.08	
South	256,700	58.12	7,030	53.66	
West	40,525	9.18	1,055	8.05	
Census Division					0.030
New England	9,465	2.14	240	1.83	
Middle Atlantic	57,935	13.12	2,390	18.24	
East North Central	63,760	14.44	2,020	15.42	
West North Central	13,275	3.01	365	2.79	
South Atlantic	163,330	36.98	4,450	33.97	
East South Central	30,030	6.80	775	5.92	
West South Central	63,340	14.34	1,805	13.78	
Mountain	10,310	2.33	220	1.68	
Pacific	30,215	6.84	835	6.37	

Table 2. Predictors of inpatient severe maternal morbidity among non-Hispanic Black Women

Risk Factor	cOR	95% CI
Age	1.02	1.01-1.03
Length of Stay (days)	1.10	1.09-1.12
Number of Chronic Conditions	1.61	1.57-1.65
Primary Payer		
Medicare	1.00	
Medicaid	0.36	0.29-0.45
Private Insurance	0.32	0.25-0.40
Self Pay	0.42	0.30-0.59
No Charge	0.34	0.11-1.05
Other	0.27	0.19-0.40
Patient Location (rurality)		
Central county metro area of ≥1M	1.00	
Fringe county metro area of ≥1M	0.89	0.78-1.02
County metro area of 250,000-999,999	0.70	0.59-0.82
County metro area of 50,000-249,999	0.91	0.76-1.09
Micropolitan county	1.00	0.77-1.31
Not metropolitan or micropolitan county	0.76	0.58-1.00
Median Household Income		
≤ $39,999	1.00	
$40,000-$50,999	0.90	0.81-1.00
$51,000-$65,999	0.88	0.77-1.00
≥$66,000	0.97	0.84-1.13
Discharge Disposition		
Routine	1.00	
Transfer to short-term hospital	9.63	5.21-17.82
Transfer other	6.31	3.23-12.33
Home health care	2.32	1.80-2.99
Against medical advice	4.91	3.01-8.01
Died in hospital	282.57	35.35-2258.46

Hospital Control/Ownership		
Government, nonfederal	1.00	
Private, non-profit	0.83	0.68-1.00
Private, investor-owned	0.76	0.61-0.94
Hospital Location/Teaching Status		
Rural	1.00	
Urban nonteaching	0.94	0.71-1.24
Urban teaching	1.10	0.84-1.44
Census Region		
Northeast	1.00	
Midwest	0.80	0.63-1.02
South	0.71	0.58-0.87
West	0.67	0.52-0.87
Census Division		
New England	1.00	
Middle Atlantic	1.57	1.08-2.30
East North Central	1.22	0.86-1.73
West North Central	1.07	0.56-2.04
South Atlantic	1.05	0.76-1.46
East South Central	0.98	0.56-1.72
West South Central	1.11	0.79-1.56
Mountain	0.83	0.53-1.32
Pacific	1.06	0.73-1.55

cOR=crude odds ratio
CI=confidence interval

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SUMMARY

Racial and ethnic disparities in maternal health behaviors and outcomes persist in the U.S., with Black women bearing a disproportionate burden of adverse maternal health related outcomes (Berg et al., 2001; Creanga et al., 2017; Fingar et al., 2018; Martin et al., 2018; Schoendorf et al., 1992; Sing et al., 2010; Tucker et al., 2007). Despite increased research and initiatives aimed at reducing maternal health disparities, this public health crisis has persisted for decades (Centers for Disease Control and Prevention, n.d.). Much of the disparities literature in this area focuses on differences between racial and ethnic groups with limited information on disparities among Black women. For this dissertation, we conducted a population-based assessment of SMM among Black women in the U.S. to describe the prevalence and risk factors for SMM during inpatient delivery.

In the first paper, we aimed to describe SMM prevalence and assess differences between women with and without an indication of SMM during the inpatient delivery stay. We hypothesized differences based on sociodemographic, clinical, and hospital characteristics. We found significant differences between the groups based on all sociodemographic, clinical, and hospital characteristics, with the exception of hospital/control ownership which was not significant when blood products transfusion was excluded as an SMM indicator. Due to the large sample size, future studies with smaller random samples will be conducted to further assess the significance of the findings.

In the second paper, we aimed to describe the geographic distribution of SMM prevalence among the study population and assess differences by SMM status based on U.S. census region and census division. Given the geographic variability in the U.S. observed in healthcare resources and factors associated with birth outcomes (Holcomb et al., 2021; Horev et al., 2004; Howell et al., 2016; Mays & Smith, 2009; Yin, 2019), we hypothesized geographic variability in SMM prevalence across census regions and divisions. Of the total deliveries in the sample, the proportion of SMM cases by region ranged from 2.5% to 3.8%, including blood products transfusion, and from 0.7% to 1.0% not including blood products transfusion. The proportion of SMM cases by division ranged from 2.1% to 4%, including blood products transfusion, and from 0.6% to 1.0% not including blood products transfusion. We found SMM prevalence varied significantly across census regions and divisions, with and without blood products transfusion as an SMM indicator.

In the third paper, we aimed to identify risk factors for severe maternal morbidity experienced during inpatient delivery. Due to the increased likelihood finding statistical significance with large sample sizes and issues related to conducting multiple comparisons, we chose to report crude odds ratios and confidence intervals rather than p-values. As hypothesized, we found sociodemographic (age, expected primary payer, patient location/rurality, median household income for zip code), clinical (length of stay, number of chronic conditions, discharge disposition), and hospital factors (hospital control/ownership, hospital location/teaching status, hospital census region, hospital census division) were associated with the likelihood of experiencing SMM during inpatient delivery.

In summary, national data show significant differences in sociodemographic, clinical, and hospital characteristics between Black women who did and did not experience SMM during inpatient delivery. Geographic variation in SMM prevalence was also found; and sociodemographic, clinical, and hospital factors were found to be associated with the likelihood of experiencing SMM. Further analyses should be conducted to determine if the significant findings are due to the effects of a large sample size. By understanding the distribution of SMM prevalence among Black women, we are better able to identify priority subpopulations for intervention planning.

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APPENDIX

APPENDIX 1. SEVERE MATERNAL MORBIDITY INDICATORS

Diagnoses	ICD-9-CM Codes
Acute myocardial infarction	410, 4100, 41000, 41001, 41002, 4101, 41010, 41011, 41012, 4102, 41020, 41021, 41022, 4103, 41030, 41031, 41032, 4104, 41040, 41041, 41042, 4105, 41050, 41051, 41052, 4106, 41060, 41061, 41062, 4107, 41070, 41071, 41072, 4108, 41080, 41081, 41082, 4109, 41090, 41091, 41092
Aneurysm	441, 4410, 44100, 44101, 44102, 44103, 4411, 4412, 4413, 4414, 4415, 4416, 4417, 4419
Acute renal failure	584, 5845, 5846, 5847, 5848, 5849, 6693, 66930, 66932, 66934
Adult respiratory distress syndrome	5185, 51851, 51852, 51853, 51881, 51882, 51884, 7991
Amniotic fluid embolism	6731, 67310, 67311, 67312, 67313, 67314
Cardiac arrest/ventricular fibrillation/ventricular flutter	42741, 42742, 4275
Disseminated intravascular coagulation	2866, 2869, 6663, 66630, 66632, 66634
Eclampsia	6426, 64260, 64261, 64262, 64263, 64264
Heart failure/arrest during surgery or procedure	9971

Diagnoses	ICD-9-CM Codes
Puerperal cerebrovascular disorders	430, 431, 432, 4320, 4321, 4329, 433, 4330, 43300, 43301, 4331, 43310, 43311, 4332, 43320, 43321, 4333, 43330, 43331, 4338, 43380, 43381, 4339, 43390, 43391, 434, 4340, 43400, 43401, 4341, 43410, 43411, 4349, 43490, 43491, 436, 437, 4370, 4371, 4372, 4373, 4374, 4375, 4376, 4377, 4378, 4379, 6715, 67150, 67151, 67152, 67153, 67154, 6740, 67400, 67401, 67402, 67403, 67404, 99702
Pulmonary edema/Acute heart failure	5184, 4281, 4280, 42821, 42823, 42831, 42833, 42841, 42843
Severe anesthesia complications	6680, 66800, 66801, 66802, 66803, 66804, 6681, 66810, 66811, 66812, 66813, 66814, 6682, 66820, 66821, 66822, 66823, 66824
Sepsis	038, 0380, 0381, 03810, 03811, 03812, 03819, 0382, 0383, 0384, 03840, 03841, 03842, 03843, 03844, 03849, 0388, 0389, 99591, 99592, 6702, 67020, 67022, 67024
Shock	6691, 66910, 66911, 66912, 66913, 66914, 7855, 78550, 78551, 78552, 78559, 9950, 9954, 9980, 99800, 99801, 99802, 99809
Sickle cell disease with crisis	28242, 28262, 28264, 28269
Air and thrombotic embolism	4151, 41511, 41512, 41513, 41519, 6730, 67300, 67301, 67302, 67303, 67304, 6732, 67320, 67321, 67322, 67323, 67324, 6733, 67330, 67331, 67332, 67333, 67334, 6738, 67380, 67381, 67382, 67383, 67384

Procedures	ICD-9-CM Codes
Conversion of cardiac rhythm	996, 9960, 9961, 9962, 9963, 9964, 9969
Blood products transfusion	990, 9900, 9901, 9902, 9903, 9904, 9905, 9906, 9907, 9908, 9909
Hysterectomy	683, 6831, 6839, 684, 6841, 6849, 685, 6851, 6859, 686, 6861, 6869, 687, 6871, 6879, 688, 689
Temporary tracheostomy	311
Ventilation	9390, 9601, 9602, 9603, 9605

APPENDIX 2. NATIONAL INPATIENT SAMPLE: VARIABLES OF INTEREST

Variable Name	Description	Coding	NIS File(s)
AGE	Age in years at admission	0-124 . Missing .A Invalid .C Inconsistent	Inpatient Core
CM_AIDS	Comorbidity: Acquired immune deficiency syndrome	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_ALCOHOL	Comorbidity: Alcohol abuse	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_ANEMDEF	Comorbidity: Deficiency anemias	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_ARTH	Comorbidity: Rheumatoid arthritis/ collagen vascular diseases	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_BLDLOSS	Comorbidity: Chronic blood loss anemia	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_CHF	Comorbidity: Congestive heart failure	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_CHRNLUNG	Comorbidity: Chronic pulmonary disease	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures

Variable Name	Description	Coding	NIS File(s)
CM_COAG	Comorbidity: Coagulopathy	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_DEPRESS	Comorbidity: Depression	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_DM	Comorbidity: Diabetes, uncomplicated	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_DMCX	Comorbidity: Diabetes with chronic complications	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_DRUG	Comorbidity: Drug abuse	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_HTN_C	Comorbidity: Hypertension	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_HYPOTHY	Comorbidity: Hypothyroidism	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_LIVER	Comorbidity: Liver disease	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures

Variable Name	Description	Coding	NIS File(s)
CM_LYMPH	Comorbidity: Lymphoma	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_LYTES	Comorbidity: Fluid and electrolyte disorders	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_METS	Comorbidity: Metastatic cancer	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_NEURO	Comorbidity: Other neurological disorders	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_OBESE	Comorbidity: Obesity	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_PARA	Comorbidity: Paralysis	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_PERIVASC	Comorbidity: Peripheral vascular disorders	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_PSYCH	Comorbidity: Psychoses	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures

Variable Name	Description	Coding	NIS File(s)
CM_PULMCIRC	Comorbidity: Pulmonary circulation disorders	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_RENLFAIL	Comorbidity: Renal failure	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_TUMOR	Comorbidity: Solid tumor without metastasis	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_ULCER	Comorbidity: Peptic ulcer disease excluding bleeding	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_VALVE	Comorbidity: Valvular disease	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures
CM_WGHTLOSS	Comorbidity: Weight loss	0 Comorbidity is not present 1 Comorbidity is present .A Invalid	Disease Severity Measures

Variable Name	Description	Coding	NIS File(s)
DISCWT	Weight to the discharges in the universe	nn.nnnn weight to discharges in the universe (used to calculate national estimates for all analyses)	Inpatient Core Hospital Weights
DISPUNIFORM	Disposition of patient at discharge	1 Routine 2 Transfer to short-term hospital 5 Transfer other: includes skilled nursing facility, intermediate care facility, another type of facility 6 Home health care 7 Against medical advice 20 Died in hospital 21 Discharged/transferred to court/law enforcement 99 Discharge alive, destination unknown . Missing .A Invalid	Inpatient Core
DRG	DRG value	nnn	Inpatient Core

Variable Name	Description	Coding	NIS File(s)
DXn (DX1 - DX30)	ICD-9-CM diagnosis	annnn Diagnosis code blank Missing invl Invalid incn Inconsistent	Inpatient Core
FEMALE	Indicator of sex	0 Male 1 Female . Missing .A Invalid .C Inconsistent	Inpatient Core
H_CONTRL	Control/ownership of hospital	1 Government, nonfederal 2 Private, non-profit 3 Private, investor-own . Missing	Hospital Weights
HOSP_DIVISION	Census Division of hospital	1 New England 2 Middle Atlantic 3 East North Central 4 West North Central 5 South Atlantic 6 East South Central 7 West South Central 8 Mountain 9 Pacific	Inpatient Core Hospital Weights

Variable Name	Description	Coding	NIS File(s)
HOSP_LOCTEACH	Location/teaching status of hospital	1 Rural 2 Urban nonteaching 3 Urban teaching . Missing	Hospital Weights
HOSP_NIS	NIS hospital number	5.n	Inpatient Core Hospital Weights Disease Severity Measures
HOSP_REGION	Census Region of hospital	1 Northeast 2 Midwest 3 South 4 West	Hospital Weights
KEY_NIS	NIS record number	8.n string	Inpatient Core Disease Severity Measures
LOS	Length of stay	0-365 days . Missing .A Invalid .C Inconsistent	Inpatient Core
NCHRONIC	ICD-9-CM number of chronic conditions	0-nn .A Invalid	Inpatient Core

Variable Name	Description	Coding	NIS File(s)
PAY1	Expected primary payer	1 Medicare (FFS and managed care) 2 Medicaid (FFS and managed care) 3 Private insurance 4 Self pay 5 No charge 6 Other (Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other Government programs) . Missing .A Invalid	Inpatient Core

Variable Name	Description	Coding	NIS File(s)
PL_NCHS	Patient location: NCHS Urban-Rural code	1 "Central" counties of metro areas of ≥1 million population 2 "Fringe" counties of metro areas of ≥1 million population 3 Counties in metro areas of 250,000-999,999 population 4 Counties in metro areas of 50,000-249999 population 5 Micropolitan counties 6 Not metropolitan or micropolitan counties . Missing	Inpatient Core
PRn (PR1-PR15)	ICD-9-CM Procedure	nnnn Procedure code Blank Missing invl Invalid incn Inconsistent	Inpatient Core

Variable Name	Description	Coding	NIS File(s)
RACE	Race/ethnicity	1 White 2 Black 3 Hispanic 4 Asian or Pacific Islander 5 Native American 6 Other . Missing .A Invalid	Inpatient Core
ZIPINC_QRTL	Median household income for patient's zip code	1 $1 - 39,999 2 $40,000 - 50,999 3 $51,000 - 65,999 4 ≥ $66,000 . Other	Inpatient Core