Examination of the Black-White racial disparity in severe maternal morbidity among Georgia deliveries, 2016 to 2020

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BACKGROUND: Studies find that delivery hospital explains a significant portion of the Black-White gap in severe maternal morbidity. No such studies have focused on the US Southeast, where racial disparities are widest, and few have examined the relative contribution of hospital, residential, and maternal factors.

OBJECTIVE: This study aimed to estimate the portion of Georgia's Black-White gap in severe maternal morbidity during delivery through 42 days postpartum explained by hospital, residential, and maternal factors.

STUDY DESIGN: Using linked Georgia hospital discharge, birth, and fetal death records for 2016 through 2020, we identified 413,124 deliveries to non-Hispanic White (229,357; 56%) or Black (183,767; 44%) individuals. We linked hospital data from the American Hospital Association and Center for Medicare and Medicaid Services, and area data from the Area Resource File and American Community Survey. We identified severe maternal morbidity indicator conditions during delivery or subsequent hospitalizations through 42 days postpartum. Using race-specific logistic models followed by a decomposition technique, we estimated the portion of the Black-White severe maternal morbidity gap explained by the following: (1) sociodemographic factors (age, education, marital status, and nativity), (2) medical conditions (diabetes mellitus, gestational diabetes, chronic hypertension, gestational hypertension or preeclampsia, and smoking), (3) obstetrical factors (singleton or multiple, and birth order); (4) access to care (no or third trimester care, and payer), (5) hospital factors that are time-varying (delivery volume, deliveries per full-time equivalent nurse, doctor communication, patient safety, and adverse event composite score) or measured time-invariant characteristics (ownership, profit status, religious affiliation, teaching status, and perinatal level), and (6) residential factors (county urban/rural classification, percent uninsured women of reproductive age, obstetrician-gynecologists per women of reproductive age, number of federally-qualified and community health centers, medically-underserved area [yes/no], and census tract neighborhood deprivation index). We estimated models with and without hospital fixed-effects, which account for unobserved time-invariant hospital characteristics such as within-hospital care processes or unmeasured hospital-specific factors.

RESULTS: There was 1.8 times the rate of severe maternal morbidity per 100 discharges among non-Hispanic Black (3.15) than among White (1.73) individuals, with an explained proportion of 30.4% in models without and 49.8% in models with hospital fixed-effects. In the latter, hospital fixed-effects explained the largest portion of the Black-White severe maternal morbidity gap (15.1%) followed by access to care (14.9%) and sociodemographic factors (14.4%), with residential factors being protective for Black individuals (-7.5%). Smaller proportions were explained by medical (5.6%), obstetrical (4.0%), and time-varying hospital factors (3.2%). Within each category, the largest explanatory portion was payer type (13.3%) for access to care, marital status (10.3%) for sociodemographic, gestational hypertension (3.3%) for medical, birth order (3.6%) for obstetrical, and patient safety indicator (3.1%) for time-varying hospital factors.

CONCLUSION: Models with hospital fixed-effects explain a greater proportion of Georgia's Black-White severe maternal morbidity gap than models without them, thereby supporting the point that differences in care processes or other unmeasured factors within the same hospital translate into racial differences in severe maternal morbidity during delivery through 42 days postpartum. Research is needed to discern and ameliorate

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sources of within-hospital differences in care. The substantial proportion of the gap attributable to racial differences in access to care and sociodemographic factors points to other needed policy interventions.

Key words: access to care, hospital of delivery, maternal morbidity, medical risks, obstetrical risks, patient safety, postpartum outcomes, racial disparities, sociodemographic determinants, statistical analysis

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Why was this study conducted?

To evaluate the relative importance of sociodemographic, medical, obstetric, access to care, hospital and residential factors in explaining the Black-white gap in severe maternal morbidity (SMM) during delivery through 42 days postpartum in Georgia, 2016-2020.

What are the key findings?

The largest proportion of Georgia's Black-white gap in SMM during delivery through 42 days postpartum is explained by potential differences in care processes or other unmeasured factors within the same delivery hospital. Racial differences in access to care and sociodemographic factors follow closely in importance in explaining Georgia's Black-white gap in SMM.

What does this study add to what is already known?

Within-hospital processes, which may reflect implicit bias or other unmeasured factors, explain the largest portion of the Black-white gap in SMM during delivery through 42 days postpartum in Georgia, a state with high and racially disparate rates of SMM.

Introduction

Severe maternal morbidity (SMM), unintended outcomes of labor and delivery resulting in short-term or long-term health consequences, is regarded as a near-miss outcome proximate to maternal death.[1] SMM is approximately 100 times more common than maternal death,[2] and the US rates of both are increasing.[3] National data for 2006 to 2015 show a 45 percent increase in delivery SMM, with occurrence more likely among those who are racial and ethnic minorities, of youngest (<20 years) and oldest (≥40 years) ages, insured by Medicaid or uninsured, residing in low-income communities, and at hospitals that serve vulnerable populations (safety-net, minority-serving, teaching, and public).[3] Across the 10-year period, delivery SMM rates were highest among Black mothers with the Black-White disparity remaining stable.[3] Earlier studies show that non-Hispanic Black compared to White mothers have 2 to 7 times the likelihood of SMM, with racial differences in sociodemographic and medical factors accounting for a portion of the disparity but much remaining unexplained.[4–6]

A growing literature finds that delivery hospital contributes to racial gaps in SMM. Identifying the underlying reasons for lower complication rates in high-performing hospitals appears critical to understanding disparities in SMM.[7] A New York City study estimated probabilities of SMM "as if" the distribution of deliveries to Black mothers matched those of White mothers across hospitals ranked by risk-adjusted SMM, concluding that between-hospital differences may contribute as much as 47.7% to the city's racial disparity. They also found that within the same hospital and insurance stratum (private, Medicaid), deliveries to Black compared to White mothers had higher risk of SMM.[8] A national study concluded that pathways other than insurance status need investigation.[9] A multi-state study found hospitals serving a "medium to high" proportion of Black patients had higher SMM rates for both White and Black patients than hospitals serving predominantly-White patients. Given that 74% of deliveries to Black mothers were in hospitals serving predominantly-Black patients,[10] the between-hospital method of using "minority-serving" as a surrogate for quality was found to significantly underestimate the racial disparity in readmissions.[11]

To build on previous findings and fill gaps in knowledge, we use population-based administrative data from Georgia to analyze the relative importance of sociodemographic, medical, obstetric, access to care, delivery hospital, and residential factors on the Black-White gap in SMM during the delivery hospitalization through 42 days postpartum. Although it is known that improving delivery hospital quality can reduce disparities,[12] postpartum disparities are understudied. Considering that postpartum SMM rates are increasing and a growing majority of SMM and mortality occurs after delivery discharge, it is essential that analyses include SMM in this broader time period.[2] In this analysis we considered SMM during the delivery admission or any subsequent admission during the first 42 days following delivery. Because the system-level and individual-level factors that associate with SMM vary across the postpartum period (within 42 days and 43−365 days), we restricted our analysis to the first 42 days.[13,14] This study is, to our knowledge, the first to use multivariable analysis and a decomposition technique to analyze racial disparities in SMM in Georgia, a state with a 31% higher rate of SMM than the overall national rate (189.2 vs 144 per 10,000 deliveries).[15]

Materials and Methods

Data

Using deterministically-linked Georgia hospital discharge, birth, and fetal death records for 2016 through 2020, we identified 413,124 deliveries to 348,572 individuals reported as non-Hispanic White (229,357; 56%) or non-Hispanic Black (183,767; 44%); 64,552 (17.0%) were repeat deliveries to the same individual. We linked hospital-level data from the American Hospital Association and the Center for Medicare and Medicaid Services Hospital Consumer Assessment of Healthcare Providers and Systems survey using a state-level facility identity from the Georgia Department of Public Health. Using these linked data, we derived both time-varying hospital measures (eg, delivery volume, physician communication) that may relate to quality of care as well as measured time-invariant hospital characteristics (eg, ownership).

We also linked data from the Area Resource File (ARF) and the American Community Survey based on the Federal Information Processing System (FIPS) code for the maternal county and census tract of residence at time of delivery. We used the ARF data to categorize maternal residence according to the National Center for Health Statistics urban-rural continuum which was designed to better reflect differences in the health of county residents as those in "fringe" vs "central" metropolitan areas are known to fare better on several health measures.[16] The FIPS code was used to link data reflective of access to care within the county (eg, to obstetrician-gynecologists and other providers in county) and area-level social and economic conditions[17] as detailed in Table 1. We defined the presence of SMM using vital records and the International Classification of Diseases, 10th Revision (ICD-10) diagnosis codes from hospital discharge.

Analysis

We used established ICD codes to identify occurrences of any of the 21 SMM indicator conditions during the delivery or any subsequent hospitalization through 42 days postpartum.[18] We estimated logistic models separately for deliveries to non-Hispanic Black and White individuals. We used these results and the Oaxaca-Blinder decomposition technique[19–23] to derive an "explained portion" of the Black-White SMM gap attributed to differences in the averages of the covariates between the racial groups and an "unexplained portion" attributed to differences in the coefficient estimates for the racial groups. We focus here on the portion explained and the factors accounting for that portion.

For the following sets of covariates (Table 1), we estimated the odds of SMM and the relative contribution of each to the "explained" portion of the Black-White SMM gap: (1) sociodemographic factors (age, level of education, marital status, and nativity), 2) medical conditions (diabetes mellitus, gestational diabetes, chronic hypertension, gestational hypertension or preeclampsia, and smoking tobacco during pregnancy), (3) obstetrical factors (singleton and prior births), (4) access to care (no/3rd trimester care, and payer), (5) hospital factors that are time-varying (delivery volume, deliveries per full-time equivalent registered nurse, doctor communication, patient safety and adverse event composite score) or measured time-invariant characteristics (ownership, profit status, religious affiliation, teaching status, perinatal level), and (6) residential characteristics (urban/rural classification, percent uninsured women of reproductive age [WRA], obstetrician-gynecologists per WRA, number of federally-qualified health centers [FQHCs] and community health centers [CMHCs], medically-underserved area [yes/no] and a validated neighborhood deprivation index (NDI) used in the maternal and child health area, at the census tract level.[24] We estimated models with and without hospital fixed-effects, which account for unobserved time-invariant hospital characteristics such as within-hospital care processes or unmeasured hospital-specific factors.

We used an extension of the Oaxaca-Blinder method for binary outcome measures in Stata version 17.[25,26] We conducted sensitivity analyses as follows: (1) randomly sampled a single delivery among individuals with more than 1 in the period to assess whether possibly correlated repeat births to the same person biased our estimates; and (2) excluded blood transfusion from the SMM definition because previous research has demonstrated[27] the low construct validity for SMM identified by blood transfusion only given that the number of units of blood transfused is not available as an ICD code (Supplemental Tables).

Results

Descriptive

The SMM rate for delivery through 42 days postpartum was 3.151 per 100 deliveries for Black individuals and 1.730 for White individuals, for a difference of 1.421 percentage points (pp) ($P<.01$). Characteristics of deliveries to Black and White individuals are given in Table 1. Compared to White mothers, Black mothers were younger, were more likely to have less than high school education (11.8% vs 8.7%), have 3 or more prior births (16.9% vs 8.8%), have chronic hypertension (7.8% vs 4.1%), have gestational hypertension (15.3% vs 13.4%) and were far less likely to be married (26.7% vs 71.3%) and less likely to smoke (9% vs 14.9%). Black mothers were far more likely to have Medicaid (67.2% vs 35.1%) and more likely to have no or third trimester prenatal care (9.7% vs 4.5%) and to deliver at nonprofit, major teaching hospitals and those with larger delivery volumes, characteristics of 'safety-net' hospitals, than White mothers.[28] A higher percentage of Black mothers than White mothers delivered at a regional perinatal center and at hospitals with more deliveries per full-time equivalent registered nurse and with higher (worse) scores on the patient safety and adverse event composite score.[29] Finally, more Black mothers than White mothers resided in large metropolitan counties with more FQHCs, CMHCs, and obstetrician/gynecologists per WRA, but in census tracts with higher NDI.

TABLE 1
Characteristics of deliveries to Non-Hispanic Black and White individuals in Georgia, 2016 to 2020

Delivery Characteristics[a]	Non-Hispanic Black n=183,767	Non-Hispanic White n=229,357
Severe maternal morbidity rate (per 100 deliveries)		
Delivery hospitalization to 42 d	3.151	1.730[d]
Delivery hospitalization	2.552	1.429[d]
Delivery hospital discharge to 42 d	0.691	0.331[d]
Maternal sociodemographic factors		
Age (y): <20	7.5%	4.6%[d]
20–29	56.6%	49.6%
30–34	21.5%	30.0%
35–39	11.5%	13.3%
40–44	2.7%	2.4%
45+	0.2%	0.2%
Education: <High school	11.8%	8.7%[d]
High School graduate	38.6%	24.7%
Some college	49.6%	66.7%
US born	90.8%	95.4%[d]
Married	26.7%	71.3%[d]
Medical factors[b]		
Diabetes mellitus	1.8%	1.2%[d]
Gestational diabetes	7.2%	7.8%[d]
Chronic hypertension	7.8%	4.1%[d]
Gestational hypertension	15.3%	13.4%[d]
Smoker	9.0%	14.9%[d]
Obstetrical factors		
Prior births None	37.8%	41.4%[d]
1	27.7%	33.8%
2	17.7%	16.0%
3 or more	16.9%	8.8%
Singleton	99.0%	99.2%[d]
Access to care		
Payer at delivery Private insurance	27.1%	59.6%[d]
Medicaid	67.2%	35.1%
Self-Pay	2.6%	1.8%
Other Payer	3.2%	3.5%
No or third trimester prenatal care	9.7%	4.5%[d]
Hospital characteristics		
Ownership For-profit	10.5%	9.1%[d]
Government hospital	3.7%	5.1%
Non-Profit hospital	82.2%	79.7%
Religious affiliation	3.6%	6.2%
Teaching Status None	23.9%	36.3%[d]

(continued)

TABLE 1
Characteristics of deliveries to Non-Hispanic Black and White individuals in Georgia, 2016 to 2020 *(continued)*

Delivery Characteristics[a]	Non-Hispanic Black n=183,767	Non-Hispanic White n=229,357
Minor teaching	51.5%	53.3%
Major teaching	24.6%	10.4%
Perinatal Level 0 or 1	5.3%	10.1%[d]
2	22.8%	28.7%
3 or 4	71.9%	61.2%
Delivery Volume Highest quartile	70.0%	61.7%[d]
2nd quartile	22.3%	27.0%
3rd quartile	6.7%	10.2%
Lowest quartile	1.1%	1.1%
Deliveries per full-time equivalent registered nurse, mean	4.16	4.09[d]
Patient safety indicator score, mean	1.07	1.04[d]
Doctor communication score, mean	78.80	79.47[d]
Residential characteristics[c]		
Residential area: Large central metropolitan	13.5%	6.8%[d]
Large fringe metropolitan	46.3%	44.3%
Medium metropolitan	12.4%	11.0%
Small metropolitan	14.1%	16.1%
Micropolitan	8.3%	12.7%
Noncore	5.5%	9.1%
Neighborhood deprivation index (NDI)	0.25	−0.50[d]
Uninsured women of reproductive age (WRA)	16.1%	12.6%[d]
Obstetrician/gynecologists per 10,000 women of reproductive age (Mean)	6.70	5.10[d]
Federally qualified health centers (FQHC), mean	5.42	3.19[d]
Medically underserved area (Yes)	13.1%	18.4%[d]
Community mental health centers, mean	0.40	0.27[d]
Year of delivery 2016	20.0%	20.8%[d]
2017	20.5%	20.6%
2018	20.1%	20.1%
2019	20.0%	19.8%
2020	19.4%	18.7%

[a] Data SourcesHospital discharge: SMM; Vital records: age, education, US born, married, prior births, singleton birth, payer at delivery, no or third trimester PNC, delivery volume, year of delivery; Vital records and hospital discharge: pre-pregnancy diabetes and hypertension, gestational diabetes and hypertension, smoker (**see codes below)**; American Hospital Association (AHA): hospital ownership, teaching status, full-time equivalent registered nurses; Area Health Resource File (AHRF): percent uninsured women of reproductive age (WRA), Ob/Gynecologists per 10,000 WRA, number FQHCs, medically underserved area, number community mental health centers; American Community Survey (ACS): NDI **(**NDI scaled to distribution in Georgia in 2015 with 1 unit equal to 1 standard deviation increase; higher scores represent more deprivation**);** Center for Medicare and Medicaid Services (CMS): patient safety and adverse event composite score (Hospital Compare-Agency for Healthcare Research and Quality quality indicator), doctor communication (Hospital Consumer Assessment of Healthcare Providers and Systems Survey — percent responding doctors always communicate well); National Center for Health Statistics (NCHS): Residential area 2013 urban—rural classification scheme for counties (https://www.cdc.gov/nchs/data/series/sr_02/sr02_166.pdf); [b] Defined using vital records (VR) and ICD-10 diagnosis codes from hospital discharge (HD)Pre-pregnancy diabetes: VR — Pre-pregnancy diabetes (yes) HD — E08, E09, E10, E11, O240, O241, O242, O243, O248Gestational diabetes: VR — Gestational diabetes (yes) HD — O244, O99810, O99814,Chronic hypertension: VR - Chronic hypertension (yes) or hypertension eclampsia (yes) HD — I10, O10, O11Gestational hypertension: VR — Gestational hypertension (yes) HD — O13, O14, O15Smoker: VR — Tobacco use during pregnancy (yes) HD — F172, O9933, Z87891; [c] All residential characteristics are measured at county level, except NDI scale is measured at census tract.; [d] $P<.001$ (significant differences between Non-Hispanic Black and White estimated with Pearson Chi-square for categorical variables and Student t-tests for continuous measures)

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Multivariable

The covariates associated with higher odds of SMM at delivery through 42 days for Black and White mothers (Table 2) are shown for models without (model 1) and with hospital fixed-effects (model 2). For many covariates, the association with SMM was similar for both racial groups, including significantly lower odds of SMM among deliveries to those of younger ages, higher education, who were married, had a singleton pregnancy, at a minor teaching or religious affiliated hospital; and significantly higher odds of SMM among deliveries to those with chronic or gestational hypertension, no or third trimester prenatal care, and at a government or non-profit hospital. Notably, whereas chronic and gestational hypertension increased the odds of SMM for both Black and White mothers, the odds estimates for gestational hypertension were substantially higher than those for chronic hypertension for both racial groups; however, the odds estimates for chronic hypertension for Black mothers was substantially higher than that for White mothers (the point estimate for Black mothers did not lie within the 95% confidence limits of that for White mothers). In contrast, for other covariates, the odds estimates varied according to racial group. For example, having 3 or more prior births and delivery at a major teaching hospital were associated with an increased odds of SMM for Black but not White mothers, whereas higher (worse) patient safety and adverse event composite score was associated with increased odds of SMM only for White mothers. Residence in counties other than large central metropolitan counties was associated with lower odds of SMM only for Black mothers.

Decomposition

Decomposition of the 1.421 pp Black-White difference in SMM is shown in Table 3 and the Figure. Nearly a third (30.4%) of the total Black-White SMM gap is explained by predictors in model 1, with the largest discriminatory explanatory contribution from access to care (10.3%) followed by sociodemographic factors (10.1%). In model 1, hospital factors that were time-varying and measured time-invariant hospital characteristics explained the next highest percentage, 4.7%; with the remaining factors contributing less than 4% each, including maternal medical factors (3.8%) and obstetrical factors (2.8%). In model 2, with the addition of hospital fixed-effects, the total percentage of the Black-White difference explained increased markedly to 49.8%; hospital fixed-effects were the largest single explanatory contributor (15.1%) with access to care (14.9%) and sociodemographic factors (14.4%) explaining similar proportions, and a substantially smaller discriminatory contribution from maternal medical factors (5.6%), obstetrical factors (4.0%), and time-varying hospital characteristics (3.2%). For both model 1 and model 2, the largest discriminatory contribution for sociodemographic factors was marital status (7.6% and 10.3%, respectively); for medical factors, it was gestational hypertension (2.4% and 3.3%, respectively) followed closely by chronic hypertension (2.1% and 3.1%, respectively); for obstetrical factors, it was birth order (2.5% and 3.6%, respectively); for access to care, it was payer type (9.0% and 13.3%, respectively); and for residential factors, it was NDI (4.9% and 4.0%, respectively) and number of FQHCs (-5.3% and -4.7%, respectively, which were protective for Black mothers as indicated by the negative sign).

Sensitivity Analyses

In our sensitivity analysis for which we randomly sampled a single delivery to the same individual, we found no meaningful differences in the distribution of delivery characteristics for non-Hispanic Black and White individuals (Supplemental Table 1) or the odds of SMM (Supplemental Table 2) compared to findings for the full sample (Table 1 and Table 2). Likewise, the proportions of the Black-White SMM gap explained in the decomposition for the single delivery per individual sample (Supplemental Table 3) were largely comparable to the decomposition for the full sample (Table 3); however, the proportion accounted for by hospital fixed-effects was greater (16.2% vs 15.1%, respectively) whereas the proportion explained by sociodemographic factors was less (12.4% vs 14.4%, respectively).

In our sensitivity analyses for which we excluded blood transfusions from the definition of SMM, the odds of SMM for deliveries to both racial groups was greater for maternal age groups over 20 to 29 years (Supplemental Table 4) in comparison to findings for the full sample (Table 2), whereas the odds of SMM were higher for White (not Black) mothers residing in large fringe metropolitan, micropolitan and non-core counties (vs large central metropolitan areas) in comparison to findings for the full sample. For the decomposition analysis for which blood transfusion was excluded from the definition, there was a smaller Black-White difference in SMM (0.688) corresponding to the lower SMM rate for Black and White individuals (1.526 and 0.838 per 100 deliveries, respectively) in comparison with findings from the full sample; however, the proportion of the gap explained was greater (34.4% vs 30% for model 1; 53.2% vs 49.8% for model 2) (Supplemental Table 5, Table 3).

Comment

Principal findings

In Georgia, models with hospital fixed-effects explain a substantially greater proportion of the Black-White gap in SMM during delivery through 42 days postpartum for 2016 to 2020 than models without them (49.8% vs 30.4%); and hospital fixed-effects were the largest explanatory contributor (15.1%). This finding suggests that care processes and other unmeasured factors within the same delivery hospital may differ in a way that translates into racial differences in SMM during delivery through 42 days postpartum. Of near equal explanatory importance to the Black-White SMM gap were access to care (14.9%) and sociodemographic factors (14.4%). Smaller proportions were explained by medical factors (5.6%), obstetrical factors (4.0%), and time-varying hospital factors (3.2%). Within

TABLE 2
Odds of severe maternal morbidity during delivery through 42 days postpartum according to sociodemographic, medical, obstetric, access, hospital, and residential factors for Non-Hispanic Blacks and Whites in Georgia, 2016 to 2020

	Model 1[a]		Model 2[b] Hospital Fixed-effects	
Delivery Characteristics	Non-Hispanic Black (n=183,767) Odds ratio (95% CI)	Non-Hispanic White (n=229,357) Odds ratio (95% CI)	Non-Hispanic Black (n=183,767) Odds ratio (95% CI)	Non-Hispanic White (n=229,357) Odds ratio (95% CI)
Maternal sociodemographic factors				
Age (y): <20	1.14 (1.02–1.28)	0.98 (0.84–1.14)	1.15 (1.03–1.28)	0.98 (0.84–1.14)
20–29	Ref.	Ref.	Ref.	Ref.
30–34	1.09 (1.02–1.17)	1.08 (1.00–1.18)	1.09 (1.02–1.18)	1.07 (0.99–1.17)
35–39	1.22 (1.12–1.33)	1.41 (1.27–1.56)	1.23 (1.12–1.34)	1.39 (1.25–1.54)
40–44	1.56 (1.36–1.80)	1.78 (1.50–2.12)	1.57 (1.36–1.81)	1.73 (1.45–2.07)
45 +	2.32 (1.57–3.42)	3.48 (2.19–5.53)	2.41 (1.63–3.57)	3.43 (2.15–5.46)
Education: <High school	Ref.	Ref.	Ref.	Ref.
High school graduate	0.95 (0.87–1.04)	0.82 (0.73–0.92)	0.98 (0.90–1.07)	0.84 (0.75–0.94)
Some college	0.84 (0.77–0.92)	0.71 (0.63–0.80)	0.87 (0.79–0.96)	0.72 (0.64–0.81)
US born	1.03 (0.93–1.15)	1.03 (0.88–1.21)	0.99 (0.89–1.11)	1.03 (0.88–1.21)
Married	0.91 (0.85–0.98)	0.89 (0.82–0.96)	0.91 (0.85–0.98)	0.89 (0.82–0.97)
Medical factors				
Diabetes mellitus	1.48 (1.29–1.71)	1.85 (1.52–2.25)	1.48 (1.28–1.71)	1.89 (1.55–2.31)
Gestational diabetes	0.99 (0.90–1.09)	1.05 (0.94–1.17)	0.99 (0.90–1.09)	1.06 (0.95–1.18)
Chronic hypertension	1.89 (1.75–2.04)	1.48 (1.31–1.67)	1.84 (1.71–1.99)	1.50 (1.33–1.70)
Gestational hypertension	2.35 (2.21–2.49)	2.47 (2.30–2.66)	2.26 (2.13–2.40)	2.42 (2.25–2.61)
Smoker	1.12 (1.03–1.22)	1.16 (1.06–1.26)	1.08 (0.99–1.17)	1.15 (1.05–1.25)
Obstetrical factors				
Prior Births: None	Ref.	Ref.	Ref.	Ref.
1	0.95 (0.88–1.02)	0.69 (0.64–0.75)	0.94 (0.88–1.01)	0.69 (0.64–0.75)
2	1.00 (0.92–1.08)	0.83 (0.76–0.92)	1.00 (0.92–1.08)	0.83 (0.75–0.92)
3 or more	1.18 (1.09–1.28)	0.98 (0.87–1.10)	1.19 (1.09–1.29)	0.98 (0.87–1.10)
Singleton	0.34 (0.29–0.40)	0.34 (0.28–0.42)	0.33 (0.28–0.39)	0.34 (0.27–0.42)
Access to care				
Payer at delivery: Private	Ref.	Ref.	Ref.	Ref.
Medicaid	1.04 (0.96–1.12)	1.21 (1.10–1.32)	1.02 (0.95–1.10)	1.21 (1.11–1.33)
Self-pay	1.19 (1.00–1.40)	1.65 (1.35–2.02)	1.08 (0.91–1.28)	1.57 (1.28–1.92)
Other payer	1.19 (1.02–1.38)	1.16 (0.97–1.38)	1.12 (0.95–1.32)	1.04 (0.86–1.26)
No or third trimester prenatal care	1.12 (1.03–1.22)	1.19 (1.04–1.37)	1.09 (1.00–1.19)	1.15 (1.00–1.33)
Hospital Characteristics[c]				
Ownership: For-profit	Ref.	Ref.	Ref.	Ref.
Government hospital	1.51 (1.25–1.83)	1.40 (1.15–1.71)		
Non-Profit hospital	1.55 (1.36–1.76)	1.27 (1.10–1.47)		
Religious affiliation	0.66 (0.50–0.88)	0.66 (0.52–0.83)		

(continued)

TABLE 2
Odds of severe maternal morbidity during delivery through 42 days postpartum according to sociodemographic, medical, obstetric, access, hospital, and residential factors for Non-Hispanic Blacks and Whites in Georgia, 2016 to 2020 *(continued)*

	Model 1[a]		Model 2[b] Hospital Fixed-effects	
Delivery Characteristics	Non-Hispanic Black (n=183,767) Odds ratio (95% CI)	Non-Hispanic White (n=229,357) Odds ratio (95% CI)	Non-Hispanic Black (n=183,767) Odds ratio (95% CI)	Non-Hispanic White (n=229,357) Odds ratio (95% CI)
Teaching Status: None	Ref.	Ref.	Ref.	Ref.
Minor teaching	0.88 (0.81–0.97)	0.80 (0.73–0.87)		
Major teaching	1.38 (1.24–1.54)	0.98 (0.86–1.12)		
Perinatal Level: 0 or 1	Ref.	Ref.	Ref.	Ref.
2	1.00 (0.84–1.19)	1.00 (0.86–1.16)		
3 or 4	1.19 (0.97–1.45)	1.08 (0.90–1.30)		
Delivery volume: highest quartile	Ref.	Ref.	Ref.	Ref.
Second quartile	0.93 (0.84–1.02)	0.75 (0.67–0.84)	1.15 (0.93–1.41)	0.93 (0.73–1.19)
Third quartile	1.03 (0.86–1.22)	0.86 (0.72–1.04)	1.50 (0.98–2.30)	0.92 (0.58–1.44)
Lowest quartile	1.66 (1.24–2.23)	1.11 (0.82–1.51)	1.19 (0.49–2.89)	1.08 (0.37–3.19)
Deliveries per RN FTE	1.02 (1.00–1.04)	1.04 (1.02–1.06)	0.98 (0.94–1.02)	1.00 (0.95–1.04)
Patient safety indicator score (PSI)	0.73 (0.60–0.89)	1.27 (1.01–1.60)	0.89 (0.69–1.15)	1.60 (1.17–2.17)
Doctor communication	1.03 (1.02–1.04)	1.03 (1.01–1.04)	1.02 (1.01–1.04)	1.01 (0.99–1.03)
Residential characteristics				
Residential area:				
Large central metropolitan	Ref.	Ref.	Ref.	Ref.
Large fringe metropolitan	0.88 (0.78–0.99)	1.01 (0.83–1.24)	1.18 (1.03–1.35)	1.18 (0.96–1.45)
Medium metropolitan	0.68 (0.60–0.78)	0.64 (0.51–0.80)	0.94 (0.70–1.26)	1.06 (0.79–1.44)
Small metropolitan	0.73 (0.64–0.84)	0.84 (0.68–1.04)	1.05 (0.81–1.38)	1.19 (0.92–1.54)
Micropolitan	0.79 (0.67–0.93)	0.99 (0.79–1.24)	1.31 (0.99–1.72)	1.33 (1.03–1.72)
Noncore	0.82 (0.68–0.99)	0.98 (0.77–1.24)	1.20 (0.89–1.61)	1.33 (1.01–1.75)
Neighborhood deprivation index (NDI)	1.03 (0.99–1.07)	1.05 (0.99–1.12)	1.02 (0.98–1.06)	1.03 (0.96–1.10)
Percent uninsured women of reproductive age (WRA)	0.88 (0.57–1.37)	0.63 (0.34–1.18)	0.93 (0.59–1.46)	0.78 (0.41–1.49)
Obstetrician/gynecologists per 10,000 WRA	1.01 (1.00–1.02)	1.00 (0.99–1.02)	1.01 (0.99–1.02)	1.00 (0.98–1.01)
FQHC	0.98 (0.97–0.99)	0.98 (0.97–1.00)	1.00 (0.99–1.01)	0.99 (0.97–1.01)
Medically underserved area (Yes)	0.97 (0.87–1.08)	1.01 (0.9–1.13)	1.00 (0.89–1.13)	0.99 (0.88–1.12)
Number of community mental health centers	1.04 (0.98–1.11)	1.02 (0.95–1.11)	0.93 (0.87–1.00)	1.01 (0.93–1.10)
Year of Delivery: 2016	Ref.	Ref.	Ref.	Ref.
2017	1.06 (0.97–1.15)	0.98 (0.89–1.09)	1.05 (0.96–1.15)	0.98 (0.89–1.09)
2018	1.01 (0.93–1.11)	1.00 (0.90–1.11)	1.01 (0.93–1.11)	0.95 (0.85–1.05)
2019	1.04 (0.95–1.13)	1.06 (0.96–1.17)	1.04 (0.95–1.15)	1.00 (0.90–1.11)
2020	1.33 (1.21–1.47)	1.19 (1.07–1.33)	1.24 (1.11–1.38)	1.08 (0.95–1.22)

CI, confidence interval; *FQHC*, federally-qualified health center; *FTE*, fulltime equivalent; *NDI*, Neighborhood deprivation index; *RN*, registered nurse; *WRA*, women of reproductive age.

[a] Adjusted for all characteristics presented; [b] Adjusted for all characteristics presented and hospital fixed-effects. Hospital fixed-effects are not shown. Time invariant hospital characteristics of hospital ownership, teaching status, and perinatal level excluded from fixed-effects models.

Adams. Examining the Black-White gap in severe maternal morbidity. Am J Obstet Gynecol Glob Rep 2024.

TABLE 3
Decomposition of the Black-White difference in SMM during delivery through 42 days postpartum

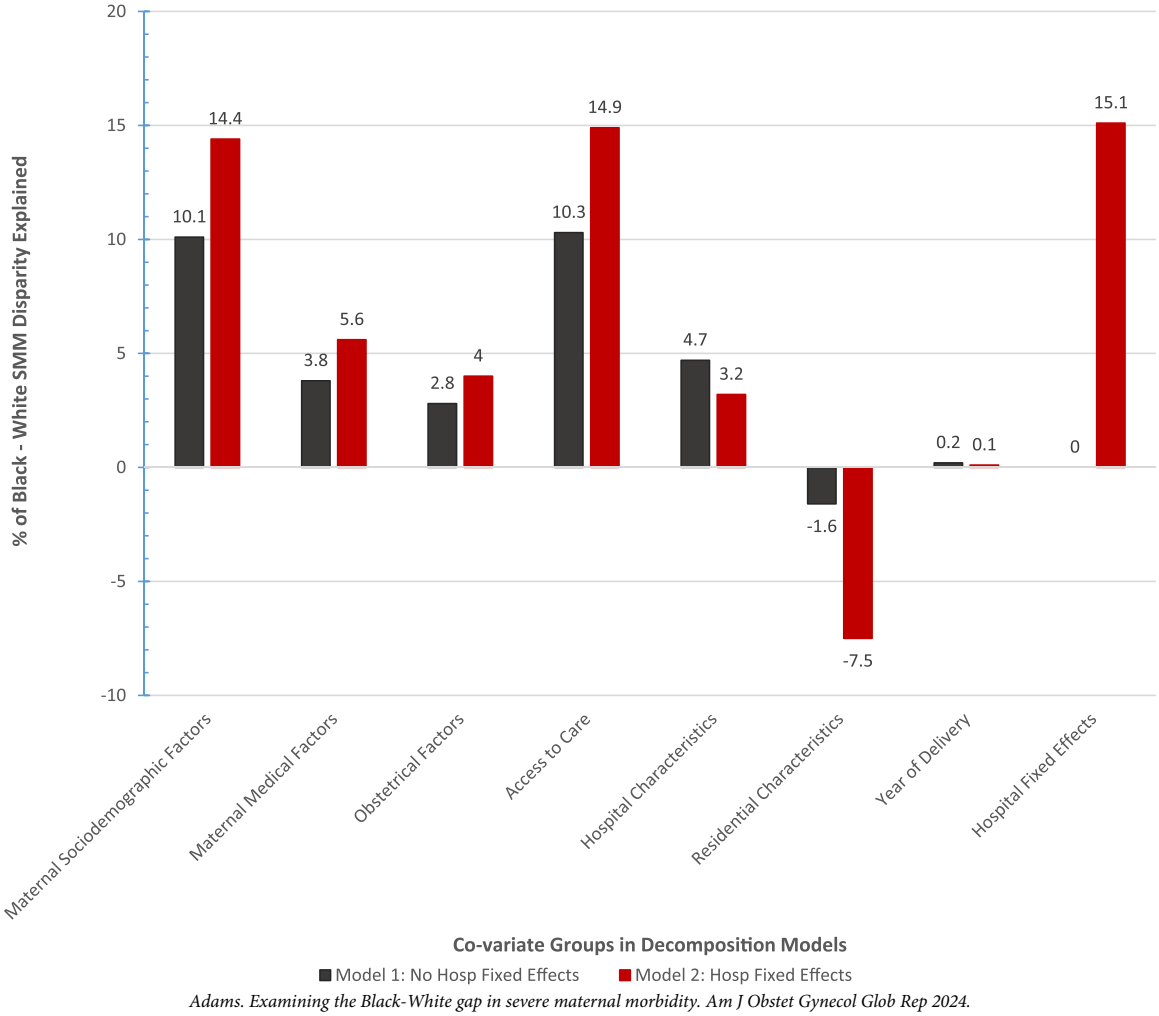
Characteristics	Model 1[a] Non-Hispanic Black and White (n=413,124)	Model 2[b] Hospital Fixed-effects Non-Hispanic Black and White (n=413,124)
SMM rate (per 100 deliveries) delivery to 42 days postpartum: Black-White difference	1.421	1.421
Explained gap $(\overline{X}_b - \overline{X}_w)'\hat{\beta}_w$	0.431 (30.4%)[c]	0.708 (49.8%)[c]
Maternal sociodemographic factors	0.144 (10.1%)[c]	0.205 (14.4%)[c]
Married	7.6%	10.3%
Education	4.3%	6.4%
US born	-0.2%	-0.3%
Age	-1.6%	-2.1%
Medical factors	0.054 (3.8%)[c]	0.08 (5.6%)[c]
Gestational hypertension	2.4%	3.3%
Chronic hypertension	2.1%	3.1%
Diabetes mellitus	0.6%	0.9%
Gestational diabetes	0.0%	-0.1%
Smoker	-1.2%	-1.6%
Obstetrical factors	0.04 (2.8%)[c]	0.057 (4.0%)[c]
Birth order	2.5%	3.6%
Singleton birth	0.3%	0.5%
Access to care	0.146 (10.3%)[c]	0.211 (14.9%)[c]
Payer type	9.0%	13.3%
No or third trimester prenatal care	1.3%	1.5%
Hospital Characteristics	0.067 (4.7%)[c]	0.046 (3.2%)
Delivery Volume	2.6%	1.3%
Ownership	1.7%	–
Perinatal Level	1.2%	–
Patient Safety Indicator Score	1.1%	3.1%
Deliveries per RN FTE	0.4%	-0.1%
Teaching Status	0.2%	–
Doctor Communication	-2.4%	-1.1%
Residential Characteristics	-0.022 (-1.6%)	-0.107 (-7.5%)
NDI	4.9%	4.0%
Ob/Gyn per 10,000 WRA	0.9%	-0.8%
Number of Comm. Mental Health Centers	0.5%	0.2%
Medically Underserved Area	-0.1%	0.1%
Residential Area	-0.2%	-4.5%
Percent Uninsured WRA	-2.2%	-1.8%
FQHC	-5.3%	-4.7%
Year of Delivery	0.003 (0.2%)**	0.002 (0.1%)
Hospital Fixed-effects	–	0.214 (15.1%)**
Unexplained gap	0.99 (69.6%)[c]	0.713 (50.2%)[c]

FQHC, federally-qualified health center; *FTE*, fulltime equivalent; *NDI*, Neighborhood deprivation index; *RN*, registered nurse; *WRA*, women of reproductive agez.

[a] Adjusted for all characteristics presented; [b] Adjusted for all characteristics presented and hospital fixed-effects. Hospital fixed-effects are not shown. Time-invariant hospital characteristics of hospital ownership, teaching status, and perinatal level excluded from fixed-effects models.; [c] $P<.001$.

Adams. Examining the Black-White gap in severe maternal morbidity. Am J Obstet Gynecol Glob Rep 2024.

FIGURE
Percent of Black-White disparity in severe maternal morbidity explained by covariate groups in a model without (model 1) and with (model 2) hospital fixed-effects



Adams. Examining the Black-White gap in severe maternal morbidity. Am J Obstet Gynecol Glob Rep 2024.

each category, the largest discriminatory contributions were attributable to payer type (13.3%) for access to care, marital status (10.3%) for sociodemographic factors, gestational hypertension (3.3%) and chronic hypertension (3.1%) for medical factors, birth order (3.6%) for obstetrical factors, and patient safety indicator (3.1%) for time-varying hospital characteristics.

Results in context of what is known

Our findings are consistent with national data demonstrating within-hospital racial differences in patient safety indicators and adverse events,[30] other within-hospital analyses,[10,31] and that between-hospital methods of analyzing disparities in adverse hospital outcomes underestimates them.[11] Our findings are also consistent with the earlier study of SMM in New York City,[8] in terms of the importance of delivery hospital in explaining the Black-White gap in SMM. However, our decomposition analysis adds significant new information on the relative importance of sociodemographic, medical, obstetric, access to care, and hospital factors. Further, with respect to hospital factors, our study adds new information on the relative importance of between vs within-hospital effects. Finally, our findings add emphasis to Black-White differences in access to care (especially related to the payer type at delivery) and sociodemographic factors (especially marital status and level of education) as other key determinants of the Black-White gap in SMM through 42 days postpartum.

Clinical and policy implications

Considering that racial differences in processes within the same delivery hospital are most explanatory for Georgia's Black-White gap in SMM during delivery through 42 days postpartum, hospitals should consider employing the existing Alliance for Innovation (AIM) Peripartum Racial and Ethnic Disparities Patient Safety Bundle, which includes developing and implementing a dashboard to monitor disparities in

process and outcome metrics, quality improvement projects around identified disparities, and staff-wide implicit bias training.[32,33] The finding that time-varying hospital characteristics related to quality help explain disparities suggests hospitals also continue to focus on improving measures such as patient safety indicators.

The substantial proportion of the gap attributable to access to care and sociodemographic factors points to the need for broader policy interventions to increase equity in access to care, support for marriage and stable families, as well as educational attainment. For example, the stark differences in marital status for Georgia's Black and White mothers, and its protective effect on SMM risk, reflects need for attention to policies that have led to high rates of unemployment and incarceration among Black men,[34] including safer policing and bail allowances. The stronger protective effect of some college for Black mothers found here suggests policies to promote higher education, through a focus on reducing structural barriers that hinder racial and ethnic minority individuals' attainment (eg, residential segregation).[35,36] Efforts would need to focus on reducing societal and structural barriers that hinder racial and ethnic minority individuals' educational attainment, such as segregation in lower income neighborhoods with fewer and lower opportunities.[37]

The higher prevalence of gestational and chronic hypertension among Black mothers than White mothers, and the stronger effect of chronic hypertension on odds of SMM among Black mothers, underscores both the importance of equitable access to quality care for appropriate diagnosis and management of these conditions as well as attention to other social determinants of health found to associate with their prevalence among reproductive aged women, including food insecurity.[38] As previous research has established that Black mothers are at higher risk of hypertension-related severe morbidities (such as stroke, heart failure, and pulmonary edema),[39] delay in treatment of hypertensive emergency is one of the most important contributing factors to this morbidity, and expeditious treatment of hypertensive emergency reduces the risk of SMM and maternal death,[40] hospitals should adhere to American College of Obstetricians and Gynecologists guidelines for emergency management of severe hypertension[41] and implement the AIM Severe Hypertension in Pregnancy Patient Safety Bundle to achieve related quality improvements.[42]

The Center for American Progress outlines a comprehensive policy framework for addressing US racial disparities in maternal and infant mortality through health, healthcare and social policy approaches.[43] The framework includes policy strategies in 5 key areas, including improving access to critical services, improving quality of care provided to pregnant and individuals, addressing maternal and infant mental health, enhancing support for families before and after birth, and improving data collection and oversight. Within this framework, a number of recommendations relate specifically to our findings.

Research implications

To achieve a better understanding of factors underlying within-hospital Black-White differences in processes, studies should investigate sources of these racial differences—including whether they reflect implicit bias, patient-provider racial discordance, or other factors within the hospitals—and whether targeted interventions can improve care-related differences and, ultimately, health disparities. Given the importance of delivery hospital, there is also need for further research on policies affecting hospital revenue and quality while assuring that safety-net hospitals, which serve more minorities, are not adversely affected.[44–47] Relatedly, given the importance of payer in influencing access to care and hospital of delivery, and the comparatively large percentage of deliveries to Black mothers that are covered by Medicaid, there is a need for further investigation of factors affecting access to Medicaid participating providers as well as potential "segmentation" of Medicaid and private insured markets.[48,49] Future work using Georgia data will investigate hospital choice based on patient preference with physicians acting as their agent. Previous studies indicate that patients, controlling for distance, prefer hospitals with greater service capacity but age, complexity of illness, and patient-physician ties matter; rural residents seeking obstetrical care are willing to bypass their closest hospital for those with higher delivery volume and level of infant services.[50–52] Results of this type of analysis will elucidate the importance of federal and state policies around adequacy of Care Management Organization (CMO) networks for obstetrical care.[53,54] Finally, our findings of the strong protective effect of marital status and some college and higher education in reducing SMM, and the lower prevalence of these protective factors among Black mothers, supports the need for the development and evaluation of innovative social and economic policies that promote increased marriage rates and educational levels among Black families in Georgia.

Strengths and limitations

Our inclusion of all Georgia deliveries linked with a hospital discharge abstract data over a multi-year period, uniform ascertainment of SMM from the discharge abstracts for the delivery or any subsequent hospitalization through 6 weeks (42 days) postpartum, and use of a decomposition analysis not previously applied to SMM represent our study's strengths. Because hospital discharge abstract was required for SMM ascertainment, births that did not link to a hospital discharge record were excluded, representing a limitation.

Conclusions

Addressing racial disparities in SMM in Georgia requires actions not only to ameliorate medical and obstetrical risks that disproportionately affect Black mothers but also to address socioeconomic and structural factors that disproportionately impact them. In particular, the significant percentage of the explained Black-White SMM disparity related to site of delivery points

to the need for further investigation of underlying contributors to within-hospital differences in processes and quality for non-Hispanic Black and White individuals, as well as the need for targeting quality improvement and bias training efforts within-hospitals. ■

CRediT authorship contribution statement

E. Kathleen Adams: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing − original draft, Writing − review & editing. **Michael R. Kramer:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing − review & editing, Supervision. **Peter J. Joski:** Formal analysis, Investigation, Writing − review & editing. **Marissa Coloske:** Investigation, Writing − review & editing. **Anne L. Dunlop:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Writing − original draft, Writing − review & editing. ■

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.xagr.2023.100303.

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