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Editor's Choice

Severe Maternal Morbidity and Mortality Risk at the Intersection of Rurality, Race and Ethnicity, and Medicaid

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A B S T R A C T

Objective: We examined differences in rates of severe maternal morbidity and mortality (SMMM) among Medicaid-funded compared with privately insured hospital births through specific additive and intersectional risk by rural or urban geography, race and ethnicity, and clinical factors.
Methods: We used maternal discharge records from childbirth hospitalizations in the Healthcare Cost and Utilization Project's National Inpatient Sample from 2007 to 2015. We calculated predicted probabilities using weighted multivariable logistic regressions to estimate adjusted rates of SMMM, examining differences in rates by payer, rurality, race and ethnicity, and clinical factors. To assess the presence and extent of additive risk by payer, with other risk factors, on rates of SMMM, we estimated the proportion of the combined effect that was due to the interaction.
Results: In this analysis of 6,357,796 hospitalizations for childbirth, 2,932,234 were Medicaid funded and 3,425,562 were privately insured. Controlling for sociodemographic and clinical factors, the highest rate of SMMM (224.9 per 10,000 births) occurred among rural Indigenous Medicaid-funded births. Medicaid-funded births among Black rural and urban residents, and among Hispanic urban residents, also experienced elevated rates and significant additive interaction. Thirty-two percent (Bonferroni-adjusted 95% confidence interval, 19%–45%) of SMMM cases among patients with chronic heart disease were due to payer interaction, and 19% (Bonferroni-adjusted 95% confidence interval, 17%–22%) among those with cesarean birth were due to the interaction.
Conclusions: Heightened rates of SMMM among Medicaid-funded births indicate an opportunity for tailored state and federal policy responses to address the particular maternal health challenges faced by Medicaid beneficiaries, including Black, Indigenous, and rural residents.

In the United States, maternal health is marked by long-standing inequities based on income, geography, and race and ethnicity (Admon et al., 2018; Kozhimannil, Interrante, Henning-Smith, & Admon, 2019). Addressing high rates of severe maternal morbidity and mortality (SMMM) and maternal health equity are top policy priorities (State Policies to Improve Maternal Health Outcomes, 2020). Every year in the United States, approximately 700 people die from pregnancy-related causes, and more than 50,000 individuals per year experience severe maternal morbidity (potentially life-threatening complications of childbirth, including blood clots, acute renal failure, shock, cardiac arrest, respiratory distress, amniotic fluid embolism, eclampsia, and anesthesia complications) (Centers for Disease Control and Prevention, 2019; Creanga et al., 2014). The incidence of SMMM increased by 40% between 2007 and 2015 in the United States (Kozhimannil et al., 2019).

There are known differences in risk of SMMM by rural/urban geography and by race and ethnicity (Kozhimannil et al., 2019;

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Luke et al., 2021; Petersen et al., 2019). Rural individuals giving birth face higher risks for adverse health outcomes, more limited access to healthcare around pregnancy, and higher rates of SMMM (Kozhimannil, Hung, Prasad, Casey, & Moscovice, 2014; Kozhimannil et al., 2019; Luke et al., 2021). Non-Hispanic Black (Black) and American Indian/Alaska Native (Indigenous) birthing people have nearly three times the risk of mortality and heightened risk of morbidity, compared with those who are non-Hispanic White (White) (Admon et al., 2018; Petersen et al., 2019), and some of the highest risks occur among Black and Indigenous people who are rural residents (Kozhimannil, Interrante, Tofte, & Admon, 2020; Luke et al., 2021).

The same groups at an increased risk for SMMM—Black, Indigenous, and rural residents—are over-represented among individuals with Medicaid-funded births (Foutz, Artiga, & Garfield, 2017; Kaiser Family Foundation, 2016). Pregnant Medicaid beneficiaries are at an increased risk of adverse neonatal outcomes because they tend to have worse overall health status and a greater prevalence of chronic conditions such as diabetes, hypertension, and obesity, which may also increase the risk of SMMM (Admon et al., 2017; MACPAC, 2018). Pregnancy-related Medicaid eligibility varies across states but is tied to income (ranging from a Federal Poverty Level threshold for eligibility of 138% in Idaho and South Dakota to 380% in Iowa); as such, pregnant Medicaid beneficiaries may also face considerable financial constraints compared with privately insured pregnant people (Kaiser Family Foundation, 2021b). Socioeconomic status, structural factors such as urbanism and racism, and other social determinants of health also influence maternal health inequities (Bailey et al., 2017; Gadson, Akpovi, & Mehta, 2017; Probst, Eberth, & Crouch, 2019). In 2020, 42% of U.S. births were funded by Medicaid (Kaiser Family Foundation, 2021a).

Findings from a handful of studies indicate that Medicaid beneficiaries may also be at increased risk for SMMM (Brown, Adams, & Moore, 2021; Creanga et al., 2014; Fingar, Hambrick, Heslin, & Moore, 2006). However, these studies have limitations, including some not controlling for confounding, not statistically comparing risk factors by payer, and not examining intersectional effects on risks. Building on prior studies, we examined differences in risk of SMMM for Medicaid-funded compared with privately insured hospital births among U.S. residents through specific additive and intersectional risk by rural or urban geography, race and ethnicity, and clinical factors to better understand the interplay between Medicaid and other correlated sociodemographic and clinical factors that may contribute to SMMM.

Methods

We obtained hospital discharge data for childbirth hospitalizations between 2007 and 2015 from the National Inpatient Sample (NIS), a nationally representative sample of all-payer inpatient claims collected by the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (HCUP, 2019). Maternal records from childbirth hospitalizations were identified using standard methods (Kuklina et al., 2008). This multiyear, cross-sectional study of de-identified data was deemed exempt by the Institutional Review Board at the University of Minnesota.

The primary outcome variable was a composite measure of SMMM during the childbirth hospitalization, defined by *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) and coded using a standard algorithm provided by the Centers for Disease Control and Prevention (Admon et al., 2018; Centers for Disease Control and Prevention, 2021). We also examined a dichotomized, mutually exclusive measure of SMMM in supplemental analyses: 1) SMMM excluding cases in which blood transfusion was the only indicator of SMMM and 2) SMMM in which blood transfusion was the only indicator of SMMM. SMMM without blood transfusion is sometimes used as a stand-alone measure of SMMM given the relative frequency of blood transfusion compared with the other individual indicators of SMMM and the limitations of administrative data for measuring blood transfusion (Himes & Bodnar, 2020; Main et al., 2016).

The main predictor was primary payer (i.e., insurance payer for the childbirth hospitalization), categorized as Medicaid (both fee-for-service and managed care) or private insurance. These are the most common primary payers of childbirth hospitalizations, and, as such, were the focus of comparison for this analysis. Only 5.5% of records indicated no insurance, and 0.7% had Medicare and were excluded from this analysis (Appendix Figure A). The main sociodemographic variables of interest were rural/urban maternal residence and maternal race and ethnicity. Metropolitan (urban—population centers of $\geq$50,000) or either micropolitan or noncore (rural—population centers of $<$50,000 or no population center) residency was determined at the county level, based on the Office of Management and Budget's standard definition of Metropolitan Statistical Areas and provided in the NIS (HCUP, 2019). Records with missing data on rural or urban residency (1.3%) were excluded from the analyses. Race and ethnicity were examined as indicators of maternal health risks driven by racism, encompassing the social, environmental, and structural factors that result in outcomes that differ by race and by ethnicity (Boyd, Lindo, Weeks, & McLemore, 2020). Race and ethnicity, as classified by HCUP (HCUP, 2019), was reported as one of six categories (White, Black, Hispanic, Asian or Pacific Islander, Indigenous, and other or unknown). Patients with missing data on race and ethnicity (17% of records in this analysis) were included in the other or unknown category; such missing data are a known challenge with using information from the NIS and are considered not missing at random (HCUP, 2016).

Patient clinical conditions were selected a priori based on known associations and correlates with SMMM. These were coded as binary indicator variables—cesarean birth, chronic respiratory disease, chronic hypertension, diabetes (preexisting or gestational), chronic heart disease, chronic kidney disease, pulmonary hypertension, systemic lupus erythematosus, HIV/AIDS, substance use disorder, and depression—and were identified using ICD-9-CM diagnosis codes defined in prior work (Admon et al., 2017; Bansil et al., 2010; Bateman et al., 2013; Kozhimannil et al., 2019).

Other patient sociodemographic characteristics included age, year of childbirth hospitalization, median income quartile for ZIP code of residence, and hospital region. Patient age was categorized (10–24, 25–29, 30–34, or 35–55 years) to allow for curvilinear associations and year was included as a fixed effect. We added an indicator for patients who lived in a ZIP code where the median income was in the bottom national income quartile. Hospital region was categorized as Northeast, Midwest, South, or West. Patients ages of less than 10 or more than 55 years (outside the range of biological plausibility for childbirth; $<$0.01%) and those with missing values for patient characteristics (except for race and ethnicity; 3.0%) were excluded for complete case analyses.

Statistical Analysis

We conducted a pooled, cross-sectional analysis of maternal discharge records from childbirth hospitalizations. Analyses were weighted using weights provided by HCUP for use with NIS data to allow for national inference, consistent with guidance for the use of these data (HCUP, 2018). ICD-9-CM diagnosis codes were available for only the first three quarters of 2015; therefore, survey weights were adjusted in 2015 to generate annualized estimates (Elixhauser, Heslin, & Owens, 2017). We used weighted frequencies and 95% confidence intervals (CIs) to describe the unadjusted prevalence of SMMM, as well as sociodemographic and clinical risk factors for SMMM by primary payer. Unadjusted differences were compared statistically using Rao-Scott χ^2 tests for categorical variables and two-sample *t* tests for continuous variables.

We calculated predicted probabilities using weighted multivariable logistic regression models to generate adjusted predicted rates and adjusted rate differences (aRDs) by payer of SMMM per 10,000 births with Bonferroni-adjusted 95% CIs (aCIs). We included payer interaction terms in models to examine whether sociodemographic characteristics (rurality, race and ethnicity, and the intersection of rurality and race and ethnicity) and clinical risk factors for SMMM differed between Medicaid-funded compared with privately insured births.

To evaluate the significance of payer interaction with sociodemographic and clinical variables, we assessed the interaction on the additive scale, rather than the multiplicative odds ratio scale, which methodologists have argued is the appropriate way to assess the presence of synergistic effects (Rothman, 2002; VanderWeele & Robins, 2007). Additive interaction tells us whether the joint effect of two factors (payer and each risk factor) was greater than the sum of its individual effects. That is, we examined whether the two factors interacted to increase the risk of SMMM above and beyond what would be found if the individual risks were simply added together. We tested for additive interaction by calculating the attributable proportion of SMMM risk owing to interaction (AP; the proportion of the combined effect that is due to the interaction), the relative excess risk owing to interaction (RERI; the part of the total effect that is due to the interaction), and the synergy index (S; the excess risk from having both factors when interaction exists relative to the risk when interaction does not exist) (Andersson, Alfredsson, Källberg, Zdravkovic, & Ahlbom, 2005), with aCIs and *p* values for each measure calculated using the delta method (Hosmer & Lemeshow, 1992). An AP and RERI of zero and an S of one suggest no additive interaction.

In supplemental analyses, we calculated adjusted odds ratios with aCIs using the models described elsewhere in this article for our composite and our dichotomized SMMM measures (also described elsewhere in this article) to compare our results with prior studies. We present additive interaction *p* values in these supplemental analyses to summarize the additive interaction effects across the different measures.

All models were adjusted for each of the sociodemographic and clinical characteristics listed above. To ensure that a 5% type I error rate was maintained for tests of interaction within each model, Bonferroni corrections were used, setting the alpha to 0.05/14 (e.g., 99.6% CIs). All analyses were performed with SAS 9.4 (SAS Institute, Cary, NC) and Stata 16.0 (StataCorp, College Station, TX).

Results

The analytic sample included 2,932,234 (unweighted) Medicaid-funded and 3,425,562 (unweighted) privately insured births that occurred in US hospitals between 2007 and 2015 (Appendix Figure A). Medicaid-funded births were more often rural residents (Medicaid, 16.3% [95% CI, 15.5–17.1]; private, 12.5% [95% CI, 11.9–13.1]) and less often White (Medicaid, 33.9% [95% CI, 32.8–35.0]; private insurance, 57.0% [95% CI, 55.6–58.3]) compared with their privately insured counterparts (Table 1). Cesarean birth, diabetes, and chronic heart disease were less common, whereas chronic respiratory disease, HIV/AIDS, and substance use disorder were more common among Medicaid-funded births than those privately insured ($p < .001$ for all comparisons). At the intersection of rural/urban residence and race and ethnicity, Medicaid was the most common payer for births among Black (76.2%; 95% CI, 74.6–77.8) and Indigenous (74.4%; 95% CI, 69.2–79.6) rural residents, while it was the least common among Asian or Pacific Islander (27.6%; 95% CI, 25.2–30.0) and White (30.2%; 95% CI, 29.3–31.2) urban residents (Appendix Figure B).

In unadjusted weighted assessments, composite SMMM occurred more frequently among Medicaid-funded births compared with the privately insured (Medicaid, 1.6% [95% CI, 1.6–1.6]; private, 1.1% [95% CI, 1.1–1.1]), largely owing to higher rates of blood transfusion among Medicaid-funded births (Medicaid, 1.1% [95% CI, 1.1–1.2]; private, 0.7% [95% CI, 0.7–0.8]) (Table 1). These cases of SMMM included 200 maternal deaths during the study period identified among Medicaid-funded births and 140 among those privately insured (data not shown). Across all 24 categories of Medicaid/private insurance by rural/urban residence by race and ethnicity, four of the top five highest incidences of composite SMMM occurred among births by Black birthing people (privately insured urban, range, 2.0% [95% CI, 1.9–2.0]; Medicaid-funded rural, 2.5% [95% CI, 2.2–2.6]). Rural and urban Medicaid-funded births to people who were Hispanic or Indigenous also had incidences of SMMM among the top 10 highest (Figure 1).

In adjusted analyses, we found a significantly greater rate of SMMM among Medicaid-funded births compared with those privately insured for both rural and urban residents and for all racial and ethnic groups (Table 2, Appendix Figure C). Urban Medicaid-funded births had an adjusted predicted SMMM rate of 33.1 per 10,000 births (aCI, 29.5–36.6) more than those with private insurance; similarly, rural Medicaid-funded births had an adjusted SMMM rate of 31.7 per 10,000 births (aCI, 25.0–38.3) more than privately insured births. However, there was no evidence of an additive interaction between payer and rural or urban residence. Indigenous Medicaid-funded births experienced an SMMM rate of 47.9 per 10,000 births (aCI, 21.6–74.2) more than their privately insured counterparts, and Black Medicaid-funded births faced SMMM of 39.7 per 10,000 births (aCI, 31.9–47.5) more than their privately insured counterparts. Comparatively, White Medicaid-funded births had an SMMM rate of 23.9 per 10,000 births (aCI, 20.6–27.2) more than White privately insured births, the lowest racial and ethnic difference in rates between Medicaid and privately insured births. Only births among Black and Hispanic birthing people experienced significant additive interaction between payer and race and ethnicity, both with APs of 0.09. This means that, in each group, 9% (aCI, 3%–14% and 2%–16%, respectively) of SMMM cases among births that were both Medicaid funded and either Black or Hispanic were due to the interaction of the two factors.

We found wide-ranging differences in rates of SMMM between Medicaid-funded and privately insured births based on clinical characteristics. Having chronic kidney disease or chronic heart disease each had an adjusted predicted SMMM rate of

Table 1
Unadjusted Sociodemographic and Clinical Characteristics of Medicaid-Funded and Privately Insured Hospital Births, United States 2007–2015 (Unweighted $N = 6{,}357{,}796$)*

Characteristic	Medicaid Funded Hospital Births (Unweighted $n = 2{,}932{,}234$)	Privately Insured Hospital Births (Unweighted $n = 3{,}425{,}562$)	p Value†
	Weighted Percent (95% CI)	Weighted Percent (95% CI)	
SMMM Measures			
Composite SMMM	1.6 (1.6–1.6)	1.1 (1.1–1.1)	<.001
SMMM excluding blood transfusion	0.5 (0.4–0.5)	0.4 (0.4–0.4)	<.001
Blood transfusion only	1.1 (1.1–1.2)	0.7 (0.7–0.8)	<.001
Residence‡			<.001
Urban	83.7 (82.9–84.5)	87.5 (86.9–88.1)	
Rural	16.3 (15.5–17.1)	12.5 (11.9–13.1)	
Race and ethnicity			<.001
Non-Hispanic White	33.9 (32.8–35.0)	57.0 (55.6–58.3)	
Non-Hispanic Black	18.1 (17.2–18.9)	7.7 (7.2–8.1)	
Hispanic	29.0 (27.5–30.5)	10.8 (10.2–11.4)	
Asian or Pacific Islander	2.9 (2.6–3.2)	6.2 (5.7–6.8)	
American Indian/Alaska Native	0.9 (0.8–1.1)	0.5 (0.4–0.6)	
Unknown/other	15.2 (14.0–16.4)	17.9 (16.3–19.4)	
Age (weighted mean [SD])	25.6 [0.06]	29.8 [0.05]	<.001
10–24	48.7 (48.3–49.1)	17.4 (16.9–17.8)	<.001
25–29	27.0 (26.9–27.1)	29.3 (29.0–29.6)	
30–34	15.7 (15.5–15.9)	33.0 (32.7–33.3)	
≥35	8.6 (8.4–8.7)	20.3 (19.9–20.8)	
Year			<.001
2007	12.0 (10.6–13.3)	12.2 (10.8–13.7)	
2008	10.8 (9.6–12.1)	12.0 (10.6–13.3)	
2009	11.4 (10.2–12.7)	11.0 (9.8–12.3)	
2010	11.1 (9.9–12.2)	10.2 (9.0–11.3)	
2011	10.6 (9.3–11.9)	10.4 (9.2–11.6)	
2012	11.1 (10.4–11.9)	10.8 (10–11.5)	
2013	10.9 (10.2–11.6)	10.9 (10.1–11.6)	
2014	11.0 (10.3–11.7)	11.2 (10.4–11.9)	
2015§	11.0 (10.4–11.7)	11.4 (10.6–12.1)	
Income: bottom quartile‖	40.5 (39.3–41.7)	16.6 (15.9–17.3)	<.001
Hospital region			<.001
Northeast	12.6 (11.6–13.6)	16.8 (15.4–18.2)	
Midwest	18.9 (17.8–20.1)	24.6 (22.9–26.3)	
South	43.7 (41.8–45.5)	33.6 (31.6–35.6)	
West	24.8 (23.1–26.5)	25.0 (23.2–26.8)	
Cesarean birth	31.6 (31.3–31.9)	34.6 (34.2–34.9)	.011
Substance use disorder	2.8 (2.7–2.9)	0.5 (0.4–0.5)	<.001
Depression	2.2 (2.1–2.3)	2.1 (2.0–2.1)	.096
HIV or AIDS	0.1 (0.1–0.2)	0.04 (0.04–0.05)	<.001
Pulmonary hypertension	0.03 (0.02–0.03)	0.01 (0.01–0.02)	<.001
Systemic lupus erythematosus	0.1 (0.09–0.1)	0.1 (0.1–0.1)	<.001
Chronic kidney disease	0.3 (0.3–0.3)	0.2 (0.2–0.3)	<.001
Chronic heart disease	0.3 (0.3–0.3)	0.5 (0.5–0.5)	<.001
Diabetes¶	6.9 (6.8–7.0)	7.5 (7.3–7.6)	<.001
Chronic hypertension	2.1 (2.0–2.2)	2.2 (2.1–2.2)	<.001
Chronic respiratory disease	3.9 (3.8–4.1)	3.3 (3.2–3.4)	<.001

Abbreviations: CI, confidence interval; SD, standard deviation; SMMM, severe maternal morbidity and mortality.

* Percentages are weighted to represent the childbearing U.S. population. Data are complete case based; therefore, no missing data are represented (except for race and ethnicity where missing data was included in the unknown/other category to control for large numbers of missing data from many states in earlier years). Payer (Medicaid or private) represents the expected primary payer at birth. Medicaid includes fee-for-service and managed care.

† p values are Rao–Scott χ^2 or two-sample t tests.

‡ Rural residence is defined as counties with population centers of <50,000 or no population center; urban residence is counties with population centers of ≥50,000.

§ In 2015, *ICD-9-CM* diagnoses codes were available only for the first three quarters, and survey weights were adjusted in 2015 to generate annualized estimates from these data.

‖ Quartiles of the estimated median household income of residents within the patient's ZIP code within each year.

¶ Diabetes includes both preexisting and gestational diabetes mellitus.

more than 100 per 10,000 births more for Medicaid-funded births than those with private insurance, and those with systemic lupus erythematosus, cesarean birth, and chronic hypertension also had elevated differences in rates. The most significant additive interaction was found with chronic heart disease and cesarean birth, with 32% (aCI, 19%–45%) of SMMM cases among births who were both Medicaid funded and had chronic heart disease owing to the interaction and 19% (aCI, 17%–22%) among births who were both Medicaid funded and had cesarean birth owing to the interaction.

We examined SMMM differences between Medicaid-funded births and those privately insured at the intersection of rurality and race and ethnicity (Table 3). Rural Indigenous Medicaid-funded births had the highest adjusted predicted rate of SMMM (224.9 per 10,000 births; aCI, 187.0–262.9), followed by urban Black (210.9 per 10,000 births; aCI, 202.8–219.0) and rural

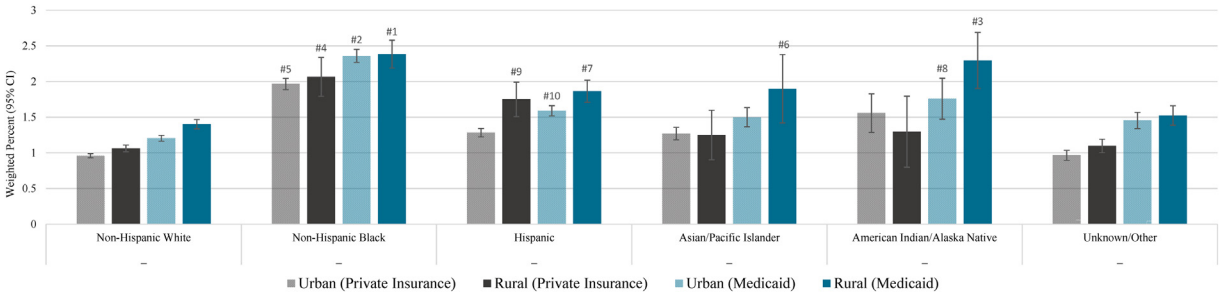

Figure 1. Unadjusted weighted differences in severe maternal morbidity and mortality by race and ethnicity, rural/urban residence, and Medicaid-funded and privately insured hospital births in the United States from 2007 to 2015 (unweighted $N = 6{,}357{,}796$). Data are weighted to represent the childbearing U.S. population. In 2015, *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis codes were available only for the first three quarters, and survey weights were adjusted in 2015 to generate annualized estimates from these data. Data are complete case based; therefore. no missing data are represented (except for race and ethnicity where missing data was included in the unknown/other category to control for large numbers of missing data from many states in earlier years). Rural residence is defined as counties with population centers of less than 50,000 or no population center; urban residence is counties with population centers of 50,000 or more. Medicaid represents the expected primary payer at delivery and includes fee-for-services and managed care. Error bars represent 95% confidence intervals. Number labels on top of bars indicate the groups with the 10 highest incidences of severe morbidity and mortality across categories shown, with #1 showing the highest incidence.

Black Medicaid-funded births (207.9 per 10,000 births; aCI, 191.8–223.9). Among rural residents, births by Indigenous people had the greatest differences in rates between Medicaid-funded and privately insured births (aRD, 97.8; aCI, 50.4–145.3), and among urban residents, the greatest difference based on payer (Medicaid vs. private insurance) was among Black births (aRD, 41.2; aCI, 33.0–49.3). Unlike the previous model, where rural residency alone showed no additive interaction with payer, when examining the intersection of rurality and race and ethnicity, births among Indigenous rural residents had significant additive interaction, with 40% (aCI, 11%–69%) of SMMM cases in that population owing to the interaction. The significant additive interaction found among Black and Hispanic births in the previous model was largely among urban, rather than rural, residents, with 16% (aCI, 10%–21%) and 19% (aCI, 11%–26%), respectively, owing to the interaction. As an example in interpreting these findings in terms of cases of SMMM, these results suggest that, if the excess risk of SMMM associated with Medicaid could be mitigated (i.e., if the risk of SMMM among Medicaid-funded births could be decreased to the risk among the privately insured), this would not only prevent the 23 cases per 10,000 births that occur among White urban residents, but an additional 98 cases per 10,000 births among Indigenous rural residents, 41 cases per 10,000 births among Black urban residents, and 38 cases per 10,000 births among Hispanic urban residents that would have occurred because of the interaction of these factors (Figure 2). Additional measures of additive interaction (RERI, S) for the models are shown in Appendix Tables A and B.

Discussion

Overall, people with Medicaid at the time of childbirth have moderately increased rates of SMMM during childbirth hospitalization compared with those insured by private insurance (as shown in unadjusted weighted results). However, this examination of the adjusted rates of SMMM associated with rural residency and likely experiences of racism, as well as primary payer, reveal important differences. Medicaid-funded births among Indigenous rural residents experience dramatically higher rates of SMMM, compared with other groups. Medicaid-funded births among Black residents of both rural and urban areas, and Medicaid-funded births among Hispanic urban residents, also experience higher rates. This finding indicates that known racial and geographic disparities are not decreased when accounting for Medicaid coverage; moreover, there is substantive interaction between these factors and Medicaid coverage.

This study builds on prior findings using hospital discharge data to examine racial, geographic, or payer-based disparities in SMMM (Brown et al., 2021; Kozhimannil et al., 2019; 2020; Luke et al., 2021). These studies generally found increased odds of SMMM, separately, among Black, Hispanic, Indigenous, and Asian individuals; among rural residents; and among Medicaid-funded births. Although our study confirmed findings that the magnitude of the odds (on the multiplicative scale) for sociodemographic and clinical correlates of SMMM was similar among Medicaid-funded as privately insured births (Appendix Table C), we found that predicted rates (on the additive scale) differed. We found significantly greater rates of SMMM among Medicaid-funded births compared with those privately insured for both rural and urban residents and for all racial and ethnic groups. In contrast with prior studies using multiple stratified models to compare these risk factors between Medicaid and privately insured births (Brown et al., 2021), we statistically assessed these differences by including interaction terms within our model. This analysis is the first to measure the specific additive and intersectional risks of geography, race and ethnicity, and poverty; understanding these effects is of practical significance when designing policies and programs to reduce SMMM and make meaningful improvements to maternal health in the United States. This analysis highlights the importance of tailoring policy to particular populations when addressing SMMM (Chen et al., 2021).

Strengths and Limitations

As a population-based, nationally representative sample of all inpatient hospitalizations, these findings are generalizable to the United States as a whole. However, these analyses are subject to important limitations. First, these findings reflect hospital discharge diagnoses during childbirth hospitalization, meaning that they exclude SMMM that occurred prior to or after childbirth hospitalization. Therefore, our analysis is not inclusive of all maternal morbidity or mortality (Kozhimannil et al., 2019), and, as such, our results necessarily underestimate the overall

Table 2
Weighted Adjusted Predicted Rate of SMMM and Additive Interaction of Sociodemographic and Clinical Characteristics With Medicaid-Funded and Privately Insured Hospital Births, United States 2007–2015*

Characteristic	Medicaid-Funded† Hospital Births	Privately Insured Hospital Births	Adjusted Predicted Difference in Rates per 10,000 (aCI‡)	Attributable Proportion (Proportion of Effect owing to Additive Interaction) (aCI‡)
	Adjusted Predicted Rate per 10,000 (aCI‡)	Adjusted Predicted Rate per 10,000 (aCI‡)		
Residence§				
Urban	149.4 (145.5–153.4)	116.4 (113.5–119.3)	33.1 (29.5–36.6)	Reference
Rural	160.9 (154.6–167.2)	129.3 (124.1–134.4)	31.7 (25.0–38.3)	0.00 (−0.07 to 0.07)
Race and ethnicity				
Non-Hispanic White	121.8 (118.2–125.3)	97.9 (95.3–100.4)	23.9 (20.6–27.2)	Reference
Non-Hispanic Black	211.4 (203.7–219.0)	171.7 (164.9–178.5)	39.7 (31.9–47.5)	0.09 (0.03–0.14)
Hispanic	167.5 (160.4–174.6)	130.4 (124.6–136.2)	37.1 (29.2–45.0)	0.09 (0.02–0.16)
Asian or Pacific Islander	165.2 (151.8–178.7)	133.5 (124.9–142.0)	31.8 (17.9–45.7)	0.05 (−0.07 to 0.18)
American Indian/Alaska Native	196.3 (172.6–219.9)	148.4 (124.6–172.1)	47.9 (21.6–74.2)	0.12 (−0.07 to 0.31)
Unknown or other	159.0 (149.6–168.5)	110.5 (104.6–116.4)	48.5 (39.8–57.2)	0.16 (0.08–0.24)
Clinical characteristics				
Cesarean birth	284.7 (277.6–291.8)	216.5 (211.0–221.9)	68.2 (61.5–74.9)	0.19 (0.17–0.22)
Substance use disorder	231.7 (220.3–243.1)	208.7 (184.9–232.5)	23.0 (−2.4 to 48.3)	−0.06 (−0.23 to 0.11)
Depression	187.4 (176.7–198.0)	166.6 (156.0–177.2)	20.8 (6.4–35.1)	−0.08 (−0.19 to 0.04)
HIV or AIDS	229.0 (193.9–264.1)	185.2 (125.7–244.8)	43.7 (−25.3 to 112.8)	0.05 (−0.41 to 0.51)
Pulmonary hypertension	898.5 (733.4–1063.7)	975.0 (774.5–1175.6)	−76.5 (−328.5 to 175.5)	0.03 (−0.39 to 0.46)
Systemic lupus erythematosus	335.6 (281.3–389.9)	243.7 (204.4–283.1)	91.8 (24.6–159.0)	0.19 (−0.09 to 0.46)
Chronic kidney disease	715.2 (665.4–764.9)	606.2 (557.5–654.8)	109.0 (41.4–176.6)	0.14 (0.00–0.28)
Chronic heart disease	439.8 (396.4–483.1)	267.0 (242.0–292.0)	172.8 (124.0–221.6)	0.32 (0.19–0.45)
Diabetes‖	149.6 (144.0–155.2)	127.1 (122.0–132.2)	22.5 (15.8–29.2)	−0.06 (−0.13 to 0.01)
Chronic hypertension	249.6 (238.6–260.7)	182.5 (173.1–191.9)	67.1 (53.9–80.3)	0.13 (0.06–0.21)
Chronic respiratory disease	183.5 (175.3–191.8)	154.2 (146.6–161.9)	29.3 (18.9–39.7)	−0.03 (−0.11 to 0.06)

Abbreviations: aCI, Bonferroni-adjusted confidence interval; SMMM, severe maternal morbidity and mortality.

* Data are weighted to represent the childbearing U.S. population. In 2015, *International Classification of Diseases, Ninth Revision, Clinical Modification*, diagnosis codes were available only for the first three quarters, and survey weights were adjusted in 2015 to generate annualized estimates from these data. Data are complete case based; therefore, no missing data are represented (except for race and ethnicity where missing data was included in the unknown/other category to control for large numbers of missing data from many states in earlier years). Each model (one for each SMMM measure) adjusts for maternal race and ethnicity, maternal residence (rural/urban), maternal age, childbirth year, bottom quartile of income (quartiles of the estimated median household income of residents within the patient's ZIP code within each year), hospital region, cesarean birth, substance use disorder, depression, HIV or AIDS, pulmonary hypertension, systemic lupus erythematosus, chronic kidney disease, chronic heart disease, diabetes (preexisting or gestational), chronic hypertension, and chronic respiratory disease.

† Medicaid represents the expected primary payer at birth and includes fee-for-services and managed care.

‡ All 95% CIs are Bonferroni adjusted to account for multiple comparisons (e.g., 99.6% CIs).

§ Rural residence is defined as counties with population centers of <50,000 or no population center.

‖ Diabetes includes both preexisting and gestational diabetes mellitus.

incidence of SMMM. Despite this limitation, our findings are important; data from the Centers for Disease Control and Prevention indicate that 36% of maternal deaths occur on the day of or within 1 week after childbirth (Petersen et al., 2019), and 85% of severe maternal morbidities occur during the childbirth hospitalization (Chen et al., 2021). Further, because the unit of analysis is the individual discharge record, repeat pregnancies during the study period could not be determined. If repeat pregnancies among high-risk patients are greater among Medicaid beneficiaries, for example, this could impact study findings. Second, hospital discharge data do not consistently include some potentially important maternal characteristics (e.g., maternal education, nativity, obesity, smoking) that may differ between Medicaid beneficiaries and patients with private insurance. These important confounders could attenuate some of the observed associations. Third, state of birth is not coded separately in these data, so we were not able to produce estimates at the state level, which is a limitation because Medicaid programs differ substantially across states. This limitation is potentially important, given state differences in Medicaid expansion under the Affordable Care Act (ACA). Just more than one-half of all states had expanded Medicaid by 2015 (Kaiser Family Foundation, 2021c); however, this was only applicable to the last 2 years of the 9 years in the study period. In fact, although we did find differences in the Medicaid population between the two years before and after ACA changes (Appendix Table D), restricting our analyses to only pre-ACA years (2007–2013) did not change the study findings (Appendix Table E). Further, rates of SMMM for both Medicaid-funded and privately insured births increased across the study period in a similar pattern (Appendix Figure D). Broader efforts to improve maternal health, including decreasing early elective deliveries, especially through Medicaid policies, were also implemented during the study period (Allen & Grossman, 2020; Fowler, Schiff, Applegate, Griffith, & Fairbrother, 2014). Although we cannot isolate the specific effects of the myriad efforts to address maternal health over the study period, our results were stable across the various sensitivity analyses mentioned elsewhere in this article. Fourth, some counties may have changed rural versus urban designation during the study period. Finally, hospital variation in coding could bias these results if variability followed payer patterns. Despite these limitations, we believe these data are important for informing tailored clinical and policy efforts for addressing hospital-based SMMM, particularly among Medicaid beneficiaries.

Implications for Policy and Practice

In this analysis, insurance status plays multiple roles, as an indicator of socioeconomic status as well as an important policy

Table 3
Weighted-Adjusted Predicted Rate of SMMM and Additive Interaction of the Intersection of Rural/Urban Residence and Race and Ethnicity With Medicaid-Funded and Privately Insured Hospital Births, United States 2007–2015*

Characteristic	Medicaid-Funded† Hospital Births	Privately Insured Hospital Births	Adjusted Predicted Difference in Rates per 10,000 (aCI‡)	Attributable Proportion (Proportion of Effect owing to Additive Interaction) (aCI‡)
	Adjusted Predicted Rate per 10,000 (aCI‡)	Adjusted Predicted Rate per 10,000 (aCI‡)		
Rural residents§				
Non-Hispanic White	132.3 (126.2–138.5)	106.1 (101.3–110.8)	26.3 (19.7–32.8)	0.13 (0.05–0.21)
Non-Hispanic Black	207.9 (191.8–223.9)	175.6 (152.2–198.9)	32.3 (7.4–57.2)	0.13 (−0.05 to 0.31)
Hispanic	189.3 (173.5–205.1)	168.6 (145.0–192.3)	20.6 (−4.8 to 46.1)	0.07 (−0.14 to 0.27)
Asian or Pacific Islander	193.9 (143.6–244.2)	128.5 (92.3–164.8)	65.3 (9.4–121.3)	0.30 (−0.06 to 0.66)
American Indian/Alaska Native	224.9 (187.0–262.9)	127.1 (82.1–172.1)	97.8 (50.4–145.3)	0.40 (0.11–0.69)
Unknown or other	161.8 (147.8–175.7)	122.7 (112.5–132.9)	39.0 (24.6–53.4)	0.19 (0.06–0.31)
Urban residents				
Non-Hispanic White	119.4 (115.5–123.2)	96.5 (93.7–99.3)	22.9 (19.2–26.6)	Reference
Non-Hispanic Black	210.9 (202.8–219.0)	169.8 (162.8–176.7)	41.2 (33.0–49.3)	0.16 (0.10–0.21)
Hispanic	164.9 (157.3–172.5)	126.7 (120.8–132.6)	38.2 (30.0–46.4)	0.19 (0.11–0.26)
Asian or Pacific Islander	162.1 (148.4–175.8)	131.7 (123.1–140.4)	30.4 (16.2–44.5)	0.14 (0.02–0.26)
American Indian/Alaska Native	180.2 (151.7–208.7)	158.1 (132.0–184.3)	22.1 (−9.3 to 53.4)	0.06 (−0.20 to 0.32)
Unknown or other	159.2 (148.3–170.2)	108.4 (102.0–114.8)	50.8 (40.9–60.7)	0.27 (0.18–0.35)

Abbreviations: aCI, Bonferroni-adjusted confidence interval; SMMM, severe maternal morbidity and mortality.

* Data are weighted to represent the childbearing U.S. population. In 2015, *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes were available only for the first three quarters, and survey weights were adjusted in 2015 to generate annualized estimates from these data. Data are complete case-based, therefore no missing data are represented (except for race and ethnicity where missing data was included in the unknown/other category to control for large numbers of missing data from many states in earlier years). Each model (one for each SMMM measure) adjusts for maternal race and ethnicity, maternal residence (rural/urban), maternal age, childbirth year, bottom quartile of income (quartiles of the estimated median household income of residents within the patient's ZIP code within each year), hospital region, cesarean birth, substance use disorder, depression, HIV or AIDS, pulmonary hypertension, systemic lupus erythematosus, chronic kidney disease, chronic heart disease, diabetes (preexisting or gestational), chronic hypertension, and chronic respiratory disease.

† Medicaid represents the expected primary payer at birth and includes fee-for-services and managed care.

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§ Rural residence is defined as counties with population centers of <50,000 or no population center.

lever. Medicaid coverage is extraordinarily important for maternal health, and increased access is associated with lower maternal mortality (Eliason, 2020). Still, this analysis found that SMMM occurred more frequently among Medicaid beneficiaries compared with privately insured people; these risks accrue unevenly based on geography and race and ethnicity, and Medicaid coverage does not mitigate the risks presented by structural racism and by urban bias in healthcare (Crear-Perry et al., 2021; Probst et al., 2019). Additionally, Medicaid beneficiaries are disproportionately Black, Indigenous, and rural, and this analysis revealed additive risk, especially for rural Indigenous Medicaid beneficiaries who gave birth. The findings on intersectionality of SMMM risk suggest that Medicaid policy change to improve maternal health must account for the particular challenges posed by rural locations and by racism, and also that policies that lower SMMM risk among Medicaid patients could have additional additive benefits in reducing racial and ethnic and rural versus urban disparities.

As the primary payer for nearly one-half of all births in the United States, state Medicaid programs have an opportunity to contribute to efforts to improve maternal health and decrease SMMM through reimbursement and coverage policies that address the disproportionate risk of SMMM among Medicaid beneficiaries as a whole, as well as among particular groups of beneficiaries that experience heightened risks based on geography, race and ethnicity, or clinical conditions. Recent efforts to extend postpartum Medicaid coverage beyond 60 days postpartum could build on gains experienced in the fight against maternal mortality, following state Medicaid expansions, by ensuring that patients who experience pregnancy complications like severe maternal morbidity do not experience insurance disruptions that can impact access to needed ongoing care (Eliason, 2020; Ranji, Gomez, & Salganicoff, 2021). Care bundles to address racial disparities in maternal health have been developed and adopted by healthcare delivery systems (Howell et al., 2018), and the uptake of such evidence-based models could be incentivized or encouraged by state Medicaid programs (Howell, 2018). Additionally, the specific risks faced by rural residents, who have limited and decreasing access to maternity care (Kozhimannil, Hung, Henning-Smith, Casey, & Prasad, 2018), may be mitigated by Medicaid policies that focus on low-volume payment adjustments as well as coverage for nonclinical services such as transportation, housing, and community-based support (doula care, peer counseling, lactation consultants, etc.). Finally, clinical efforts to decrease SMMM nationally have focused on care bundles to ensure that all clinical risks are addressed (Arora et al., 2016; D'Alton, Main, Menard, & Levy, 2014). Because clinical preexisting comorbidities were among the strongest predictors of all measures of SMMM, the importance of focusing on clinical risk alongside broad efforts to address inequities by payer, race and ethnicity, and geography is clear. Medicaid programs can work with healthcare delivery systems and managed care organizations to ensure equitable uptake of evidence-based practices for beneficiaries with clinical conditions that render them vulnerable to SMMM.

Conclusions

Attention to the particular challenges faced by Medicaid patients based on geography and race and ethnicity is crucial to the success of state and national efforts to improve maternal health. This analysis offers new data on the increased incidence of SMMM among Medicaid beneficiaries, in particular, by looking at the specific intersectional and additive risks of geography, race

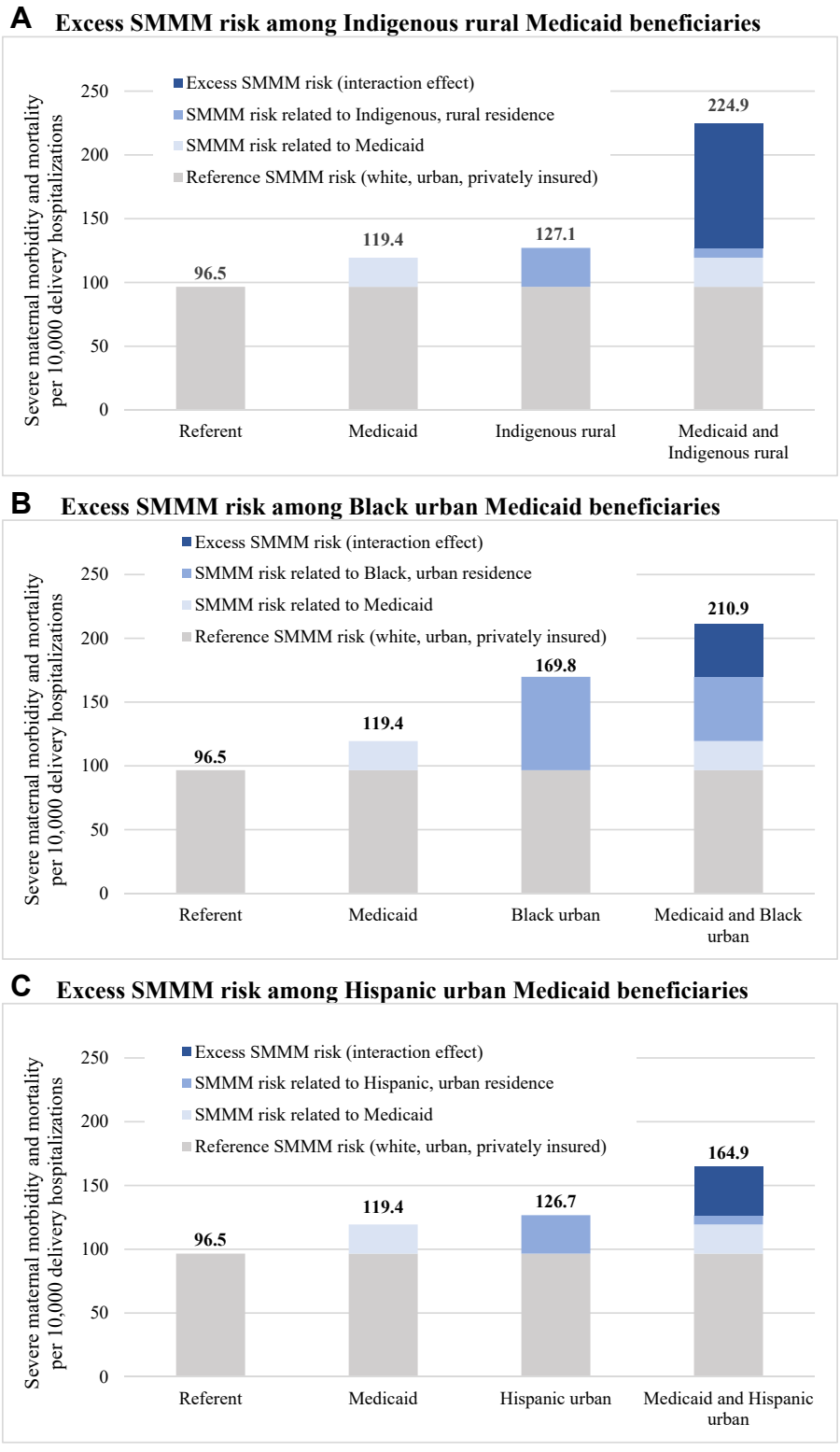

Figure 2. Highlighted additive interaction effects of the intersection of rural/urban residence and race and ethnicity with Medicaid-funded hospital births in the United States from 2007 to 2015. Data are weighted to represent the childbearing U.S. population. In 2015, *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis codes were available only for the first three quarters, and survey weights were adjusted in 2015 to generate annualized estimates from these data. Data are complete case based; therefore, no missing data are represented (except for race and ethnicity where missing data were included in the unknown/other category to control for large numbers of missing data from many states in earlier years). Risks were adjusted for maternal race and ethnicity, maternal residence (rural/urban), maternal age, childbirth year, bottom quartile of income (quartiles of the estimated median household income of residents within the patient's ZIP code within each year), hospital region, cesarean birth, substance use disorder, depression, HIV or AIDS, pulmonary hypertension, systemic lupus erythematosus, chronic kidney disease, chronic heart disease, diabetes (preexisting or gestational), chronic hypertension, and chronic respiratory disease. Medicaid represents the expected primary payer at delivery and includes fee-for-services and managed care. *Abbreviation:* SMMM, severe maternal morbidity and mortality.

and ethnicity, and poverty. It should inform tailored policy responses to address the particular risks and challenges faced by Medicaid beneficiaries, particularly Black, Indigenous, and rural residents, and those with complex clinical conditions. If policy makers use this information to more finely tune efforts to address SMMM among Medicaid beneficiaries in particular, fewer Black, Indigenous, and rural birthing people may experience life-threatening pregnancy complications or death.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.whi.2022.05.003.

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