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Rural-Urban Differences In Severe Maternal Morbidity And Mortality In The US, 2007-15

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ABSTRACT In the United States, severe maternal morbidity and mortality is climbing—a reality that is especially challenging for rural communities, which face declining access to obstetric services. *Severe maternal morbidity* refers to potentially life-threatening complications or the need to undergo a lifesaving procedure during or immediately following childbirth. Using data for 2007–15 from the National Inpatient Sample, we analyzed severe maternal morbidity and mortality during childbirth hospitalizations among rural and urban residents. We found that severe maternal morbidity and mortality increased among both rural and urban residents in the study period, from 109 per 10,000 childbirth hospitalizations in 2007 to 152 per 10,000 in 2015. When we controlled for sociodemographic factors and clinical conditions, we found that rural residents had a 9 percent greater probability of severe maternal morbidity and mortality, compared with urban residents. Attention to the challenges faced by rural patients and health care facilities is crucial to the success of efforts to reduce maternal morbidity and mortality in rural areas. These challenges include both clinical factors (workforce shortages, low patient volume, and the opioid epidemic) and social determinants of health (transportation, housing, poverty, food security, racism, violence, and trauma).

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Every year there are approximately 700 maternal deaths and an additional 50,000 cases of severe maternal morbidity in the US.^{1,2} *Severe maternal morbidity* refers to potentially life-threatening complications or the need to undergo a lifesaving procedure during or immediately following childbirth. Examples of severe maternal morbidity include heart failure, stroke, thromboembolism, and the need for a blood transfusion or an emergency hysterectomy associated with birth.³ The incidence of severe maternal morbidity nearly tripled between 1998 and 2014, and maternal mortality increased dramatically between 1990 and 2013.^{1,2}

Morbidity and mortality are also rising in the

general US population.^{4,5} Notably, there are divergent trends in rural and urban areas, with excess mortality evident among rural residents.^{6,7} Mortality rates from all of the leading causes of death in the US—heart disease, stroke, cancer, unintentional injury, and chronic lower respiratory disease—are higher in rural than in urban communities.⁸

Both of these troubling morbidity and mortality trends (that is, rising risks among people giving birth and rural residents) may render residents of rural areas particularly vulnerable to increased morbidity and mortality associated with childbirth. Furthermore, there are stark differences between rural and urban areas with respect to population demographics, access to

health care, and the broader social determinants of health (for example, transportation, housing, poverty, food security, racism, violence, and trauma)—with rural areas tending to face greater challenges to achieving improvements in health.⁹

Rural residents have limited access to health care services during pregnancy and childbirth, but outcomes have not been comprehensively assessed.^{10,11} Both risks for and consequences of severe maternal morbidity and mortality may be amplified by access barriers and financial constraints in rural communities. Compared to urban residents, rural residents face more severe health care workforce shortages and must travel longer distances to receive maternity care.¹¹ By 2014 more than half of rural counties had no hospital that provided childbirth care; 179 rural counties lost obstetric services in the period 2004–14.¹² The effects of these service losses were most acute in remote rural communities, where residents experienced increased rates of preterm births (the leading cause of infant mortality), out-of-hospital births, and births in hospitals without obstetric units.¹³ Indeed, in 2014 rural infant mortality rates were 6 percent higher than those in small and medium-size metropolitan counties, and 20 percent higher than those in large metropolitan counties.¹⁴

No prior studies have examined rural-urban differences in current trends in severe maternal morbidity and mortality. Such evidence is urgently needed to inform geographically tailored clinical and policy efforts to reverse the rising rate of maternal morbidity and mortality nationally. This study examined trends and clinical and sociodemographic predictors of severe maternal morbidity and mortality among rural and urban US residents in 2007–15.

Study Data And Methods

DATA AND STUDY POPULATION We used hospital discharge data for 2007–15 from the National Inpatient Sample, an all-payer inpatient claims database available through the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.¹⁵ Maternal hospital discharge records for obstetric deliveries were identified using a previously published method.¹⁶ Data on pregnant patients with ages outside biological plausibility for childbirth (younger than age ten or older than age fifty-five; <0.01 percent) and records with missing data on rural or urban residency (1.3 percent) were not included in analyses.

VARIABLE MEASUREMENT Rural versus urban maternal residency was determined at the county level, based on the Office of Management and

Budget's standard definition of Metropolitan Statistical Areas.¹⁷ Rural counties include those classified as nonmetropolitan—either micropolitan counties (those with a population center of 10,000–50,000) or noncore counties (those with no population center of 10,000 or larger).

The primary outcome was a composite measure of severe maternal morbidity and mortality, defined by *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM), codes using a previously validated algorithm.^{3,18} (For details on how this measure was created, see online appendix exhibit A1.)¹⁹ We also conducted a sensitivity analysis that excluded cases in which blood transfusion was the only indicator of severe maternal morbidity or mortality.

Patients' sociodemographic characteristics—including age, race/ethnicity, and payer—have been shown in prior research to be associated with severe maternal morbidity and mortality.^{18,20} In this study patient age was measured as a continuous variable. Race/ethnicity was reported as one of six categories (non-Hispanic white, non-Hispanic black, Hispanic, Asian or Pacific Islander, American Indian or Alaska Native, or other/unknown). Patients with missing data on race/ethnicity (who accounted for 17 percent of the records in this analysis) were included in the other/unknown category (such missing data are a known challenge with using information from the National Inpatient Sample). Primary expected payer was categorized as Medicaid (this category included both Medicare and Medicaid, but Medicare accounted for less than 1 percent of the sample); private payer; or uninsured/self-pay/other. Additionally, indicators for patients in low-income communities (residents of a ZIP code in the lowest national quartile for median family income) and hospital region (Northeast, Midwest, South, or West) were included as covariates. Just 1.8 percent of birth records had missing values for sociodemographic characteristics (except for race/ethnicity) and were excluded from complete case analyses.

Using ICD-9-CM diagnosis codes defined in previous work, we identified comorbidities with known associations with severe maternal morbidity and mortality—including substance use disorder, HIV/AIDS, chronic kidney disease, chronic heart disease, diabetes (preexisting or gestational), chronic hypertension, and chronic respiratory disease.²¹ Also included were depression (ICD-9-CM codes 296.2, 296.3, 300.4, and 311), pulmonary hypertension (416.0, 416.8, and 416.9), and lupus (710.0). These clinical conditions were included based on a review of prior literature and author consensus.^{22,23}

Policy efforts should go beyond clinical settings to address rural-urban differences in the social determinants of health.

ANALYSIS Weighted differences in covariates between rural and urban residents were assessed using Rao-Scott chi-square tests or two-sample *t*-tests. Annual incidences of severe maternal morbidity and mortality from 2007 to 2015 by rural or urban residence were estimated and assessed for trends using survey-weighted multivariable logistic regression models. All results were weighted to allow for national inferences. ICD-9-CM diagnosis codes were available for only the first three quarters of 2015. We adjusted the survey weights in 2015 to generate annualized estimates from these data. Adjusted odds ratios and 95% confidence intervals were calculated, with *p* values of less than 0.05 considered significant. Models were adjusted for each of the socio-demographic and clinical characteristics listed above. We estimated excess incidence of severe maternal morbidity and mortality among rural residents by multiplying the total number of weighted rural cases by their adjusted morbidity and mortality incidence rate and subtracting the number of cases that we calculated when using the adjusted incidence rate among urban residents.

Next, we calculated predicted marginal probabilities for rural-urban differences in severe maternal morbidity and mortality over time to estimate absolute risk differences. We specified covariate values for predicted marginal probability calculations based on mean values or proportions in the study population. The only factors that varied in the calculation of predicted marginal probabilities were rurality and year of childbirth.

All analyses complied with methodologic standards for working with the data from the National Inpatient Sample.²⁴ All data management and analyses were conducted in SAS, version 9.4.

This study protocol was reviewed and desig-

nated exempt by the University of Minnesota Institutional Review Board.

LIMITATIONS These analyses were subject to limitations. First, our findings reflect hospital discharge diagnoses following childbirth and do not include severe maternal morbidity and mortality that occurred during pregnancy or after hospital discharge following delivery. *Maternal mortality* is defined as a pregnancy-related death that occurs during pregnancy through one year postpartum,²⁵ so our estimates underestimate the overall incidence of severe maternal morbidity and mortality. However, temporally, the childbirth hospitalization does account for 36 percent of maternal deaths.²⁶

Second, blood transfusions are involved in the majority of cases of severe maternal morbidity and mortality. When cases in which blood transfusion was the only indicator of severe maternal morbidity and mortality were excluded in our sensitivity analysis, the sample size was limited—especially among rural residents.

Third, the data did not allow us to adjust for some maternal characteristics (such as obesity, maternal education, and nativity) that are poorly coded in administrative data and could differentially affect rural and urban women.²⁷ Thus, the findings we report likely represent a conservative estimate of the risks faced by rural residents.

Fourth, rural and urban areas are heterogeneous, and our analyses included only a dichotomous measure of metropolitan versus nonmetropolitan residence by county.¹¹

Fifth, hospital variation in coding could have biased our results if variability followed geographic patterns. Specifically, rural hospitals may detect and report fewer cases based on resources available for an adequate reporting or billing infrastructure, which implies that these results may be a conservative estimate of increased risk among rural residents.

Finally, the rare nature of the outcome limited our capacity to assess differential trends over time using interaction terms. An important direction for future research is to examine the longitudinal trends in rural-urban disparities in maternal and infant outcomes.

Study Results

This analysis included 33,708,679 births (unweighted $N = 6,793,342$) in the period 2007–15, including 4,864,686 (unweighted $n = 987,195$) among rural residents and 28,843,993 (unweighted $n = 5,806,147$) among urban residents (exhibit 1). The overall incidence of severe maternal morbidity and mortality increased from 109 to 152 per 10,000 childbirth hospitalizations during the study period ($p < 0.001$) (appendix

EXHIBIT 1

Selected characteristics of hospital deliveries in the US, 2007-15

Characteristic	Rural residents (n = 987,195)	Urban residents (n = 5,806,147)	p value
Severe maternal morbidity and mortality	1.40%	1.35%	0.066
Age (years)			<0.001
10-24	42.35	30.08	
25-29	29.77	28.10	
30-34	18.83	25.97	
35 or older	9.04	15.85	
Race/ethnicity			<0.001
Non-Hispanic white	60.80	43.57	
Non-Hispanic black	7.24	13.23	
Hispanic	8.33	21.23	
Asian/Pacific Islander	1.17	5.35	
American Indian/Alaska Native	1.81	0.52	
Unknown/other	20.65	16.10	
Insurance payer ^a			<0.001
Private	43.83	51.66	
Medicaid ^b	49.49	42.83	
Uninsured/self-pay/other ^c	6.69	5.52	
Bottom quartile of income ^d	48.60	24.20	<0.001
Census region of hospital			<0.001
Northeast	8.69	15.70	
Midwest	31.14	20.27	
South	46.29	37.49	
West	13.88	26.55	
Clinical characteristics			
Cesarean	32.82	33.09	0.193
Substance use disorder	2.05	1.51	<0.001
Depression	2.42	2.10	<0.001
HIV/AIDS	0.05	0.10	<0.001
Pulmonary hypertension	0.02	0.02	0.021
Lupus	0.08	0.12	<0.001
Chronic kidney disease	0.27	0.26	0.163
Chronic heart disease	0.37	0.41	0.009
Diabetes	6.41	7.32	<0.001
Chronic hypertension	2.22	2.14	0.054
Chronic respiratory disease	2.88	3.66	<0.001

SOURCE Authors' analysis of data for 2007-15 from the National Inpatient Sample. **NOTES** The sample size ($N = 6,793,342$) and all numbers in the table are unweighted; percentages are weighted to represent the US population. Data are based on a complete case analysis; therefore, no missing data are represented (except for race/ethnicity, where cases with missing data were included in the "unknown/other" category to control for large numbers of missing data from many states in early years of the study period). We used Rao-Scott chi-square tests or two-sample t -tests to determine p values. ^aPrimary payer at delivery. ^bIncludes both Medicaid and Medicare, both fee-for-service and managed care. ^cIncludes workers' compensation, CHAMPUS/TRICARE, Title V, and other government programs. ^dThe median family income for the patient's ZIP code of residence was in the lowest quartile nationally.

exhibit A2).¹⁹ On average over that period, severe maternal morbidity and mortality was identified in 140 per 10,000 childbirth hospitalizations among rural residents and 135 per 10,000 childbirth hospitalizations among urban residents (exhibit 1).²²

Compared to urban residents who gave birth, higher proportions of rural residents were non-Hispanic white (61 percent versus 44 percent),

had Medicaid as their primary insurance payer (50 percent versus 43 percent), and lived in ZIP codes in the bottom national income quartile (49 percent versus 24 percent) (exhibit 1). Rural residents had higher prevalences of substance use disorder and depression, but urban residents had higher prevalences of many physical health conditions—including chronic respiratory disease, diabetes, and chronic heart disease.

When we controlled for sociodemographic factors and clinical conditions, we found that rural residents had increased odds of severe maternal morbidity and mortality, compared with urban residents (adjusted odds ratio: 1.09) (exhibit 2). When the overall size of the rural population is accounted for, this increase represents an excess of approximately 4,378 cases of severe maternal morbidity and mortality among rural residents who would not have experienced morbidity or mortality had they been living in urban areas (data not shown). Non-Hispanic black, American Indian/Alaska Native, Hispanic, and Asian residents of both rural and urban areas had at least 33 percent increased odds of severe maternal morbidity and mortality compared to non-Hispanic white residents, and Medicaid beneficiaries or patients with no insurance (those who were uninsured/self-pay/other) at delivery had at least 30 percent increased odds compared to those with private health insurance (exhibit 2). Each comorbid condition examined was associated with increased risk for severe maternal morbidity and mortality (appendix exhibit A3).¹⁹ Pulmonary hypertension had the largest association (aOR: 8.01; $p < 0.001$). Cesarean deliveries and chronic kidney disease were also associated with severe maternal morbidity and mortality (aOR: 3.44 and 5.43, respectively; both $p < 0.001$). Our sensitivity analyses were limited by sample size, but we detected lower odds of severe maternal morbidity and mortality when we excluded cases in which blood transfusion was the only indicator of severe maternal morbidity and mortality for rural versus urban residents (aOR: 0.91; 95% confidence interval: 0.87, 0.96).

Exhibit 3 displays predicted marginal probabilities for severe maternal morbidity and mortality among rural and urban residents. For childbirth hospitalizations in 2007, rural residents had a predicted marginal probability of 0.97 percent, compared to 0.89 percent for urban residents—a difference of 0.08 percentage points. By 2015, however, the difference in predicted marginal probabilities between rural and urban residents had increased to 0.11 percentage points. By 2021 the difference between rural and urban residents is projected to grow to 0.14 percentage points (predicted marginal probability

of 1.64 percent for rural and 1.51 percent for urban).

Discussion

Maternal health risks vary geographically. Rural residents have higher rates of severe maternal morbidity and mortality compared to urban residents with the same sociodemographic and clinical characteristics. These findings confirm that severe maternal morbidity and mortality occurring during childbirth hospitalizations has been increasing among both rural and urban residents, but the excess risk incurred by rural residents is an important new finding that has implications for the development and implementation of programs to reduce severe maternal morbidity and mortality. A rural-specific approach is warranted in clinical and policy efforts to address severe maternal morbidity and mortality, and both rural- and urban-focused strategies must target clinically complex patients as well as those who are at greater risk of severe maternal morbidity and mortality because of social determinants of health—including racism and poverty.

While rural residence is itself an independent predictor of severe maternal morbidity and mortality, there are other important risk factors. For both rural and urban residents, non-Hispanic black, American Indian/Alaska Native, and Hispanic women had at least 33 percent increased odds of severe maternal morbidity and mortality compared with non-Hispanic white women, and Medicaid beneficiaries and those without health insurance (uninsured/self-pay/other) at delivery had at least 30 percent increased odds compared to those with private health insurance. This confirms prior findings of greater risk of severe maternal morbidity and mortality among low-income people and people of color.^{18,28}

Clinical Implications

Current clinical efforts to reduce severe maternal morbidity and mortality are myriad and include the establishment of the Alliance for Innovation on Maternal Health, a national alliance to improve clinical care and reduce maternal morbidity and mortality.²⁹ The alliance has led the development of maternal safety bundles—sets of evidence-based clinical practices that are designed to reduce the incidence and risks associated with severe maternal morbidity and mortality. Available bundles include those on obstetrical hemorrhage, severe hypertension/preeclampsia, prevention of venous thromboembolism, reduction of low-risk primary cesarean births, reduction of peripartum racial dispar-

EXHIBIT 2

Likelihood of severe maternal morbidity and mortality in the US, by selected characteristics, 2007-15

	Adjusted odds ratio ^a	95% CI	p value
Rural (ref: urban)	1.09	1.05, 1.13	<0.001
Year (continuous)	1.04	1.03, 1.05	<0.001
Age (continuous)	1.00	0.99, 1.00	0.260
Insurance payer (ref: private)			
Medicaid	1.31	1.28, 1.34	<0.001
Uninsured/self-pay/other	1.31	1.26, 1.37	<0.001
Race/ethnicity (ref: non-Hispanic white)			
Non-Hispanic black	1.79	1.72, 1.84	<0.001
Hispanic	1.38	1.33, 1.44	<0.001
Asian/Pacific Islander	1.34	1.27, 1.42	<0.001
American Indian/Alaska Native	1.61	1.44, 1.80	<0.001
Unknown/other	1.21	1.15, 1.27	<0.001
Bottom national quartile of income (ref: top three quartiles)	1.11	1.08, 1.14	<0.001
Census region of hospital (ref: South)			
Northeast	1.09	1.03, 1.15	0.003
Midwest	0.92	0.87, 0.98	0.012
West	0.90	0.85, 0.96	<0.001

SOURCE Authors' analysis of data for 2007–15 from the National Inpatient Sample. **NOTES** The sample size ($N = 6,793,342$) is unweighted; all other data are weighted to represent the US population. "Insurance payer" and "bottom national quartile of income" are explained in the notes to exhibit 1. CI is confidence interval. ^aAdjusted odds ratios controlled for continuous year, continuous age, insurance payer, race/ethnicity, bottom national quartile of income, census region of hospital, cesarean delivery, substance use disorder, depression, HIV/AIDS, pulmonary hypertension, lupus, chronic kidney disease, chronic heart disease, diabetes, chronic hypertension, and chronic respiratory disease.

ities, and postpartum care access and standards. Adoption of these practices has led to early progress toward improving maternal health.³⁰ Yet the diffusion of new practices, technologies, and care bundles is often slower in rural than in urban communities, which may exacerbate rural-urban inequities.³¹ Additionally, many of the recommended clinical practices included in care bundles—such as immediate or large-volume blood transfusion—might not be easily available in rural hospitals, which have lower birth volumes and fewer specialized clinicians and resources than urban hospitals do.³² Blood transfusions are involved in most cases of maternal morbidity, so ensuring access to this procedure deserves a particular focus, alongside a broad effort to ensure the creation of rural-relevant safety bundles and the adoption of best practices in rural settings.

In maternity care settings, clinicians play an important role by listening to patients who report concerns about their health. This is particularly important for pregnant rural patients who may be receiving care from multiple clinicians or in different locations.³³ Given the observed variation in capacity across facilities with different

EXHIBIT 3

Predicted marginal probabilities of severe maternal morbidity and mortality among rural and urban US residents, 2007–21



SOURCE Authors' analysis of data for 2007–15 from the National Inpatient Sample. **NOTES** The sample size ($N = 6,793,342$) is unweighted; all other data are weighted to represent the US population. Error bars represent 95% confidence intervals. Predicted marginal probabilities used specified covariate values based on mean values or proportions in the overall sample per delivery year, including maternal age at delivery, insurance payer, race/ethnicity, bottom quartile of income (explained in the notes to exhibit 1), hospital region, cesarean delivery, substance use disorder, depression, HIV/AIDS, pulmonary hypertension, lupus, chronic kidney disease, chronic heart disease, diabetes, chronic hypertension, and chronic respiratory disease. Predicted marginal probabilities were calculated from estimates derived from available data (through the third quarter of 2015) and predicted out (from the third quarter of 2015 on) following trends estimated from available data. The vertical line distinguishes estimated from predicted probabilities. Predicted marginal probabilities among rural and urban residents were significantly different at p values less than 0.05 for years 2009–15.

levels of maternal care, all health care delivery systems have an obligation to ensure that they have structures in place to guarantee that the questions and concerns of pregnant patients are received and addressed in a timely manner and that care plans are communicated clearly across the various sources and settings for patient care.³⁴

Policy Implications

There are a growing number of local, state, and federal policy efforts to address severe maternal morbidity and mortality.³⁵ Maternal morbidity and mortality review committees are among the most visible policy efforts currently under way. The committees play an important role in identifying risk factors for severe maternal morbidity and mortality and making recommendations to improve prevention and treatment.³⁶ However, the committees might not adequately reflect and focus on the unique needs of and challenges faced by rural residents.³⁵

Rural residents who give birth generally must travel greater distances than urban residents do to access prenatal and obstetric care,³⁷ have more limited access to specialty physician and nursing

services,³² and face overall health care workforce shortages.³² Public health crises, including the opioid epidemic and rising rates of suicide, have had a disproportionate impact on rural communities, and correspondingly on rural residents who give birth.³⁸ However, policy efforts should go beyond clinical settings to address rural-urban differences in the social determinants of health. Rural residents face particular constraints related to transportation, housing, economic resources, and food security.³⁹ Their health is also affected by histories of racism, violence, and trauma in ways that are distinct from those applicable to urban residents.^{40,41} Accounting for the socioeconomic, clinical, and public health circumstances of rural communities is essential for efforts that aim to reduce severe maternal morbidity and mortality.

Policy Recommendations

Policies at the local, state, and federal levels that aim to address severe maternal morbidity and mortality ought to ensure the representation of rural residents—and other groups that are disproportionately affected by severe maternal morbidity and mortality—on decision-making

Health insurance eligibility is not the only policy factor that affects maternal outcomes.

bodies, including maternal morbidity and mortality review committees.⁴² Additionally, ensuring both the collection of actionable data through consistent processes and access to rural-relevant quality improvement strategies and measures is crucial. To address the specific needs of rural communities, policies must offer funding for financial and logistical support to hospitals. These may include low-volume payment adjustments, resources and training for emergency obstetrics, and financial incentives for collaboration across rural communities and with higher-acuity facilities in urban settings.

Policy efforts to address rural severe maternal morbidity and mortality must also include Medicaid programs. Medicaid funds nearly half of all births in the US and is an important payer for maternity care in rural areas.^{10,43} Reimbursement rates for birth under Medicaid are approximately half of what private health plans pay,⁴⁴ which makes it especially difficult for rural providers in low-volume settings to cover the fixed costs associated with maintaining an obstetrics unit and to address complex and challenging cases.⁴⁵ For people eligible for Medicaid because of preg-

nancy, that coverage ends sixty days postpartum. Thus, more than half of all Medicaid beneficiaries experience health insurance coverage gaps shortly after childbirth.⁴⁶ Efforts to decrease health insurance churn include both national and state policies being proposed to extend pregnancy-related Medicaid eligibility.⁴⁷ The adoption of such a policy would disproportionately benefit rural residents.

However, health insurance eligibility is not the only policy factor that affects maternal outcomes. Most health insurance benefits under Medicaid and most private payers focus on medical care rather than social risk factors.⁴⁸ Rural residents may require assistance not only in accessing clinical services, but also with transportation and housing around the time of birth (especially if they need to travel for care).⁴⁹ Nonclinical support for birth and the postpartum period, including from doulas, community health workers, and lactation consultants, can also support improved outcomes.^{50,51}

Conclusion

Severe maternal morbidity and mortality is increasing among both rural and urban residents, and rural residents face elevated odds during childbirth hospitalizations. National clinical and policy efforts are under way to address severe maternal morbidity and mortality, but many national efforts do not address the specific conditions of care provided in rural contexts. Attention to the particular challenges faced by rural patients and health care facilities is crucial to the success of efforts to reduce severe maternal morbidity and mortality across the US, especially in rural areas. ■

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APPENDIX

Appendix Exhibit A1. Composite measure for severe maternal morbidity and mortality

The composite measure included patients whose discharge record indicated mortality, if a severe maternal morbidity was identified by *ICD-9-CM* procedure code, or if severe maternal morbidity was identified by *ICD-9-CM* diagnosis code and the patient was transferred, or if not transferred, had a length of hospital stay that would also indicate a complicating severity (>90th percentile, e.g., >3 days for vaginal delivery, >4 days for repeat cesarean delivery, >5 days for primary cesarean delivery).

Appendix Exhibit A2. Selected characteristics of hospital deliveries, United States 2007-2015 (N = 6,793,342)

	Rural Residents (n = 987,195)			Urban Residents (n = 5,806,147)			p value ^a
	n	Percent	95% CI	n	Percent	95% CI	
Severe maternal morbidity and mortality	13,687	1.4	1.4, 1.4	77,735	1.3	1.3, 1.4	0.066
Age (years)							<0.001
10-24	419,759	42.4	42.0, 42.8	1,758,574	30.1	29.5, 30.7	
25-29	293,594	29.8	29.6, 29.9	1,631,051	28.1	27.9, 28.3	
30-34	184,949	18.8	18.6, 19.0	1,500,125	26.0	25.6, 26.3	
≥ 35	88,893	9.0	8.9, 9.2	916,397	15.8	15.5, 16.2	
Race and ethnicity							<0.001
Non-Hispanic white	595,126	60.8	59.1, 62.5	2,520,135	43.6	42.4, 44.8	
Non-Hispanic black	73,368	7.2	6.5, 8.0	765,841	13.2	12.6, 13.9	
Hispanic	80,284	8.3	7.6, 9.1	1,235,829	21.2	20.1, 22.3	
Asian or Pacific Islander	11,141	1.2	0.9, 1.4	309,959	5.3	4.9, 5.7	
American Indian/Alaska Native	17,613	1.8	1.4, 2.2	29,920	0.5	0.4, 0.6	
Unknown/other	209,663	20.7	18.8, 22.5	944,463	16.1	14.8, 17.4	
Insurance payer^b							<0.001
Private	430,922	43.8	43.1, 44.6	2,994,640	51.6	50.5, 52.8	
Medicaid	489,074	49.5	48.7, 50.3	2,489,903	42.8	41.7, 43.9	
Uninsured/self-pay/other	67,199	6.7	6.2, 7.2	321,604	5.5	5.2, 5.8	
Income: bottom quartile^c	481,861	48.6	47.0, 50.2	1,396,646	24.2	23.2, 25.2	<0.001
Hospital region							<0.001
Northeast	85,945	8.7	7.9, 9.5	897,087	15.7	14.5, 16.8	
Midwest	309,282	31.1	29.4, 32.9	1,163,303	20.3	18.9, 21.7	
South	458,306	46.3	44.2, 48.4	2,184,472	37.5	35.6, 39.4	
West	133,662	13.9	12.7, 15.1	1,561,285	26.5	24.9, 28.2	
Clinical Characteristics							
Cesarean	323,860	32.8	32.5, 33.1	1,922,020	33.1	32.8, 33.4	0.193
Substance use	19,814	2.1	2.0, 2.1	86,435	1.5	1.5, 1.6	<0.001
Depression	23,520	2.4	2.3, 2.5	120,019	2.1	2.0, 2.2	<0.001
HIV or AIDS	480	0.05	0.04, 0.05	5,950	0.10	0.09, 0.12	<0.001
Pulmonary hypertension	163	0.02	0.01, 0.02	1,217	0.02	0.02, 0.02	0.021

Lupus	807	0.08	0.08, 0.09	6,902	0.12	0.12, 0.12	<0.001
Chronic kidney disease	2,707	0.27	0.26, 0.29	15,172	0.26	0.25, 0.27	0.163
Chronic heart disease	3,729	0.37	0.35, 0.39	23,824	0.41	0.39, 0.43	0.009
Diabetes	62,901	6.4	6.3, 6.5	422,561	7.3	7.2, 7.4	<0.001
Chronic hypertension	21,869	2.2	2.1, 2.3	123,285	2.1	2.1, 2.2	0.054
Chronic respiratory disease	28,212	2.9	2.8, 3.0	209,587	3.7	3.5, 3.8	<0.001

SOURCE: Authors' analysis of data from the National Inpatient Sample, 2007-2015. NOTES: All numbers presented are unweighted; percentages are weighted to represent the US 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). CI is confidence interval. aP values are Rao-Scott chi-square tests. bInsurance payer represents the primary payer at delivery. The Medicaid category encompasses both Medicaid and Medicare, including fee-for-service and managed care. Other includes Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other government programs. cMedian income quartile for the patient's ZIP Code of residence.

Appendix Exhibit A3. Technical appendix for odds ratios of severe maternal morbidity and mortality, United States 2007-2015 (N = 6,793,342)

	β Estimate	Standard Error	Adjusted Odds		t Value	p value
			Ratio ^a	95% CI		
Intercept	-81.945	7.525			-10.89	
Rural	0.085	0.019	1.09	1.05, 1.13	4.37	<0.001
Year (continuous)	0.038	0.004	1.04	1.03, 1.05	10.19	<0.001
Age (continuous)	0.001	0.001	1.00	0.99,1.00	1.13	0.260
Insurance payer^b						
Private	Ref.	Ref.	Ref.		Ref.	Ref.
Medicaid	0.269	0.012	1.31	1.28, 1.34	22.24	<0.001
Uninsured/self-pay/other	0.270	0.021	1.31	1.26, 1.37	12.82	<0.001
Race and ethnicity^c						
Non-Hispanic white	Ref.	Ref.	Ref.		Ref.	Ref.
Non-Hispanic black	0.576	0.016	1.79	1.72, 1.84	35.75	<0.001
Hispanic	0.324	0.019	1.38	1.33, 1.44	16.71	<0.001
Asian or Pacific Islander	0.296	0.028	1.34	1.27, 1.42	10.67	<0.001
American Indian/Alaska Native	0.477	0.057	1.61	1.44, 1.80	8.43	<0.001
Unknown/other	0.189	0.027	1.21	1.15, 1.27	6.97	<0.001
Income: bottom quartile	0.102	0.013	1.11	1.08, 1.14	8.12	<0.001
Hospital region						
South	Ref.	Ref.	Ref.		Ref.	Ref.
Northeast	0.083	0.028	1.09	1.03, 1.15	2.99	0.003
Midwest	-0.080	0.032	0.92	0.87, 0.98	-2.53	0.012
West	-0.102	0.028	0.90	0.85, 0.96	-3.58	<0.001
Clinical Characteristics						
Cesarean	1.235	0.010	3.44	3.37, 3.51	127.21	<0.001
Substance abuse	0.488	0.022	1.63	1.56, 1.70	21.82	<0.001
Depression	0.290	0.021	1.34	1.28, 1.39	14.03	<0.001
HIV or AIDS	0.420	0.065	1.52	1.34, 1.73	6.44	<0.001
Pulmonary hypertension	2.081	0.078	8.01	6.87, 9.34	26.61	<0.001
Lupus	0.805	0.056	2.24	2.00, 2.50	14.33	<0.001
Chronic kidney disease	1.692	0.029	5.43	5.13, 5.75	58.20	<0.001
Chronic heart disease	0.969	0.036	2.64	2.46, 2.83	26.90	<0.001
Diabetes	0.049	0.013	1.05	1.02, 1.08	3.75	<0.001
Chronic hypertension	0.531	0.017	1.70	1.65, 1.76	31.91	<0.001
Chronic respiratory disease	0.253	0.016	1.29	1.25, 1.33	15.60	<0.001

SOURCE: Authors' analysis of data from the National Inpatient Sample, 2007-2015. NOTES: The sample size is unweighted; all other data are weighted to represent the US population. CI is confidence interval. ^aAdjusted odds ratios controlled for continuous year, continuous age, insurance payer, race and ethnicity, income: bottom quartile, hospital region, cesarean delivery, substance abuse, depression, HIV/AIDS, pulmonary hypertension, lupus, chronic kidney disease, chronic heart disease, diabetes, chronic hypertension, chronic respiratory disease. ^bInsurance payer

represents the primary payer at delivery. The Medicaid category encompasses both Medicaid and Medicare, including fee-for-service and managed care. Other includes Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other government programs. ^cMedian income quartile for the patient's ZIP Code of residence.

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