Published in final edited form as:

Obstet Gynecol. 2020 November ; 136(5): 892–901. doi:10.1097/AOG.0000000000004057.

Associations Between Comorbidities and Severe Maternal Morbidity

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Abstract

Objective: To evaluate the associations between the number of chronic conditions and maternal race and ethnicity (“race”) with the risk of severe maternal morbidity.

Methods: Using the National Inpatient Sample, Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality, years 2016-2017, we examined risk of severe maternal morbidity among 1,480,925 delivery hospitalizations among women of different races and with different numbers of comorbid conditions using multivariable logistic regression.

Results: The rate of severe maternal morbidity was 139.7 per 10,000 deliveries. Compared to women with no comorbidities (rate=48.5 per 10,000), there was increased risk of severe maternal morbidity among women with one comorbidity (rate=238.6; OR=5.0 [95% CI: 4.8-5.2]), two comorbidities (rate=379.9; OR=8.1 [95% CI: 7.8-8.5]), or three or more comorbidities (rate=560; OR=12.1 [95% CI: 11.5-12.7]). In multivariable regressions, similar associations were noted for women with one (aOR=4.4 [95% CI: 4.2-4.6]), two (aOR=6.6 [95% CI: 6.3-6.9]), or three or more comorbidities (aOR=9.1 [95% CI: 8.7-9.6]). Black women had higher rates of comorbid conditions than all other racial and ethnic groups, with 55% (95% CI: 54%-56%) of black women having no comorbidities, compared to 67% (95% CI: 67%-68%) of white women, 68% (95% CI: 67%-69%) of Hispanic women, and 72% (95% CI: 71%-73%) of Asian women.

Conclusions: We found a dose-response relationship between number of comorbidities and risk of severe maternal morbidity, with the highest rates of severe maternal morbidity among women with three or more comorbidities. Focusing on the prevention and treatment of chronic conditions

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Financial Disclosure

The authors did not report any potential conflicts of interest.

Each author has confirmed compliance with the journal’s requirements for authorship.

among women of childbearing age may have the potential to improve maternal outcomes across races and ethnicities.

Precise

Focus on the prevention and treatment of chronic conditions among women of childbearing age may improve maternal outcomes across all races and ethnicities.

Severe maternal morbidity is defined as unintended outcomes of the process of labor and delivery that result in significant long- or short-term consequences to a women's health.¹ The rate of severe maternal morbidity in the United States has nearly doubled since 1993, affecting around 50,000 deliveries annually, with non-Hispanic black ("black") women having twice the rate as non-Hispanic white ("white") women.²⁻⁴

Chronic conditions increase the risk of adverse maternal outcomes, and deliveries among women with multiple chronic conditions have 3.8 times the rate of severe maternal morbidity and mortality compared to women without chronic conditions.⁵ Despite an overall increase in rates of chronic conditions among all pregnant women, women of minority race and ethnicity ("race") are at a higher risk of having chronic conditions during pregnancy, a disparity that has widened over time, with the difference in prevalence of one or more preexisting comorbid conditions for black women nearly twice that of white women (9.9% versus 5.6% in one study).^{6,7} Understanding interactions between race and the presence of chronic conditions as well as the association of these factors on maternal outcomes is important information for policymakers and clinicians for implementing strategies to reduce overall rates as well as racial and ethnic disparities in adverse maternal outcomes.

The purpose of this study was to assess differences in risk of severe maternal morbidity among delivery hospitalizations for women with no comorbidities or with one, two, or three or more comorbidities, overall and among women of different races. It was expected that women with more comorbidities would be at increased risk of severe maternal morbidity and that there would exist differences in the relationships between the number of comorbid conditions and risk of severe maternal morbidity among women of different races.

Methods

The data used in this study included hospital discharge data from the Healthcare Cost and Utilization Project National Inpatient Sample, years 2016 and 2017. The National Inpatient Sample is produced by the Agency for Healthcare Research and Quality through a federal and state partnership to provide the largest publicly available hospital discharge dataset, which includes a 20% sample of hospital discharges among target hospitals, along with weights to obtain national estimates (<https://www.hcup-us.ahrq.gov/nisoverview.jsp>). The National Inpatient Sample includes hospital information, patient demographics, and diagnosis and procedural codes based the International Classification of Diseases, Tenth Revision, Clinical Modification and Procedure Coding System (ICD-10).

From the 14,294,784 hospitalizations in the data, we identified 1,501,606 delivery hospitalizations using an expanded definition for delivery.⁸ This definition includes hospitalizations with a delivery diagnosis code (O80, O82) or diagnosis-related group code

(765-768, 774, 775), as well as hospitalizations with a procedure code for vaginal or cesarean delivery (10D00Z0-10D07Z8, 10E0XZZ) or for outcome of delivery (Z370-Z374, Z3750-Z3754, Z3759, Z3760-Z3764, Z3769, Z377, Z379). After excluding 3,360 deliveries with an abortion diagnosis (O00-O0899), we excluded deliveries with missing information for age (n=77), place of residence (n= 3,971), or ZIP code-level income (n= 10,681). An additional 2,592 deliveries were excluded for women who transferred out of the hospital, resulting in a final sample of 1,480,925 deliveries (7,404,617 weighted deliveries; see Appendix 1, available online at <http://links.lww.com/AOG/C28>, for flow chart).

Our primary outcome measure was severe maternal morbidity identified using the Centers for Disease Control and Prevention severe maternal morbidity indicator list, which is specifically used to identify maternal morbidity using hospital discharge data that contains ICD-10 diagnosis and procedure codes.³ The list includes a total of 21 indicators based on diagnosis (16 indicators) and procedural (five indicators) codes (Appendix 2, available online at <http://links.lww.com/AOG/C28>, contains a full list of the indicators with the associated codes).

Following previous studies, a delivery was identified as having severe maternal morbidity if that delivery: 1) had at least one of the five procedure-based indicators or 2) had at least one of the 16 diagnosis-based indicators and additionally had: a) in-hospital death, b) a cesarean delivery with a length of stay ≥ 5 days, or c) a vaginal delivery with a length of stay ≥ 3 days.^{5,9}

Previous evaluations have found that a large proportion (~65%) of deliveries with severe maternal morbidity identified using the Centers for Disease Control and Prevention algorithm included deliveries with only an indicator of blood transfusion, and no other indicator.⁴ Therefore, we included an additional outcome in our study in order to be able to assess outcomes for severe maternal morbidity overall as well as severe maternal morbidity excluding deliveries that had an indicator of blood transfusion but no other severe maternal morbidity indicator. This approach follows that used by the Centers for Disease Control and Prevention.³ As such, we included a measure of severe maternal morbidity that is calculated in the same manner as described above; however, deliveries with only a blood transfusion indicator are identified as not having severe maternal morbidity (“maternal morbidity excluding deliveries with only blood transfusion”).

Variables used in adjusted regressions included patient- and hospital-level characteristics. Patient characteristics included age (<20 years, 20-29 years, 30-39 years, ≥ 40 years), race (white, black, non-Hispanic Asian [“Asian”], Hispanic, other [including missing]), primary expected payer (private, Medicaid, Medicare, other [including missing and self-pay]), number of comorbidities (0, 1, 2, ≥ 3), delivery type (vaginal, cesarean), median household income quartile (Q1 through Q4, with Q1 representing the lowest incomes), and location of residence (large metropolitan, small or median metropolitan, micropolitan, or rural [equivalent to noncore]).

Median household income and location of residence were based on the patient’s ZIP code of residence. The number of comorbidities was defined using the 29 Elixhauser comorbidity

measures identified using the software available through the Healthcare Cost and Utilization Project (additional information in Appendix 3, available online at <http://links.lww.com/AOG/C28>). There was overlap in the ICD-10 codes used to determine severe maternal morbidity and the ICD-10 codes used for four of the Elixhauser comorbidities. As such, these four comorbidities (congestive heart failure, coagulation deficiency, pulmonary circulation disorders, and peripheral perivascular disease) were removed from our analyses. Additionally, the Elixhauser measures include a hypertension comorbidity measure that combines complicated and uncomplicated hypertension. There was overlap in ICD-10 codes for severe maternal morbidity and the ICD-10 codes specifically associated with the complicated hypertension. Therefore, any individual with complicated hypertension was designated as not having the hypertension measure used in our study. A full outline of the comorbidities and associated ICD-10 codes can be found in Appendix 3 (<http://links.lww.com/AOG/C28>). Removal of these comorbidities reduced the percent of women with at least one comorbidity from 35% to 34%. A total of 1,868 (0.1%) deliveries with missing payer information and 79,106 (5.3%) deliveries with missing race information were categorized as “other.” Hospital-level characteristics included region (Northeast, Midwest, South, West), ownership (public, private non-profit, private for-profit), and location and teaching status (rural, urban non-teaching, urban teaching).

Rates of severe maternal morbidity per 10,000 deliveries were calculated for each patient- and hospital-level characteristics, with associated 95% confidence intervals to test for differences. Bar charts were constructed to provide rates of severe maternal morbidity per 10,000, stratified by race and number of comorbidities. An additional bar chart was created to indicate the percentage of deliveries with each number of comorbid conditions, by race.

Multivariable logistic models were estimated to assess the association of characteristics and the likelihood of severe maternal morbidity. To assess for associations of characteristics of women with differing numbers of comorbidities, regressions were re-estimated and stratified by categories of the number of comorbid conditions.

Analyses were completed using survey procedures in SAS 9.4 to account for the complex survey design. Visualizations were created using Tableau 2019.4. Statistical significance was assumed at $p < .05$. This study was deemed non-human subjects research by the University of Arkansas for Medical Sciences Institutional Review Board (#260999).

Results

The overall rate of severe maternal morbidity was 139.7 per 10,000 deliveries, and the rate of severe maternal morbidity excluding deliveries with only blood transfusions was 43.9 per 10,000 deliveries. Over 91% of deliveries were in women aged 20 to 39 years old, with 49.9% of deliveries being to white women (Table 1).

Table 1 provides the rates of severe maternal morbidity per 10,000 as well as the rates of severe maternal morbidity excluding deliveries with only a blood transfusion for each patient- and hospital-level characteristic, and Table 2 provides the odds ratios and associated 95% confidence intervals (CI) to assess for unadjusted associations between patient- and

hospital-level characteristics and severe maternal morbidity. All racial and ethnic (“racial”) minorities had increased odds of severe maternal morbidity relative to deliveries among white women. Deliveries among white women had a rate of severe maternal morbidity of 104.7 per 10,000, compared to 225.7 per 10,000 for deliveries among black women (OR: 2.2; 95% CI: 2.1-2.3), 163.3 per 10,000 for deliveries among Hispanic women (OR: 1.6; 95% CI: 1.5-1.7), and 153 per 10,000 for deliveries among Asian women (OR: 1.5; 95% CI: 1.4-1.6). There were additionally lower rates of severe maternal morbidity excluding blood transfusions among white women relative to all other racial minorities, including deliveries among black women (OR: 2.2; 95% CI: 2.1-2.4), deliveries among Hispanic women (OR: 1.4; 95% CI: 1.3-1.5), and deliveries among Asian women (OR: 1.5; 95% CI: 1.4-1.7).

The rates of severe maternal morbidity per 10,000 deliveries among women with no comorbidities or with one, two, or three or more comorbidities were 48.5, 238.6, 379.9, and 560, respectively (Table 1). Thus, women with three or more comorbidities had a 1.5 OR (95% CI: 1.4-1.6) for severe maternal morbidity compared to women with two comorbidities, a 2.4 OR (95% CI: 2.3-2.5) for severe maternal morbidity compared to women with one comorbidity, and an OR of 12.1 (95% CI: 11.5-12.7) compared to women with no comorbidities (results not shown in tables). Similarly, women with two comorbidities had a 1.6 OR (95% CI: 1.5-1.7) for severe maternal morbidity compared to women with one comorbidity, and a 8.1 OR (95% CI: 7.8-8.5) for severe maternal morbidity compared to women with no comorbidities. Women with one comorbidity had an OR of 5.0 (95% CI: 4.8-5.2) compared to women with no comorbidities.

Figure 1 provides rates of severe maternal morbidity stratified by number of comorbidities and race. Deliveries among white women had the lowest rates of severe maternal morbidity, regardless of comorbidity group; however the increased odds of severe maternal morbidity among black women relative to white women sequentially fell across comorbid condition categories. The odds of severe maternal morbidity among black women relative to white women with no comorbidities (OR: 2.0; 95% CI: 1.8-2.1; 72 vs 37 per 10,000) was higher than the increased risk for black women relative to white women among births with one (OR: 1.7; 95% CI: 1.6-1.9; 306 vs 180 per 10,000), two (OR: 1.6; 95% CI: 1.5-1.8; 473 vs 296 per 10,000), or three or more comorbidities (OR: 1.4; 95% CI: 1.3-1.6; 653 vs 468 per 10,000). There was increased risk for women with comorbidities relative to women with fewer comorbidities across racial subgroups. For example, having three or more comorbidities increased risk relative to having no comorbidities among black women (OR: 9.6; 95% CI: 8.7-10.6; 653 vs 72 per 10,000), Asian women (OR: 10.8; 95% CI: 9.0-12.9; 651 vs 64 per 10,000), Hispanic women (OR: 11.2; 95% CI: 10.1-12.4; 615 vs 58 per 10,000), and white women (OR: 13.1; 95% CI: 12.1-14.2; 468 vs 37 per 10,000). Figure 2 provides rates of severe maternal morbidity excluding deliveries with only blood transfusion, stratified by number of comorbidities and race.

Figure 3 provides the percentage of women with each number of comorbidities within each racial group. Black women were more likely to have comorbidities than any other racial group. For example, 7% (95% CI: 7%-8%) of black women had three or more comorbidities, compared to 4% (95% CI: 4%-4%) of white women, 4% (95% CI: 4%-4%) of Hispanic women, and 3% (95% CI: 2%-3%) of Asian women. Only 55% (95% CI:

54%-56%) of black women had no comorbidities, compared to 67% (95% CI: 67%-68%) of white women, 68% (95% CI: 67%-69%) of Hispanic women, and 72% (95% CI: 71%-73%) of Asian women.

Table 2 provides adjusted odds ratios for the association between patient-level and hospital-level characteristics with severe maternal morbidity across all comorbidity groups. Having comorbidities remained the largest predictor of severe maternal morbidity. Compared to having no comorbidities, having one comorbidity was associated with odds of severe maternal morbidity equal to 4.4 (95% CI: 4.2-4.6) and for severe maternal morbidity excluding only blood transfusions equal to 3.1 (95% CI: 2.9-3.3). Deliveries among women with two or three comorbidities had further increased odds of severe maternal morbidity (OR: 6.6 [95% CI: 6.3-6.9] and OR: 9.1 [95% CI: 8.7-9.6]) and of severe maternal morbidity excluding blood transfusions alone (OR: 4.8 [95% CI: 4.5-5.2] and OR: 9.7 [95% CI: 8.9-10.5]), relative to deliveries among women with no comorbidities.

Adjusted regressions stratified by number of comorbidities are available in Appendixes 4 and 5, available online at <http://links.lww.com/AOG/C28>. The risk of severe maternal morbidity for black women relative to white women sequentially declined among women with no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities. Specifically, the risk of severe maternal morbidity for black women relative to white women among women with no comorbidities was 1.6 (95% CI: 1.5-1.8) compared to 1.4 (95% CI: 1.2-1.5) among women with three or more comorbidities.

Discussion

This study found a dose-response relationship between the number of comorbid conditions and rate of severe maternal morbidity. In fact, the rate was over ten times higher among women with three or more comorbidities compared to women with no comorbidities, and if the rate of severe maternal morbidity within a given racial subgroup could be reduced to the rate among women with no comorbidities in that racial category, the rate of severe maternal morbidity would be reduced by 64%, 68%, 64%, and 58% for deliveries among white, black, Hispanic, and Asian women, respectively.

Our study found relationships between patient-level characteristics that align with previous studies, such as increased rates in areas with lower household incomes as well as increased rates among the oldest and youngest age groups.^{6,10,11} Our study adds to the literature that evaluates the relationships between chronic conditions, race, and severe maternal morbidity by using additional comorbid conditions and by stratifying adjusted analyses by categories of the number of comorbidities. A previous study that used hospital discharge data from 2012 to 2015 found that women with comorbid conditions were more likely to have severe maternal morbidity regardless of race.⁵ Our study might further inform policymakers, clinicians, and patients regarding the factors that may be most associated with severe maternal morbidity. Specifically, we found reduced odds of severe maternal morbidity associated with many covariate factors in stratified multivariable regressions among deliveries with more comorbidities compared to regressions among deliveries with fewer

comorbidities, suggesting that the existence of chronic conditions may be a larger predictor of maternal morbidity compared to other patient- or hospital-factors.

Regardless of race, deliveries with any number of comorbidities had higher rates of severe maternal morbidity. Of importance is the larger percent of black women with chronic conditions. Our study found that 45% of black women had at least one comorbidity and 21% had at least two comorbid conditions, compared to 33% and 13% of white women. In analyses that were stratified by the number of comorbid conditions, we found that the relative disparity between black and white women sequentially declined for deliveries among women with one, two, or three or more chronic conditions relative to women with no comorbidities. For example, the increased odds for black women relative to white women in the overall model (OR=2.2) was decreased to an odds ratio of 1.4 in the model for women with three or more chronic conditions. Higher rates of comorbid conditions may contribute to the increased risk of severe maternal morbidity among black women; however, other factors not captured in our study are likely critical factors as well. A growing body of literature is exposing the reality that, rather than specifically race itself, other societal factors, such as exposure over a lifetime to implicit bias and racism, differences in access to family planning services and early and regular prenatal care, and other health and healthcare inequities likely contribute to the increased risk among racial minorities, particularly black women.^{6,12} As such, addressing underlying issues of implicit bias and racism, access and coverage of care, and social needs in healthcare, as well as in society as a whole, may play a more critical role in reducing disparities.

Our study had several limitations related to the use of administrative hospital discharge data. First, only maternal morbidity during the delivery hospitalization could be identified, and the timing of diagnosis codes used to identify chronic conditions cannot be differentiated from the timing for codes used to identify severe maternal morbidity. However, we removed chronic conditions with diagnosis codes that overlapped with codes used to identify severe maternal morbidity. This could bias results for women with excluded comorbidities, such as complicated hypertension. Furthermore, we followed previous methods, to identify deliveries with only a diagnosis-based severe maternal morbidity indicator as having severe maternal morbidity if the delivery met the minimum length of stay threshold for cesarean or for vaginal delivery. Relatedly, our analysis did not include deliveries outside of the hospital (e.g., in freestanding birth centers), and we excluded deliveries in which the mother transferred to another facility, which may limit the generalizability of rates of severe maternal morbidity found in our study. Therefore, the findings from our study may be biased if there are different rates of severe maternal morbidity among the excluded populations or if women of a particular race were more or less likely to be excluded from the sample. Given the observational design, the contribution of the comorbidities to increased risk of severe maternal morbidity cannot be specifically measured.

Second, a majority of the literature evaluating severe maternal morbidity uses data prior to the transition to ICD-10, which may limit comparisons of our findings with previous studies. Our study used the first two full years of data from the National Inpatient Sample that uses ICD-10 codes. While we did not perform any verification of the ICD-10 codes specifically, we followed the Centers for Disease Control and Prevention algorithms, and found overall

rates of maternal morbidity that align with findings from studies that used the 9th revision of the International Classification of Diseases.⁴

Third, given the relatively small sample size, we were unable to separately analyze Native American women, and around 5% of observations had missing information for race, which could bias results if missing race is not distributed equally across hospitals. Appendix 6, available online at <http://links.lww.com/AOG/C28>, provides adjusted odds ratios associated with regressions that excluded the 5% of records with missing racial information. We were limited in our ability to fully assess individual comorbidities because of small sample sizes. However, we found in unadjusted analyses that all 25 Elixhauser comorbidities were associated with increased risk of maternal morbidity. The five conditions that were most highly associated included fluid and electrolyte disorders, metastatic cancer, renal failure, weight loss, and valvular heart disease.

Finally, this data source did not include all relevant factors, such as behavioral characteristics, prenatal care use, and individual socioeconomic factors, that may be associated with maternal health outcomes. The data includes a proxy for household income based on the mother's ZIP code of residence, grouped into quartiles, which may not accurately reflect actual household incomes. Additionally, the severe maternal morbidity and comorbidity indicators are limited to the diagnoses indicated in the data, which are reliant on coding and may underrepresent some comorbidities such as obesity.

Despite these limitations, our study was strengthened by using a nationally representative dataset and the most current hospital discharge data and ICD-10 severe maternal morbidity algorithm. This study found large racial and ethnic disparities in rates of severe maternal morbidity during delivery hospitalization, with higher rates of severe maternal morbidity among women with comorbid conditions. Continued efforts across races and ethnicities should focus on preventing and treating chronic conditions prior to and in between pregnancies among women of childbearing age.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

The authors thank our colleagues from IBM Watson Health for assistance with organizing the data for this analysis. The authors also thank all Healthcare Cost and Utilization Project Data Partners for their contribution to the Nationwide databases. A list of the Data Partners can be found at <https://www.hcup-us.ahrq.gov/db/hcupdatapartners.jsp>.

Funding for the assistance provided by IBM Watson Health came from the Institute for Medicaid Innovation.

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Figure 1:

Rate of severe maternal morbidity per 10,000 deliveries, by race (unweighted n=1,480,925), identified using the Centers for Disease Control and Prevention severe maternal morbidity indicator list. Number of comorbidities calculated among 25 Elixhauser comorbidity measures. See Appendix 3 (<http://links.lww.com/AOG/C28>) for full comorbidity description. *Horizontal bars* indicate 95% CIs, which were constructed without using the weighted N in order to avoid artificially narrow confidence intervals.

Figure 2:

Rate of severe maternal morbidity excluding deliveries with only blood transfusion per 10,000 deliveries, by race and number of comorbid conditions (unweighted n=1,480,925; weighted n=7,404,617). The rate of Severe Maternal Morbidity excluding blood transfusions, per 10,000 deliveries, identified using the Centers for Disease Control and Prevention algorithm. Horizontal bars indicate 95% confidence intervals (CIs), which were constructed without using the weighted n to avoid artificially narrow CIs.

Figure 3:

Percentage of individuals within each comorbid condition category, by race (unweighted $n=1,480,925$). Number of comorbidities calculated among 25 Elixhauser comorbidity measures. See Appendix 3 (<http://links.lww.com/AOG/C28>) for full comorbidity description. *Horizontal bars* indicate 95% CIs, which were constructed without using the weighted N in order to avoid artificially narrow confidence intervals.

Table 1

Demographic characteristics and rates of severe maternal morbidity per 10,000 deliveries (unweighted n=1,480,925; weighted n=7,404,617).

Variable		%*	SMM†	SMM without Blood Transfusion†
Patient Characteristics			Deliveries per 10,000	Deliveries per 10,000
Age, years			Rate (95% CI)	Rate (95% CI)
	<20	5.4	196 (184-208)	47 (42-51)
	20-29‡	49.2	131.2 (126.4-136.0)	35.0 (33.4-36.6)
	30-39	42.3	134.5 (130.0-139.3)	49.4 (47.2-51.5)
	40+	3.1	246 (231-262)	104 (95-114)
Race and ethnicity				
	Non-Hispanic White‡	49.9	104.7 (101.1-108.3)	33.4 (31.9-34.9)
	Non-Hispanic Black	14.2	225.7 (214.1-237.4)	74.2 (69.7-78.7)
	Hispanic	19.5	163.3 (153.6-173.1)	47.8 (44.7-50.8)
	Non-Hispanic Asian	6.0	153 (142-164)	51 (46-57)
	Other or Missing	10.4	137.6 (128.8-146.4)	41.1 (37.3-44.8)
Payer				
	Private insurance	51.0	113.5 (109.5-117.5)	37.0 (35.4-38.7)
	Medicaid	43.0	169.3 (162.6-175.9)	51.1 (48.9-53.3)
	Medicare	0.7	285 (248-322)	130 (106-153)
	Other or Missing	5.3	131 (121-141)	39 (34-44)
Number of comorbidities§				
	0‡	66.1	48.5 (46.6-50.4)	16.8 (15.6-17.4)
	1	20.0	238.6 (229.0-248.1)	62.4 (59.1-65.6)
	2	9.8	379.9 (365.4-394.4)	107.8 (101.9-113.7)
	3+	4.1	560 (532-581)	244 (230-258)
Delivery type				
	Vaginal‡	67.8	77.0 (74.0-78.0)	18.7 (17.7-19.6)
	Cesarean Section	32.2	271.6 (262.8-280.4)	96.9 (93.3-100.5)
Median household income				
	Quartile 1	28.4	175.3 (167.2-183.5)	51.1 (48.4-53.8)
	Quartile 2	25.1	136.8 (131.5-142.1)	43.9 (41.6-46.2)
	Quartile 3	24.6	123.5 (118.6-128.5)	40.1 (37.8-42.3)
	Quartile 4‡	21.9	115.0 (109.4-120.5)	38.8 (36.3-41.2)
Location of Residence				
	Large metropolitan	57.5	146.9 (140.3-153.6)	48.1 (46.0-50.2)
	Small or medium metropolitan‡	29.2	123.3 (117.2-129.3)	39.6 (37.4-41.9)
	Metropolitan	7.9	145.5 (136.8-154.2)	35.7 (31.9-39.4)

Variable	% [*]	SMM [‡]	SMM without Blood Transfusion [‡]
Rural (noncore)	5.4	142.4 (132.0-152.8)	33.3 (29.1-37.4)
Hospital Characteristics			
Region			
Northeast	16.0	172.5 (161.8-183.1)	51.0 (47.3-54.8)
Midwest [‡]	21.2	109.7 (101.8-117.6)	39.3 (36.4-42.2)
South	38.8	147.2 (138.9-155.5)	42.5 (40.0-44.9)
West	23.9	132.2 (125.1-139.3)	45.4 (42.3-48.5)
Ownership			
Public	11.6	189.7 (169.3-210.1)	56.2 (50.6-61.8)
Private non-profit	74.1	136.1 (131.4-140.7)	44.0 (42.3-45.7)
Private for-profit [‡]	14.2	117.5 (108.8-126.3)	33.1 (30.3-35.9)
Location and teaching status			
Rural	9.3	137.7 (128.7-146.7)	18.1 (15.7-20.5)
Urban non-teaching [‡]	23.5	112.1 (106.1-118.2)	29.7 (27.6-31.7)
Urban teaching	67.2	149.6 (143.5-155.7)	52.4 (50.3-54.4)

SMM=severe maternal morbidity; CI=Confidence interval

^{*} Percentages may not total to 100 due to rounding. Percentages represent the number of deliveries within that classification of a given variable. The percentage of individuals is the same for both SMM outcomes, as the calculations for both outcomes include the same deliveries. The 95% confidence intervals were constructed without using the weighted N in order to avoid artificially narrow confidence intervals.

[‡] Identified using the Centers for Disease Control and Prevention SMM indicator list. Severe maternal morbidity without Blood Transfusion indicates that a delivery to a women with only a blood transfusion indicator, and no other SMM indicator was identified as not having SMM.

[‡] Reference category.

[§] Number of comorbidities calculated among 25 Elixhauser comorbidity measures. See Appendix 3 (<http://links.lww.com/AOG/C28>) for full comorbidity description.

Table 2

Adjusted logistic regressions for associations between patient-level and hospital-level characteristics and maternal morbidity measures (unweighted n=1,480,925; weighted n=7,404,617).

Independent Variable		Severe Maternal Morbidity*		Severe Maternal Morbidity, excluding blood transfusion only*	
Patient Characteristics		Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age, years					
	<20	1.5 (1.4-1.6)	1.6 (1.5-1.7)	1.3 (1.2-1.5)	1.5 (1.4-1.7)
	20-29	Ref	Ref	Ref	Ref
	30-39	1.0 (1.0-1.1)	1.0 (1.0-1.0)	1.4 (1.3-1.5)	1.3 (1.2-1.4)
	40+	1.9 (1.8-2.0)	1.4 (1.3-1.5)	3.0 (2.7-3.3)	2.0 (1.8-2.2)
Race and ethnicity					
	Non-Hispanic White	Ref	Ref	Ref	Ref
	Non-Hispanic Black	2.2 (2.1-2.3)	1.5 (1.4-1.6)	2.2 (2.1-2.4)	1.5 (1.4-1.6)
	Non-Hispanic Asian	1.5 (1.4-1.6)	1.7 (1.5-1.8)	1.5 (1.4-1.7)	1.5 (1.4-1.7)
	Hispanic	1.6 (1.5-1.7)	1.4 (1.4-1.5)	1.4 (1.3-1.5)	1.3 (1.2-1.4)
	Other or Missing	1.3 (1.2-1.4)	1.4 (1.3-1.4)	1.2 (1.1-1.4)	1.2 (1.1-1.4)
Payer					
	Private	Ref	Ref	Ref	Ref
	Medicaid	1.5 (1.4-1.6)	1.1 (1.1-1.2)	1.4 (1.3-1.5)	1.2 (1.1-1.2)
	Medicare	2.6 (2.2-2.9)	1.4 (1.2-1.6)	3.5 (2.9-4.3)	1.8 (1.5-2.2)
	Other or Missing	1.2 (1.3-1.3)	1.2 (1.1-1.3)	1.1 (0.9-1.2)	1.2 (1.0-1.3)
Number of comorbidities†					
	0	Ref	Ref	Ref	Ref
	1	5.0 (4.8-5.2)	4.4 (4.2-4.6)	3.8 (3.6-4.1)	3.1 (2.9-3.3)
	2	8.1 (7.8-8.5)	6.6 (6.3-6.9)	6.6 (6.1-7.1)	4.8 (4.4-5.2)
	3+	12.1 (11.5-12.7)	9.1 (8.7-9.6)	15.1 (14.0-16.3)	9.7 (8.9-10.5)
Delivery type					
	Vaginal	Ref	Ref	Ref	Ref
	Cesarean Section	3.6 (3.5-3.7)	2.8 (2.7-2.9)	5.2 (5.0-5.5)	3.9 (3.7-4.1)
Median household income					
	Quartile 1	1.5 (1.4-1.6)	1.2 (1.1-1.2)	1.3 (1.2-1.4)	1.1 (1.0-1.2)
	Quartile 2	1.2 (1.1-1.3)	1.1 (1.0-1.1)	1.1 (1.0-1.2)	1.1 (1.0-1.2)
	Quartile 3	1.1 (1.0-1.1)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	1.0 (1.0-1.1)
	Quartile 4	Ref	Ref	Ref	Ref
Location of Residence					
	Large metropolitan	1.2 (1.1-1.3)	1.1 (1.1-1.2)	1.2 (1.1-1.3)	1.1 (1.0-1.2)
	Small or medium metropolitan	Ref	Ref	Ref	Ref
	Metropolitan	1.2 (1.1-1.3)	1.2 (1.1-1.3)	0.9 (0.8-1.0)	1.7 (1.5-2.0)
	Rural (noncore)	1.2 (1.1-1.3)	1.2 (1.1-1.3)	0.8 (0.7-1.0)	1.4 (1.2-1.6)

Independent Variable		Severe Maternal Morbidity [*]		Severe Maternal Morbidity, excluding blood transfusion only [*]	
Hospital Characteristics					
Region					
	Northeast	1.6 (1.4-1.7)	1.5 (1.4-1.7)	1.3 (1.2-1.4)	1.1 (1.0-1.2)
	Midwest	Ref	Ref	Ref	Ref
	South	1.3 (1.2-1.5)	1.2 (1.1-1.3)	1.1 (1.0-1.2)	1.0 (0.9-1.0)
	West	1.2 (1.1-1.3)	1.2 (1.1-1.3)	1.2 (1.0-1.3)	1.2 (1.0-1.3)
Ownership					
	Public	1.6 (1.4-1.9)	1.3 (1.2-1.5)	1.7 (1.5-1.9)	1.3 (1.2-1.5)
	Private non-profit	1.2 (1.1-1.3)	1.1 (1.0-1.1)	1.3 (1.2-1.5)	1.1 (1.0-1.2)
	Private for-profit	Ref	Ref	Ref	Ref
Location and teaching status					
	Rural	1.2 (1.1-1.3)	1.1 (1.0-1.2)	0.6 (0.5-0.7)	0.4 (0.4-0.5)
	Urban non-teaching	Ref	Ref	Ref	Ref
	Urban teaching	1.3 (1.3-1.4)	1.1 (1.0-1.1)	1.8 (1.6-1.9)	1.4 (1.3-1.5)

OR=odds ratio; CI=confidence interval; ref=reference category

^{*} Identified using the Centers for Disease Control and Prevention severe maternal morbidity indicator list. Severe maternal morbidity excluding blood transfusion indicates that a delivery to a women with only a blood transfusion indicator, and no other SMM indicator was identified as not having SMM.

^f Number of comorbidities calculated among 25 Elixhauser comorbidity measures. See Appendix 3 (<http://links.lww.com/AOG/C28>) for full comorbidity description.

Multivariable regressions adjusted age (years), race and ethnicity, primary expected payer, number of comorbidities, delivery type (i.e., vaginal or cesarean), median household income quartile, and location of residence (large metropolitan, small or median metropolitan, micropolitan, or rural), hospital region, hospital ownership, and hospital location and teaching status (rural, urban non-teaching, urban teaching).