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Preconception care and severe maternal morbidity in the United States

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Abstract

BACKGROUND: In the United States, approximately 52,000 women per year (accounting for 1.46% of births) experience severe maternal morbidity, which is defined as a complication that causes significant maternal harm or risk of death. It disproportionately affects women from racial or ethnic minorities, people with chronic diseases, and those with Medicaid or no insurance. Preconception care has been hailed as a strategy to improve pregnancy outcomes and reduce disparities, but its broad benefits for maternal outcomes have not been demonstrated.

OBJECTIVE: Our objective was to measure the association between preconception care and the odds of severe maternal morbidity among women with Medicaid.

STUDY DESIGN: This is a secondary analysis of Medicaid claims using the Medicaid Analytic Extract files (2010–2012). We used the International Classification of Diseases, Ninth Revision codes, published by the US Office of Population Affairs' Quality Family Planning program to define 7 domains of preconception care. The primary outcome was maternal death within 12 weeks of delivery or severe maternal morbidity during birth hospitalization, defined by the presence of any diagnosis or procedure on the severe maternal morbidity International Classification of Diseases, Ninth Revision code list from the Centers for Disease Control and Prevention. Because this list may overestimate severe maternal morbidity by counting any blood transfusion, our secondary outcome used the same code list but without transfusion. We reviewed care in the year before conception and used logistic regression to estimate the association between each domain and severe maternal morbidity for all births to women enrolled in Medicaid and aged

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Supplementary materials

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15 to 45 years with births during 2012. We performed a subgroup analysis for women with chronic disease (kidney disease, hypertension, or diabetes).

RESULTS: Severe maternal morbidity or death occurred in 26,285 births (1.74%) when including blood transfusions and 9,481 births (0.63%) when excluding transfusions. Receiving contraceptive services in the year before conception was associated with decreased odds of severe maternal morbidity (adjusted odds ratio, 0.92; 95% confidence interval, 0.88–0.95) and pregnancy test services were associated with increased odds (adjusted odds ratio, 1.08; 95% confidence interval, 1.01–1.14). In the primary analysis, no significant associations were observed for other preconception care domains. Among those women with at least 1 chronic disease, contraceptive care (adjusted odds ratio, 0.84; 95% confidence interval, 0.75–0.95) and routine physical or gynecologic exams (adjusted odds ratio, 0.79; 95% confidence interval, 0.71–0.88) were associated with decreased odds of severe maternal morbidity. Similar associations were found for severe maternal morbidity when excluding blood transfusion.

CONCLUSIONS: Contraceptive services in the year before conception and routine exams for women with chronic disease are associated with decreased odds of severe maternal morbidity or death for Medicaid enrollees.

Keywords

contraception; maternal morbidity; Medicaid; preconception care

Introduction

In the United States, severe maternal morbidity (SMM), defined as a pregnancy complication that causes significant adverse consequences for the woman or puts her at risk of death,[1] has increased nearly 200% in the past 2 decades, reaching a rate of 146 per 100,000 births in 2015.[2] The rates of SMM in the United States are among the highest within developed countries.[3] It disproportionately affects women from racial and ethnic minorities, residents of low-income zip codes, and people with chronic medical conditions.[4–7]

Previous research has shown that individual-level factors account for 20% to 40% of the variation in obstetrical complications.[6] Hospital factors at the time of delivery account for only another 20%,[8] suggesting that upstream factors contribute significantly to SMM. One such potential factor is preconception care, defined as preventative healthcare that a patient receives before pregnancy to address pregnancy-related risk factors. Preconception care is hailed as a promising strategy to prevent adverse pregnancy outcomes and reduce racial and ethnic disparities in infant health,[9–11] but its benefits for maternal outcomes have not yet been demonstrated.

The Medicaid program covers almost half of all births in the United States, which is more than any other single payer.[12,13] Women with Medicaid are more likely to experience SMM than women with private insurance.[14] We used Medicaid claims data to examine the association between preconception care and the risk of SMM in this high-risk population,

hypothesizing that women who utilize preconception care will be less likely to experience SMM in a subsequent pregnancy.

Materials and Methods

This is an analysis using the Medicaid Analytic Extract (MAX) data files from the Centers for Medicare and Medicaid Services (CMS) from 2010 to 2012, which we received under an approved Data Use Agreement. These data files include person-level information on Medicaid enrollees and encounter-level information for Medicaid claims from all sources of care, including inpatient, outpatient, physician services, radiology, clinic visits, and pharmacies. The University of Chicago's Institutional Review Board approved this study.

We included all female beneficiaries aged 15 to 45 years who were enrolled in Medicaid for all states with data publicly available through CMS including Washington, DC (data were not available for the following states: AL, ID, ME, KS, RI, and SD) who experienced a delivery in 2012 and had Medicaid coverage for delivery of this index pregnancy. We identified deliveries using the following International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes: V27.xx with or without 650 for normal deliveries; and V27. xx with 644.2, 644.4, 765.0 or 765.1 for preterm births. For women with more than 1 delivery in calendar year 2012, we only used information from the first delivery.

The primary outcome was a composite of maternal death within 12 weeks of delivery or any SMM event during the delivery hospitalization (hereafter, "SMM" will refer to both severe maternal morbidity and maternal mortality). We chose to examine up to 12 weeks following delivery because of recent emphasis on the "fourth trimester," the roughly 3 month period following pregnancy in which many complications arise.[15] Further, up to 12% of maternal deaths occur after the 42-day period.[16] We wanted to strike a balance between capturing some of these deaths in the later period and the fact that, practically, many women lose Medicaid coverage after 6 to 12 weeks postpartum, and thus, we would no longer be able to track them.

We identified women who experienced SMM using the ICD-9 diagnosis codes and Current Procedural Terminology codes that the Centers for Disease Control and Prevention (CDC) has compiled.[17] This is a validated measure used in other studies on SMM.[2,18] As a secondary outcome, we examined all women who experienced SMM apart from blood transfusion, as blood transfusion as the sole indicator of SMM often overestimates the true prevalence of SMM.[19]

The main exposure of interest was preconception care, which we defined as the receipt of specific healthcare services in the 12 months before conception of the 2012 index pregnancy. We first determined the date of conception using a modified version of the approach described by Palmsten et al.[20] In brief, we calculated the date of conception to be 255 days before the delivery date of a full-term birth and 230 days before a premature birth.

We identified preconception care in the MAX outpatient files using a list of ICD 9 and 10 codes published by the United States Department of Health and Human Services (DHHS) under its Office of Population Affairs Quality Family Planning program.[21] We

utilized the following 7 domains of care, as previously defined by the CDC and DHHS: contraceptive services, pregnancy test & counseling, achieving pregnancy, basic infertility services, preconception health services, sexually transmitted infection services, and related preventative health services (which we refer to in this article as "routine physical or gynecologic exams," as we feel that it describes more specifically what this domain encapsulates).[22] In addition to each of the 7 domains listed above, we created a single binary variable indicating whether a woman had received at least ≥1 of these 7 types of preconception care (entitled "any preconception care"). Our group has previously utilized similar methods to examine SMM following ectopic pregnancy.[23] The ICD-9 codes associated with each domain are in Supplemental Table 1. Of note, we excluded pregnancy tests and counseling billed within 30 days of the estimated date of conception of the index pregnancy.

We examined several variables as potential confounders. We used the MAX personal summary file to obtain the age at delivery and the maternal race or ethnicity (self-reported at the time of Medicaid enrollment). We determined whether women had a preterm delivery using the ICD-9 code from the delivery hospitalization (as above). Using information on the 12 months before conception for the index delivery, we determined whether women had a delivery within this period using the ICD-9 codes for the deliveries listed above. We constructed a binary covariate indicating interpregnancy interval < 12 months, and determined whether women experienced SMM in this previous delivery using the same criteria we used to identify SMM in the index delivery. We used data from the MAX chronic condition file to determine whether women had a chronic medical condition in either 2011 or 2012 (any cardiac comorbidity, diabetes, hypertension, chronic kidney disease, depression, chronic obstructive pulmonary disorder, or tobacco use). We used information from the index delivery to determine the mode of delivery (any vaginal delivery vs any cesarean delivery) and whether the pregnancy resulted in multiple births.

We used logistic regression to examine whether any preconception care was predictive of SMM, and then (in separate models) whether each of the 7 domains of preconception care were predictive of SMM. We adjusted for confounders in multivariable models. We included variables as confounders in the logistic regression on the basis of known or suspected risk factors for SMM based on previous literature, such as those described above.[1,4,6] We calculated the adjusted odds ratios [aOR] and 95% confidence intervals [CI]. We used 2-sided hypothesis testing and considered the results significant at the $P<.05$ level. We fit all models using Stata Release 17 (StataCorp LLC, College Station, TX).

The only variables with missing data were race or ethnicity ("Unknown" in 67,169 cases or 4.4%, missing for 11 cases) and rural (missing for 1,508 cases, or 0.1%); in the first case "Unknown" was included as a separate category, whereas in the second case, these observations were omitted from the models including rural as a covariate.

We performed a subgroup analysis of women with at least 1 of the following 3 chronic diseases that place women at the highest risk of SMM: hypertension, diabetes, or chronic kidney disease.[24] We also conducted a sensitivity analysis using a sample of women continuously eligible for Medicaid for the full 12 months before conception, as it is possible

that women who were not eligible for Medicaid before conception may have received services that did not generate Medicaid billing claims and were thus not captured in our data.

Results

The Figure shows the total number of women aged 15 to 45 years enrolled in Medicaid in states with available data from 2012 and the number excluded for various reasons. Among 1,514,759 women with eligible deliveries in the final study sample, 26,285 women (1.74%) experienced SMM (9,481 women, 0.63%, when excluding blood transfusion). There were 198 deaths within 12 weeks of delivery. Women from racial and ethnic minorities were significantly more likely to experience the primary outcome, as were women who were older, had a preterm delivery, a short interval pregnancy, those who experienced SMM in a previous pregnancy, and those who had a medical comorbidity apart from tobacco use (Table 1).

Table 2 shows the predictors of any preconception care, any contraceptive care, and any related preventative health services in the year before the index delivery. Black non-Hispanic women were more likely to receive any preconception care, as were women with medical comorbidities, women who experienced a short interval pregnancy, and women who experienced SMM in a previous pregnancy. The findings were similar when examining the specific domains of any contraceptive care and any routine physical or gynecologic exam.

Although any preconception care was associated overall with greater odds of SMM (odds ratio [OR], 1.09; 95% CI, 1.06–1.12), after adjusting for covariates it was associated with a reduction in the odds of SMM (aOR, 0.97; 95% CI, 0.95–1.00) and in the odds of SMM excluding transfusions only (aOR, 0.93; 95% CI, 0.89–0.98) (Tables 3 and 4). This effect was greatest for contraceptive services, which was associated with a reduction in the odds of SMM of 8% (aOR, 0.92; 95% CI, 0.88–0.95) and, excluding transfusions only, of 17% (aOR, 0.83; 95% CI, 0.78–0.89). In contrast, pregnancy testing and counseling were associated with an increase in the odds of SMM (aOR, 1.08; 95% CI, 1.01–1.14) and in the odds of SMM excluding transfusions only (aOR, 1.14; 95% CI, 1.04–1.26). Previous SMM remained highly associated with SMM in the current pregnancy, as did preterm birth and having multiple births. Women from racial and ethnic minorities were also more likely to experience SMM than White women. Although cesarean delivery was associated with higher odds of SMM, including it as a covariate did not alter the odds ratios for any preconception care or its subdomains (not shown).

In our subgroup analysis of women with hypertension, diabetes, or chronic kidney disease (n=63,440), any preconception care was associated with a decrease in the odds of SMM (aOR, 0.84; 95% CI, 0.77–0.91), and contraceptive care remained associated with decreased odds of SMM (aOR, 0.84; 95% CI, 0.75–0.95). In addition, routine physical or gynecologic exams were also associated with a decrease in the odds of SMM (aOR, 0.79; 95% CI, 0.71–0.88). These results were nearly identical when excluding transfusions only.

Finally, a sensitivity analysis including only the 593,887 women continuously eligible for Medicaid during the year before conception showed findings similar to the overall cohort.

Discussion

Principal findings

Receiving any preconception care is associated with a modestly decreased risk of SMM when excluding blood transfusions and after adjusting for multiple potential confounders. Contraceptive services, which is 1 domain of preconception care in the year before an index delivery, is significantly associated with decreased odds of SMM. Routine physical or gynecologic exams among women with chronic disease were also associated with decreased odds of SMM. These findings provide concrete evidence of the value of preconception care. Conversely, after adjusting for other service domains and covariates, having an in-office pregnancy test was associated with increased odds of SMM.

Like Admon et al,[18] we also found substantial disparities in the likelihood of SMM on the basis of maternal race and ethnicity, with women from minority groups being more likely to experience SMM. We found that although Black non-Hispanic women and women from some other racial minorities were actually more likely to receive preconception care, they, nonetheless, had a higher risk of SMM, suggesting that 1 or more factors we could not measure (including possibly systematic racism) may play an important role in outcomes. Hispanic women, conversely, were less likely to have received preconception care than White non-Hispanic women; this could lead to poorer outcomes, particularly as these women are also more likely to have a chronic health condition,[25] which increases the risk of SMM.[4] These findings are also in keeping with national data, which show substantially higher rates of SMM and maternal mortality among women from racial and ethnic minorities.[26]

Finally, women with chronic diseases, including diabetes, chronic hypertension, and chronic kidney disease, were substantially more likely to experience SMM, which confirms findings from previous studies.[24,27]

Clinical and research implications

To date, there has not been much concrete evidence of the value of preconception care; our study shows that certain aspects of preconception care may improve obstetrical outcomes. Contraceptive services are associated with a decreased risk of SMM in our study, perhaps, in part, because contraception facilitates women’s abilities to plan the timing of their pregnancies. Previous research has found unwanted and mistimed pregnancies associated with a delay in initiating prenatal care and other markers of poor perinatal health.[28] This may be particularly important for women with chronic diseases such as diabetes, who can use contraception to gain time to get their chronic conditions under better control before getting pregnant.[25] Physical or gynecologic exams for women with chronic disease may offer an opportunity to discuss optimizing care for that disease before conception. These findings lend credence to the idea that all providers who see women of reproductive age may

play a role in discussing potential pregnancies with their patients, not just clinicians seeing patients specifically for the purposes of pregnancy planning or prevention.

An alternate explanation for these findings could be that women who use preconception care are in general more concerned with their health or are different from women who do not use preconception care (or have access to preconception care) in ways that affect SMM (such as poorer baseline health beyond the diagnoses we could identify). Thus, the preconception care may be a proxy for other factors associated with improved outcomes rather than the cause. Future research could build on this observational study by examining whether interventions aimed at increasing access to preconception care, including recent changes to the Medicaid eligibility criteria in several states, decrease the risk of SMM. We also found that women who access pregnancy tests and counseling are more likely to experience SMM; whether this is a marker of some other characteristic (such as being less likely to plan a pregnancy) warrants further investigation.

Access to care is based on more than just insurance eligibility; women who live in rural areas, for instance, may face physical barriers to accessing both preconception and high-quality obstetrical care in ways that affect SMM.[29] Other analyses could focus on clustering of preconception care and SMM at the neighborhood, regional, or state level to determine whether there are barriers to preconception care beyond insurance coverage.

Strengths and limitations

This study has several strengths, including a large, nationwide, ethnically and racially diverse sample. Women in the Medicaid population are at a higher risk of pregnancy complications than women who are privately insured.[30] Thus, this study focuses on a population at a high risk of SMM. Even within this population, SMM remains a rare event. Thus, our sample size is a strength.

This study has several limitations. We could not determine the content of preconception care, only that a woman had a visit. We could not know whether she was specifically counseled regarding pregnancy risks and preconception behaviors that may improve outcomes. Despite controlling for confounders, there may remain endogeneity in terms of which women seek out preconception care in ways that also affect the risk of SMM, and residual confounding may remain. We also could not observe the care that women may have received via avenues other than those funded through Medicaid, including during periods covered by private insurance, care paid for out-of-pocket, or care received through clinics free at the point of care. There may also be ascertainment bias because of the fact that all women were not covered continuously by Medicaid, though our sensitivity analyses did not show a significant difference in results when examining only women who were continuously covered through the preconception period. Although people of all gender identities can get pregnant, we specifically limited our sample to Medicaid recipients who identified as female, as Medicaid claims data do not have a consistent way to interrogate whether pregnancies among male recipients are errors or are pregnancies in individuals who identify as male. Although this sample is large and diverse in many ways, all patients in this study were insured by Medicaid. Thus, the findings may not apply to the larger obstetrical population with private or other government insurance or women without insurance. Further,

not all states were included, as not all states had available data, potentially further limiting generalizability. As we included deliveries through the end of 2012 but the data were limited or largely unavailable through 2013, we have likely undercounted the postpartum maternal morbidity and mortality events for deliveries from October 2012 to December 2012. Finally, our odds ratios, though significant, showed a relatively small effect size.

Figure 1

Conclusion

Controlling for known risk factors; receiving preconception care, especially contraceptive services in the year before conception; and routine exams for women with chronic disease are associated with decreased odds of SMM for Medicaid enrollees.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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AJOG MFM at a Glance

Why was this study conducted?

To determine whether preconception care was associated with a reduction in the incidence of severe maternal morbidity or mortality during delivery hospitalization for a subsequent pregnancy.

Key findings

Contraceptive services in the year before conception and routine exams for women with chronic disease are associated with decreased odds of severe maternal morbidity or mortality at the time of delivery among Medicaid enrollees.

What does this add to what is known?

This study emphasizes the potential role of preconception care in improving obstetrical outcomes among pregnant women enrolled in Medicaid, which is a population at a high risk of severe maternal morbidity and mortality.

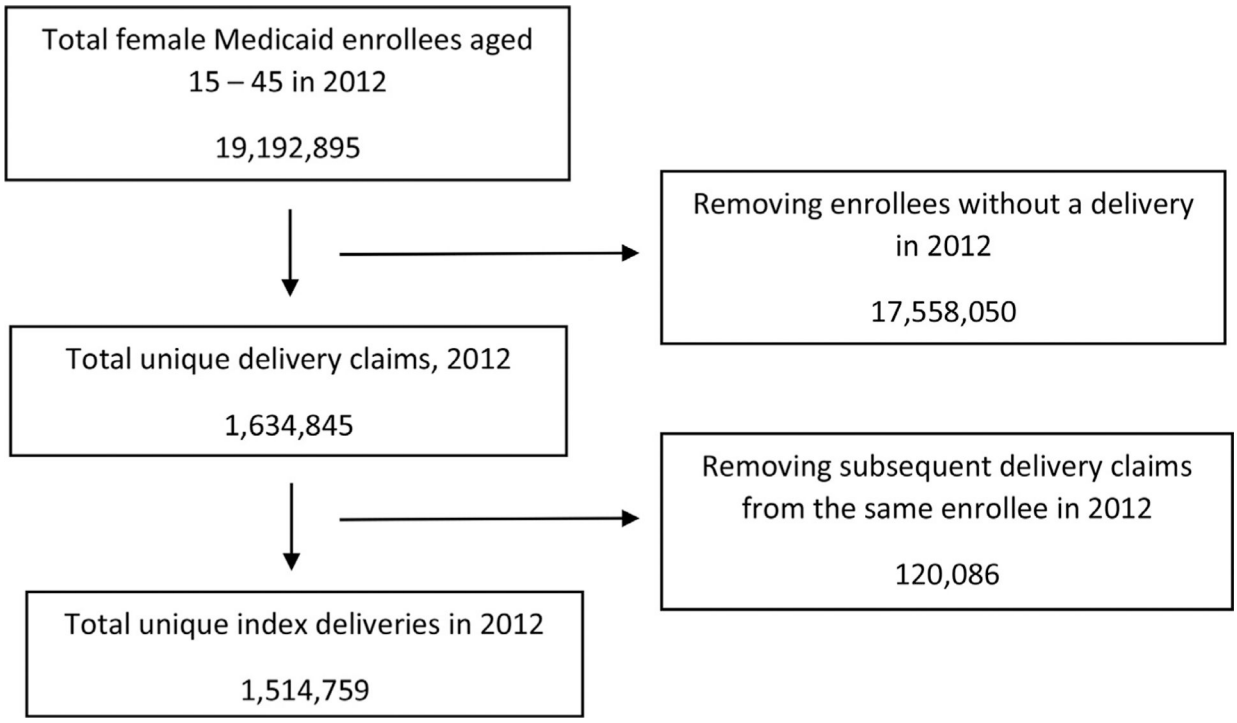

FIGURE 1. Eligibility flowchart

A flowchart showing the number of total female Medicaid beneficiaries aged 15 to 45 years in 2012, total unique deliveries in 2012, and total unique index deliveries in 2012.

TABLE 1

Sample characteristics and incidence of severe maternal morbidity

Characteristics	N	%	SMM (%)[a]	*P*-value[b]
Total	1,514,759	100.0	1.74	
Age (y)	1,514,759	25.7 (5.8)[c]		<.001[d]
Race/ethnicity				<.001
White non-Hispanic	588,203	38.8	1.42	
Black non-Hispanic	321,824	21.3	2.56	
Hispanic	453,021	29.9	1.56	
Asian, Pacific Islander or Native Hawaiian	54,125	3.6	1.54	
American Indian or Alaskan Native	23,631	1.6	2.26	
More than 1 race	6,775	0.5	1.86	
Unknown	67,169	4.4	1.67	
Rural residence				.289
Yes	281,221	18.6	1.71	
No	1,232,030	81.4	1.74	
Previous SMM				<.001
Yes	2,098	0.1	12.25	
No	1,512,661	99.9	1.72	
Interpregnancy interval <12 mo				<.001
Yes	124,828	8.2	1.92	
No	1,389,931	91.8	1.72	
Preterm delivery				<.001
Yes	107,980	7.1	3.51	
No	1,406,779	92.9	1.60	
Multiple births				<.001
Yes	15,659	1.0	5.38	
No	1,499,100	99.0	1.70	
Cesarean delivery				<.001

Characteristics	N	%	SMM (%)[a]	*P*-value[b]
Yes	413,900	27.3	3.46	
No	1,100,859	72.7	1.09	
Any cardiometabolic comorbidity[e]				<.001
Yes	63,440	4.2	5.11	
No	1,451,319	95.8	1.59	
Diabetes				<.001
Yes	24,113	1.6	3.44	
No	1,490,646	98.4	1.71	
Hypertension				<.001
Yes	29,166	1.9	6.25	
No	1,485,593	98.1	1.65	
Chronic kidney disease				<.001
Yes	16,246	1.1	8.19	
No	1,498,513	98.9	1.67	
Depression				<.001
Yes	115,580	7.6	2.17	
No	1,399,179	92.4	1.70	
Chronic obstructive pulmonary disease				<.001
Yes	4,033	0.3	3.47	
No	1,510,726	99.7	1.73	
Tobacco use				.654
Yes	151,299	10.0	1.75	
No	1,363,460	90.0	1.73	

SMM, severe maternal morbidity or mortality.

[a] Percent of births within each group affected by SMM;

[b] *P* value from chi-squared test of independence, unless otherwise noted;

[c] Mean (standard deviation);

[d] *P* value for 2-sample *t* test;

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[e] Includes diabetes, hypertension, and chronic kidney disease

TABLE 2

Prevalence of any preconception care, contraceptive care, and related preventative health services during the year before conception, overall and separately by demographic and clinical subgroups

	Any preconception care		Contraceptive care[a]		Related preventative health services[b]	
Comorbidity	**%**	***P*-value[c]**	**%**	***P*-value[c]**	**%**	***P*-value[c]**
Total	22.9		12.3		11.2	
Race/ethnicity		<.001		<.001		<.001
White non-Hispanic	24.1		12.7		12.1	
Black non-Hispanic	32.5		17.4		15.2	
Hispanic	15.7		9.0		7.4	
Asian, Pacific Islander, or Native Hawaiian	17.3		6.0		11.5	
American Indian or Alaskan Native	28.4		16.5		10.3	
More than 1 race	32.3		18.0		15.5	
Unknown	17.2		8.6		9.0	
Rural residence		<.001		<.001		<.001
Yes	26.8		15.9		12.0	
No	22.0		11.4		11.0	
Previous SMM		<.001		<.001		<.001
Yes	48.9		21.2		20.1	
No	22.9		12.2		11.2	
Interpregnancy interval <12 mo		<.001		<.001		<.001
Yes	46.6		21.0		19.7	
No	20.8		11.5		10.4	
Preterm delivery		<.001		<.001		<.001
Yes	26.2		13.5		12.5	
No	22.7		12.2		11.1	
Multiple births		<.001		<.001		<.001
Yes	25.7		13.2		12.8	
No	22.9		12.2		11.2	

	Any preconception care		Contraceptive care[a]		Related preventative health services[b]	
Comorbidity	**%**	***P*-value[c]**	**%**	***P*-value[c]**	**%**	***P*-value[c]**
Cesarean delivery		<.001		<.001		.491
Yes	22.4		11.7		11.2	
No	23.1		12.5		11.2	
Any cardiometabolic comorbidity[d]		<.001		<.001		<.001
Yes	30.0		13.8		16.6	
No	22.6		12.2		10.9	
Diabetes		<.001		.905		<.001
Yes	28.9		12.2		16.7	
No	22.8		12.3		11.1	
Hypertension		<.001		<.001		<.001
Yes	30.3		13.7		17.2	
No	22.8		12.2		11.1	
Chronic kidney disease		<.001		<.001		<.001
Yes	31.6		15.7		16.4	
No	22.8		12.2		11.1	
Depression		<.001		<.001		<.001
Yes	40.0		20.2		21.1	
No	21.5		11.6		10.4	
Chronic obstructive pulmonary disease		<.001		<.001		<.001
Yes	36.5		17.7		19.7	
No	22.9		12.2		11.2	
Tobacco use		<.001		<.001		<.001
Yes	32.2		15.9		15.7	
No	21.9		11.9		10.7	

SMM, severe maternal morbidity or mortality.

[a] Subset of “Any preconception care”;

[b] Physical exam, gynecologic exam, or Pap smear; a subset of “Any preconception care”;

[c] *P* value from chi-squared test of independence, unless otherwise noted;

[d] Includes diabetes, hypertension, and chronic kidney disease.

TABLE 3

Logistic regressions of severe maternal morbidity on measures of preconception care

	Model (1)		Model (2)		Model (3)		Model (4)	
Variables	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Covariate								
Any preconception care	1.09	(1.06–1.12)	0.97	(0.95–1.00)				
Contraceptive services					0.95	(0.91–0.98)	0.92	(0.8–80.95)
Pregnancy testing and counseling					1.15	(1.08–1.21)	1.08	(1.01–1.14)
Achieving pregnancy					1.37	(0.82–2.29)	1.29	(0.76–2.19)
Infertility services					1.07	(0.83–1.37)	0.95	(0.74–1.22)
Preconception health services					1.05	(0.93–1.20)	0.96	(0.84–1.10)
Sexually transmitted infection services					1.11	(1.05–1.17)	1.00	(0.95–1.05)
Routine physical or gynecologic exams					1.05	(1.01–1.09)	0.99	(0.95–1.03)
Maternal age (decades)			0.98	(0.95–1.00)			0.97	(0.95–1.00)
Maternal age squared			1.25	(1.22–1.28)			1.25	(1.22–1.28)
Short interpregnancy interval (<12 mo)			0.98	(0.94–1.03)			0.98	(0.94–1.03)
Previous SMM			6.78	(5.89–7.81)			6.77	(5.88–7.80)
Preterm birth			1.79	(1.72–1.86)			1.79	(1.72–1.85)
Race/ethnicity								
White non-Hispanic			1.00				1.00	
Black non-Hispanic			1.72	(1.66–1.78)			1.72	(1.67–1.78)
Hispanic			1.14	(1.10–1.18)			1.14	(1.11–1.18)
Asian, Pacific Islander, or Native Hawaiian			1.13	(1.05–1.22)			1.13	(1.05–1.21)
American Indian or Alaskan Native			1.60	(1.47–1.75)			1.60	(1.46–1.75)
More than 1 race			1.29	(1.08–1.54)			1.29	(1.08–1.54)
Unknown			1.18	(1.11–1.26)			1.18	(1.11–1.26)
Diabetes			1.22	(1.13–1.32)			1.22	(1.13–1.32)
Hypertension			2.64	(2.51–2.79)			2.64	(2.51–2.79)
Chronic kidney disease			4.02	(3.78–4.27)			4.02	(3.78–4.27)
Depression			1.18	(1.13–1.24)			1.18	(1.13–1.23)

Variables	Model (1)		Model (2)		Model (3)		Model (4)	
	Odds ratio	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Chronic obstructive pulmonary disease			1.30	(1.09–1.56)			1.30	(1.09–1.56)
Tobacco use			0.97	(0.93–1.01)			0.97	(0.93–1.01)
Rural residence			1.05	(1.02–1.09)			1.06	(1.02–1.09)
Multiple births			2.46	(2.28–2.64)			2.46	(2.28–2.64)

CI, confidence interval; *SMM*, severe maternal morbidity.

TABLE 4

Logistic regressions of severe maternal morbidity, excluding blood transfusions, on measures of preconception care

	Model (1)		Model (2)		Model (3)		Model (4)	
Variable	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Covariate								
Any preconception care	1.03	(0.98–1.08)	0.93	(0.89–0.98)				
Contraceptive services					0.82	(0.77–0.88)	0.83	(0.78–0.89)
Pregnancy testing and counseling					1.20	(1.09–1.32)	1.14	(1.04–1.26)
Achieving pregnancy					1.28	(0.53–3.10)	1.04	(0.41–2.66)
Infertility services					1.11	(0.74–1.66)	0.89	(0.59–1.33)
Preconception health services					1.14	(0.93–1.40)	1.04	(0.84–1.28)
Sexually transmitted infection services					1.03	(0.94–1.13)	0.98	(0.90–1.07)
Routine physical/gynecologic exams					1.11	(1.04–1.19)	0.99	(0.93–1.06)
Maternal age (decades)			1.18	(1.13–1.23)			1.18	(1.13–1.23)
Maternal age squared			1.17	(1.12–1.23)			1.17	(1.12–1.22)
Short interpregnancy interval (<12 mo)			0.80	(0.73–0.87)			0.79	(0.72–0.86)
Previous SMM			6.37	(5.00–8.10)			6.35	(4.99–8.07)
Preterm birth			1.95	(1.84–2.06)			1.94	(1.83–2.06)
Race/ethnicity								
White non-Hispanic			1.00				1.00	
Black non-Hispanic			1.43	(1.35–1.50)			1.43	(1.35–1.51)
Hispanic			0.99	(0.94–1.05)			0.99	(0.94–1.05)
Asian, Pacific Islander, or Native Hawaiian			0.98	(0.87–1.11)			0.98	(0.87–1.11)
American Indian or Alaskan Native			1.43	(1.23–1.66)			1.42	(1.22–1.66)
More than 1 race			0.94	(0.68–1.31)			0.94	(0.68–1.31)
Unknown			1.14	(1.03–1.26)			1.14	(1.03–1.26)
Diabetes			1.13	(1.01–1.27)			1.13	(1.01–1.26)
Hypertension			3.50	(3.25–3.78)			3.50	(3.25–3.77)
Chronic kidney disease			7.63	(7.09–8.22)			7.63	(7.08–8.21)
Depression			1.24	(1.15–1.32)			1.23	(1.15–1.32)

	Model (1)		Model (2)		Model (3)		Model (4)	
Variable	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Chronic obstructive pulmonary disease			1.48	(1.17–1.89)			1.48	(1.16–1.89)
Tobacco use			0.99	(0.93–1.06)			0.99	(0.92–1.06)
Rural residence			0.99	(0.94–1.05)			0.99	(0.94–1.05)
Multiple births			1.18	(1.01–1.38)			1.18	(1.01–1.38)

CI, confidence interval; *SMM*, severe maternal morbidity.