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Postpartum Readmissions Among Women With Diabetes

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Abstract

OBJECTIVE: To estimate whether women with diabetes are at risk for 60-day postpartum readmissions and associated complications.

METHODS: The Nationwide Readmissions Database from 2010 to 2014 was analyzed to determine risk for 60-day postpartum readmissions among women with type 1 diabetes mellitus (DM), type 2 DM, gestational diabetes mellitus (GDM), and unspecified diabetes mellitus compared to no diabetes. Secondary outcomes included evaluating risk for overall severe maternal morbidity during readmissions as well as wound complications, acute diabetic complications such as diabetic ketoacidosis, venous thromboembolism, and hypertensive diseases of pregnancy. Billing data was used to ascertain both exposures and outcomes. Adjusted log-linear regression models including demographic, hospital, medical and obstetric and hospital factors were performed with adjusted risk ratios (aRR) as with 95% confidence intervals (CI) as measures of association.

RESULTS: Of an estimated 15.7 million delivery hospitalizations, 1.1 million occurred among women with diabetes, of whom 3.2% had type 1 DM, 9.1% type 2 DM, 86.6% GDM, and 1.1% unspecified diabetes. Compared to nondiabetic women (1.5% risk for readmission), risk for readmission was significantly higher for women with type 1 DM (4.4%), unspecified diabetes (4.0%), type 2 DM (3.9%), and GDM (2.0%) ($p<0.01$). After adjusting for hospital, demographic, medical, and obstetric risk factors, type 1 DM (aRR 1.77, 95% CI 1.69, 1.87), type 2 DM (aRR 1.46, 95% CI 1.42-1.51), unspecified (aRR 1.73, 95% CI 1.59, 1.89) and gestational diabetes (aRR 1.16, 95% CI 1.14, 1.17) retained increased risk. Among women with diabetes public insurance, lower ZIP code income quartiles, and hospitals with high safety net burdens were associated with higher risk for readmission. In both unadjusted and adjusted analyses, all diabetes diagnoses were

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associated with readmissions for wound complications, hypertensive diseases of pregnancy, and severe maternal morbidity.

CONCLUSION: While overall risk for readmission is low, pregnancies complicated by pregestational diabetes in particular are at increased risk. This high risk group should receive coordinated care and be monitored closely in the postpartum period.

PRECIS

Women with diabetes are at increased risk for hospital readmission in the postpartum period.

INTRODUCTION

Diabetes during pregnancy is increasing in the United States [1]. Pregnancies with gestational diabetes, type 1 diabetes, and type 2 diabetes have all become more common.[1] While the most common diabetes-related maternal complications occur in the antepartum and intrapartum period, complications requiring re-hospitalization may also occur in the postpartum period.[2]

There are multiple studies on readmission risk among patients with diabetes in the general population;[3-6] however, there are limited data on the readmission risk of women with diabetes in the postpartum period. It is well known that pregnancy can exacerbate diabetes-related complications, especially in women with poorly controlled pre-gestational diabetes, and this can have major long term health effects.[7,8] With the current focus on redefining postpartum care,[9] further characterization of outcomes related to postpartum complications and readmissions among women with diabetes may assist in optimizing management after delivery.

Given the knowledge gap related to postpartum complications amongst pregnancies with both gestational and pre-gestational diabetes, the aim of this study was to assess risk for postpartum readmissions and associated complications within 60 days of delivery hospitalization discharge for women with diabetes analyzing data from the Nationwide Readmissions Database. Additionally, we sought to determine the differences in readmission rates amongst women with gestational versus type 1 and 2 diabetes mellitus.

METHODS

This study used the 2010-2014 Nationwide Readmissions Database (NRD), one of the largest national administrative discharge databases. The NRD is assembled on an annual basis on a state level by the Healthcare Cost and Utilization Project (HCUP).[10] The NRD is drawn from State Inpatient Databases and in 2014 included data from 22 states accounting for 51% of the US population and 49% of all hospitalizations. Given its structure, the NRD can track patients across hospitalizations within a state during a single year. The data in the NRD can be weighted to provide national estimates. The weights account for over and under-representation of hospitals and discharges with the target universe based on American Hospital Association data; in addition to hospital factors, the weighting accounts for patient demographic factors including age and sex. These weights were applied in this analysis to create national estimates.[10] Because 60-day readmissions cannot be fully ascertained for

November and December discharges, only discharges occurring January through October were included in the analysis. The NRD has been used across multiple specialties to evaluate national readmission hospitalization trends.[10] The Columbia University Institutional Review Board granted an exemption given the de-identified nature and public availability of the data.

Delivery hospitalizations were identified using International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) diagnosis codes 650 and V27.x which capture >95% of delivery hospitalizations.[11] Women ages 15-54 years were included for this analysis and readmissions were identified utilizing HCUP methodologies. Women were classified as non-diabetic or having (i) type 1 diabetes mellitus (DM), (ii) type 2 DM, (iii) unspecified diabetes, and (iv) gestational diabetes mellitus (GDM).[12] A small minority of women were classified with unspecified diabetes because the ICD-9-CM diagnosis codes are non-specific (790.29, 648.0–648.04, and 250–250.9).

The primary outcome for this analysis was 60-day postpartum readmission from delivery hospitalization discharge. To assess risk for this outcome among women with diabetes, factors associated with risk for readmission for the entire population were analyzed with diabetes as the primary exposure. To determine which factors among women with diabetes were specifically associated with readmission, a repeat analysis was performed with the cohort restricted to women with diabetes at delivery.

A number of secondary outcomes were also analyzed and included: (i) risk for severe maternal morbidity during the readmission, (ii) readmission for acute venous thromboembolism, (iii) readmission for wound complications, (iv) readmission for hypertensive diseases of pregnancy, and (v) readmission for serious acute complications of diabetes including diabetic ketoacidosis, hyperglycemic hyperosmolar syndrome, and coma (ICD-9-CM 250.1x-250.3x). Diabetes was also the primary exposure assessed with these outcomes. Wound complications, thromboembolism, hypertensive diseases of pregnancy, and complications of diabetes were identified through ICD-9-CM codes.[13-15] Severe maternal morbidity was analyzed utilizing criteria from the Centers for Disease Control and Prevention's composite which includes ICD-9-CM codes for 18 conditions including hysterectomy, shock, acute renal failure, and stroke (Appendix 1, **available online at** http://links.lww.com/xxx).[16]

The NRD includes data on patient demographics, clinical factors, and hospital characteristics. Patient factors included age (15-19, 20-24, 25-29, 30-34, 35-39, and 40-54 years old), payer information (Medicare, Medicaid, private insurance, self-pay, no charge, other), and median ZIP code income quartile. Hospital factors included teaching status (metropolitan non-teaching, metropolitan teaching, non-metropolitan), and hospital bed size (small, medium, large). Hospital safety net burden[17] was analyzed based on the proportion of patients with no insurance or Medicaid or Medicare coverage and classified into high-burden hospitals (highest quartile), medium-burden (middle two quartiles), and low-burden hospitals (lowest quartile).[17,18] Clinical factors possibly associated with readmission were ascertained during the delivery hospitalization utilizing ICD-9-CM codes and included: cesarean delivery, postpartum hemorrhage at delivery, systemic lupus erythematosus,

multiple gestation, asthma, chronic kidney disease, hypertensive diseases of pregnancy including preeclampsia and gestational hypertension, and chronic hypertension.

The relationship between patient, hospital, and clinical factors and risk for the primary outcome of 60-day postpartum readmission were compared using unadjusted log-linear regression analyses. Multivariable log-linear regression models were then fit to assess the relationship between these factors and readmission risk. In addition to the primary outcome, unadjusted and adjusted analyses were performed for the following secondary outcomes: (i) risk for severe maternal morbidity during the readmission, (ii) readmission for acute venous thromboembolism, (iii) readmission for wound complications, (iv) readmission for hypertensive diseases of pregnancy, and (v) readmission for serious acute complications of diabetes. Measures of association were demonstrated using risk ratios (RR) in unadjusted analyses and adjusted risk ratios (aRR) in adjusted analyses with 95% confidence intervals (CI). For the severe maternal morbidity analyses, patients with these outcomes during the delivery hospitalization were excluded to prevent misclassification. For the venous thromboembolism analysis, women with acute venous thromboembolism during the delivery hospitalization were similarly excluded; history of venous thromboembolism prior to the delivery hospitalization was added as a risk factor for the thromboembolism model. Because model overfitting for rare outcomes is a concern, adjusted analyses for specific adverse outcomes during readmission were repeated with the models limited to diabetes status, maternal age, mode of delivery, and hypertensive diseases of pregnancy. Readmission length of stay and charges are included in the NRD. Mean and median lengths of stay and charges were calculated for delivery and postpartum admissions based on diabetes status. Costs were calculated utilizing cost-to-charge ratios provided by the NRD and adjusted for the cost of inflation to represent 2016 dollars. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC) with a level of significance set at $p<0.05$.

RESULTS

Of an estimated 15.7 million delivery hospitalizations from 2010 to 2014, 1.1 million delivery hospitalization (7.2%) were to women with diabetes. Of women with diabetes, 3.2% had a diagnosis of type 1 DM (n=35,463), 9.1% had type 2 DM (n=103,902), 86.6% had GDM (n=984,001), and 1.1% had unspecified diabetes (n=13,312). Women with diabetes on average had longer lengths of stay and higher costs during delivery admissions with highest mean length of stay and costs among patients with type 1 DM (Table 1). Risk for cesarean was higher for women with diabetes with risk ranging from 44.7% for women with GDM to 67.6% for women with type 1 DM; the cesarean rate for women without diabetes was 31.9% ($p<0.01$). In addition, women with all forms of diabetes were more likely to have hypertensive diseases of pregnancy, chronic hypertension, and asthma, and were more likely to delivery at metropolitan teaching hospitals ($p<0.01$ for all) (Table 1 and Appendix 2 **[**Appendix 2 **is available online at** http://links.lww.com/xxx).

Risk for all-cause 60-day readmission (n=248,241) was significantly higher for women with diabetes; women with type 1 DM were most likely to be readmitted (4.4%; RR 2.92, 95% CI 2.78, 3.07 compared to women without diabetes), followed by those with unspecified diabetes (4.0%; RR 2.63, 95% CI 2.42, 2.87), those with type 2 DM (3.9%; RR 2.55, 95%

CI 2.47, 2.63), and those with GDM (2.0%; RR 1.34, 95% CI 1.33, 1.36) (Table 2). Nondiabetic women were at a 1.5% risk of readmission. After adjusting for hospital, demographic, medical, and obstetric risk factors, type 1 DM (aRR 1.77, 95% CI 1.69, 1.87), type 2 DM (aRR 1.46, 95% CI 1.42, 1.51), unspecified (aRR 1.73, 95% CI 1.59, 1.89) and gestational diabetes (aRR 1.16, 95% CI 1.14, 1.17) retained increased risk (Table 2). Demographic factors associated with increased risks for all-cause readmission in unadjusted and adjusted analyses included younger age (15-19, 20-24 years versus 25-29 years) and older age (35-39, 40-54 years versus 25-29 years), Medicare and Medicaid versus commercial insurance, and lower versus higher income quartiles. Medical and obstetric risk factors were associated with elevated readmission risk in unadjusted and adjusted analysis.

Mean readmission length of stay and costs for women with type 1 DM (3.33 days (95% CI 3.03, 3.63), $7,785 (95% CI $6,587, $8,984)), type 2 DM (3.74 days (95% CI 3.50, 3.98), $7,980 (95% CI $7,365, $8,595)), GDM (3.19 days (95% CI 3.10, 3.27), $7,623 (95% CI $7,322, $7,923), and unspecified (3.76 days (95% CI 3.18, 4.35), $8,355 (95% CI $7,064, $9,646) diabetes were generally longer and higher, respectively, compared to women with no diabetes (3.11 days (95% CI 3.08, 3.14), $7143 (95% CI: $7,051, $7,235)) ($p<0.01$ for length of stay and costs for type 2 DM compared to no diabetes and costs for GDM compared to no diabetes). As costs and length of stay may be skewed, these analyses were repeated analyzing medians; while differences in length of stay were no longer statistically significant, costs were significantly higher for type 2 DM ($5,437 95% CI $5,137, $5,736), GDM ($5,220, 95% CI $5,078, $5,361), and unspecified diabetes ($5,931, 95% CI $5,022, $6,840) compared to no diabetes ($4,896, 95% CI $4,840, $4,950) ; median type 1 DM readmission cost was not significantly different ($4,968, 95% CI $4,522, $5,414).

In the analysis for all-cause readmission restricted to patients with diabetes, significant factors in both unadjusted and adjusted analyses included maternal age 15-19 compared to 25-29 years (RR 1.44, 95% CI 1.34, 1.54; aRR 1.27, 95% 1.18, 1.36), Medicare (RR 3.45, 95% CI 3.20, 3.72; aRR 2.32, 95% CI 2.15, 2.50) and Medicaid insurance (RR 1.56, 95% 1.52, 1.60; aRR 1.39, 95% CI 1.35, 1.43) compared to private insurance, and medical and obstetric factors such as cesarean compared to vaginal delivery, chronic kidney disease, hypertensive disease of pregnancy, and multiple gestation (Table 3). Type 2 DM (RR 0.87, 95% CI 0.82, 0.93; aRR 0.84, 95% CI 0.80, 0.90) and GDM (RR 0.46, 95% CI 0.44, 0.49; aRR 0.64, 95% CI 0.60, 0.67) were associated with decreased risk for readmission compared to type 1 DM.

In evaluating risk for readmissions complicated by severe maternal morbidity and other adverse outcomes, diabetes was generally associated with increased risk. Analyzing overall risk for severe maternal morbidity during readmission (n=35,742), compared to no diabetes,type 1 DM was associated with highest risk in unadjusted and adjusted analyses (RR 3.44 95% CI 3.04, 3.89; aRR 2.09 95% 1.85, 2.37 compared to no diabetes) followed by unspecified diabetes (RR 3.05, 95% 2.47, 3.77; aRR 1.90, 95% 1.53, 2.35), type 2 DM (RR 2.97, 95% 2.75, 3.21; aRR 1.57, 95% 1.45, 1.70), and GDM (RR 1.47, 95% 1.42, 1.53; aRR 1.19, 95% CI 1.14, 1.23) (Table 4 and Appendix 3 **[**Appendix 3 **is available online at** http://links.lww.com/xxx**]**). Risk for readmissions for wound complications (n=26,439) was also increased for patients with diabetes compared to those without diabetes, with highest

risk among women with type 2 DM (RR 5.42, 95% 5.07, 5.80; aRR 2.13, 95% 1.99, 2.29) and unspecified diabetes (RR 4.84, 95% 3.98, 5.89; aRR 2.34, 95% 1.92, 2.85) followed by type 1 DM (RR 3.30, 95% 2.86, 3.82; aRR 1.39, 95% 1.20, 1.61) and GDM (RR 1.73, 95% 1.66, 1.80; aRR 1.25, 95% 1.20, 1.30) (Table 4). Evaluating serious acute diabetic complications (n=697), risk was lower for type 2 DM (RR 0.13, 95% CI 0.11, 0.16; aRR 0.20 95% CI 0.16, 0.24) and unspecified DM (RR 0.52, 95% CI 0.40, 0.66; aRR 0.73, 0.50, 0.94) compared to type 1 DM. For readmission for hypertensive diseases of pregnancy (n=37,795), type 1 DM, type 2 DM, unspecified diabetes, and GDM were all associated with increased risk compared to no diabetes in both adjusted and unadjusted analyses. For venous thromboembolism (n=7,271), GDM and type 2 DM were associated with increased risk compared to no diabetes in unadjusted analyses; only GDM retained significance in the adjusted model (aRR 1.19, 95% CI 1.10, 1.30). In evaluating risk for readmissions complicated by severe maternal morbidity and other adverse outcomes, GDM was associated with significantly decreased risk for all outcomes compared to type 2 DM with the exception of venous thromboembolism ($p<0.01$ for all). When models were repeated with fewer risk factors to avoid overfitting, estimates were similar (Appendix 4, **available online at** http://links.lww.com/xxx).

DISCUSSION

While overall all-cause 60-day postpartum readmission is low, this analysis demonstrated that women with diabetes are at increased risk with a 4.4% risk of readmission for women with type 1 DM, 3.9% for type 2 DM, and 2.0% for gestational diabetes compared to 1.5% for women without diabetes. Women with all types of diabetes were at increased risk for severe maternal morbidity and hypertensive diseases of pregnancy. Women with diabetes also had higher rates of cesarean, with two thirds of women with type 1 DM undergoing the procedure and were at an increased risk for wound complications. Socio-demographic factors were important determinants of readmission with young women, women receiving Medicaid or Medicare insurance, women from lower ZIP code income quartiles, and women delivering at hospitals with high safety net burdens at higher risk for readmission. Older maternal age was also an important comorbid factor in outcomes associated with more than three times the risk for type 2 DM and increased risk for readmission among women with diabetes for women 40 and older in adjusted analyses.

Research has demonstrated that for non-pregnant patients with diabetes interventions such as nursing support and case management can reduce risk for readmissions.[19] Evidence supports that a multidisciplinary care approach for patients with poor glycemic management in particular may improve outcomes.[20] The degree to which similar interventions can improve outcomes for women at risk for a range of complications specific to the postpartum period is unclear but an important avenue for future research. In particular, for patients with poorly controlled pre-pregnancy diabetes multi-disciplinary care including endocrinology may be critical in not only reducing immediate postpartum readmission risk but optimizing long-term health outcomes. A prior analysis in the NRD evaluating readmission risk among all patients with type 1 DM found that socio-demographic factors including young age, public insurance, and lower ZIP code income quartile were all associated with increased risk for diabetic ketoacidosis readmissions,[21] factors that were also significant in our analysis;

targeted improvements in care for populations with these characteristics may be important in improving care. This analysis cannot determine whether women in this analysis with these factors were at increased risk for readmission because of inability to access support services due to insurance issues, whether glycemic control in the postpartum period was optimal, difficulty in care coordination, poor social support, or for other reasons. During the time period from discharge to 60-days postpartum women with pre-gestational diabetes should have established care with an endocrinologist or primary medical provider if they do not have one already; the degree to which establishment of this care reduces readmission risk should be determined and could be evaluated with payer data.

Improving diabetes management may represent an important focus of overall efforts to optimize postpartum care. The American College of Obstetricians and Gynecologists has recently revised recommendations regarding postpartum care stating, “To optimize the health of women and infants, postpartum care should become an ongoing process, rather than a single encounter, with services and support tailored to each woman’s individual needs,” and that, “women with chronic medical conditions, such as hypertensive disorders, obesity, diabetes, thyroid disorders, renal disease, mood disorders, and substance use disorders, should be counseled regarding the importance of timely follow-up with their obstetrician–gynecologists or primary care providers for ongoing coordination of care.”[9] Further research is indicated to determine what specific interventions may best optimize postpartum care in the setting of diabetes. Determination of optimal care for women with GDM in particular may be an important focus for subsequent research efforts.

Strengths of this study include the large number of patients available for analysis that allowed meaningful statistical comparisons for relatively rare outcomes, that the state-level linkages were population-based and allowed for calculation of national estimates, and that patients with index delivery hospitalization morbidity diagnoses were excluded from the severe maternal morbidity analysis to enhance validity of that model. Limitations of the study include weaknesses inherent to administrative data which provide a broad overview of population-based risk, but lack many important clinical details. For example, we were not able to assess for glycemic control throughout the pregnancy and postpartum knowing that women with poorer control are at higher risks of complications. Furthermore, under-ascertainment of secondary diagnoses is, in particular, a concern with billing data; in general, the adjusted models demonstrated decreased risk for adverse outcomes and there is the possibility that risk estimates would be even lower if the prevalence of comorbid conditions other than diabetes were higher. Given that capture of obesity is extremely poor in administrative data we did not include this variable but it may account for the higher risk for wound complications among women with type 2 DM compared to type 1 DM. We were unable to account for important details in individual postpartum outpatient management care plans including whether patients were compliant with their medications, were closely monitored for glycemic control, and had follow up with their health care providers. Other limitations of the database include that we could not track patients across calendar years and for that reason the analysis was limited to January through October of each year. In addition, the database is state-based, so if a patient delivered in a state different from where a readmission occurred we would not have linked the hospitalizations. Additionally, we could not determine to what degree differences in inpatient care for women with specific risk

factors could have affected readmission risk. Additionally, because of the ICD-9-CM coding framework there was a small minority of patients who were classified with unspecified diabetes. We elected to include these patients in the analysis to demonstrate (i) the full population of diabetics, and (ii) that only a small proportion of diabetes diagnoses were nonspecific. Finally, it is important to consider that while some estimates were statistically significant, such as the marginally increased risk for severe maternal morbidity during readmission associated with GDM, these findings are not of major clinical significance, particularly given that there may be some unaccounted unmeasured confounding.

In conclusion, this study demonstrated increased population-based risk for postpartum hospitalizations among women with diabetes. Specifically, our results support that women with diabetes, particularly type 1 DM, are at an increased risk for maternal morbidity and readmission in the postpartum period. Further research is required to determine how optimizing postpartum follow up with obstetric providers, endocrinologists, or both can reduce risk for this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Patient demographics during delivery hospitalizations by diabetes status

	No diabetes		Type 1 diabetes		Type 2 diabetes		Gestational diabetes	
Delivery length of stay (mean days)	2.64		4.49		3.87		3.12	
Delivery costs (mean 2016 $)	$15,426.00		$25,851.00		$23,861.00		$18,858.00	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Demographic factors								
Maternal age in years								
15-19 years old	1,251,574	8.6%	2,441	6.9%	2,133	2.1%	23,056	2.3%
20-24 years old	3,466,381	23.8%	8,411	23.7%	11,814	11.4%	119,964	12.2%
25-29 years old	4,159,533	28.6%	10,561	29.8%	23,573	22.7%	248,850	25.3%
30-34 years old	3,650,720	25.1%	9,415	26.6%	32,093	30.9%	317,300	32.3%
35-39 years old	1,650,768	11.3%	3,813	10.8%	25,302	24.4%	207,919	21.1%
40-54 years old	385,648	2.7%	822	2.3%	8,987	8.7%	66,912	6.8%
Payer								
Medicare	84,950	0.6%	790	2.2%	2,758	2.7%	7,637	0.8%
Medicaid	6,261,338	43.0%	13,154	37.1%	53,367	51.4%	390,438	39.7%
Private insurance	7,461,751	51.2%	19,709	55.6%	43,443	41.8%	542,450	55.1%
Self-pay	233,427	1.6%	324	0.9%	1,336	1.3%	13,153	1.3%
No charge	9,200	0.1%	10	0.0%	75	0.1%	537	0.1%
Other	474,176	3.3%	1,323	3.7%	2,642	2.5%	27,518	2.8%
Missing	39,781	0.3%	154	0.4%	281	0.3%	2,270	0.2%
Median ZIP code income quartile								
Lowest income quartile	4,060,954	27.9%	9,562	27.0%	38,290	36.9%	248,918	25.3%
2nd lowest quartile	3,560,111	24.4%	9,237	26.1%	26,368	25.4%	237,383	24.1%
2nd highest quartile	3,589,084	24.6%	9,049	25.5%	23,314	22.4%	251,927	25.6%
Highest income quartile	3,203,943	22.0%	7,267	20.5%	14,435	13.9%	235,317	23.9%
Missing	150,532	1.0%	348	1.0%	1,495	1.4%	10,456	1.1%
Clinical factors								
Cesarean delivery	4,649,722	31.9%	23,960	67.6%	64,632	62.2%	440,166	44.7%
Delivery postpartum hemorrhage	417,573	2.9%	1,003	2.8%	3,246	3.1%	32,098	3.3%
Systemic lupus erythematosus	17,711	0.1%	40	0.1%	266	0.3%	1,267	0.1%
Multiple gestation	269,554	1.9%	622	1.8%	2,041	2.0%	26,294	2.7%
Asthma	525,582	3.6%	1,834	5.2%	8,143	7.8%	44,833	4.6%
Chronic kidney disease	35,923	0.3%	1,463	4.1%	1,661	1.6%	3,165	0.3%
Hypertensive diseases of pregnancy	1,092,800	7.5%	9,698	27.4%	22,951	22.1%	123,891	12.6%
Chronic hypertension	203,639	1.4%	2,092	5.9%	16,489	15.9%	41,631	4.2%
Thromboembolism at delivery	8,701	0.1%	47	0.1%	137	0.1%	781	0.1%
Other history of thromboembolism	36,779	0.3%	180	0.5%	795	0.8%	3,529	0.4%
Hospital factors								
Hospital teaching status								
Metropolitan non-teaching	5,391,737	37.0%	9,618	27.1%	30,938	29.8%	349,519	35.5%

	No diabetes		Type 1 diabetes		Type 2 diabetes		Gestational diabetes	
Metropolitan teaching	7,568,583	52.0%	23,397	66.0%	63,683	61.3%	550,031	55.9%
Non-metropolitan	1,604,304	11.0%	2,449	6.9%	9,282	8.9%	84,452	8.6%
Hospital bed size								
Small	1,638,125	11.3%	2,169	6.1%	8,984	8.7%	113,778	11.6%
Medium	3,840,628	26.4%	8,084	22.8%	25,575	24.6%	250,078	25.4%
Large	9,085,871	62.4%	25,211	71.1%	69,343	66.7%	620,146	63.0%
Hospital safety								
Low burden	2,571,452	17.7%	6,105	17.2%	13,451	13.0%	192,980	19.6%
Medium burden	7,696,818	52.9%	19,202	54.2%	49,967	48.1%	497,546	50.6%
High burden	4,296,353	29.5%	10,156	28.6%	40,484	39.0%	293,475	29.8%

Hypertensive diseases of pregnancy includes gestational hypertension and preeclampsia.

Table 2.

Unadjusted and adjusted models for 60-day postpartum readmission

	RR	95% CI	aRR	95% CI
Diabetes				
Type 1 diabetes	2.92	2.78, 3.07 *	1.77	1.69, 1.87 *
Type 2 diabetes	2.55	2.47, 2.63 *	1.46	1.42, 1.51 *
Gestational diabetes	1.34	1.33, 1.36 *	1.16	1.14, 1.17 *
Unspecified diabetes	2.63	2.42, 2.87 *	1.73	1.59, 1.89 *
No diabetes	Reference		Reference	
Maternal age in years				
15-19 years old	1.26	1.25, 1.28 *	1.18	1.16, 1.19 *
20-24 years old	1.14	1.13, 1.16 *	1.07	1.06, 1.08 *
25-29 years old	Reference		Reference	
30-34 years old	0.95	0.94, 0.97	0.99	0.98, 1.00
35-39 years old	1.11	1.10, 1.13 *	1.09	1.08, 1.11 *
40-54 years old	1.44	1.41, 1.47 *	1.27	1.24, 1.29 *
Payer				
Medicare	3.22	3.12, 3.33 *	2.52	2.44, 2.60 *
Medicaid	1.51	1.50, 1.53 *	1.43	1.42, 1.44 *
Private insurance	Reference		Reference	
Self-pay	1.00	0.97, 1.04	1.02	0.99, 1.06
No charge	1.14	0.97, 1.35	1.11	0.94, 1.31
Other	1.09	1.06, 1.12 *	1.11	1.08, 1.14 *
Median ZIP code income quartile				
Lowest income quartile	1.50	1.48, 1.52 *	1.21	1.19, 1.23 *
2nd lowest quartile	1.29	1.28, 1.31 *	1.14	1.13, 1.16 *
2nd highest quartile	1.19	1.17, 1.20 *	1.10	1.08, 1.11 *
Highest income quartile	Reference		Reference	
Cesarean delivery	1.87	1.86, 1.89 *	1.72	1.71, 1.73 *
Delivery postpartum hemorrhage	1.67	1.64, 1.70 *	1.61	1.58, 1.64 *
Systemic lupus erythematosus	3.41	3.21, 3.62 *	2.26	2.12, 2.40 *
Multiple gestation	1.83	1.80, 1.87 *	1.33	1.30, 1.36 *
Asthma	1.66	1.63, 1.69 *	1.42	1.39, 1.44 *
Chronic kidney disease	3.20	3.07, 3.34 *	2.08	2.00, 2.18 *
Hypertensive diseases of pregnancy	2.48	2.46, 2.51 *	2.07	2.05, 2.09 *
Chronic hypertension	2.68	2.63, 2.74 *	2.10	2.05, 2.14 *
Hospital teaching status				
Metropolitan non-teaching	Reference		Reference	

	RR	95% CI	aRR	95% CI
Metropolitan teaching	1.11	1.10, 1.12 *	1.06	1.05, 1.06 *
Non-metropolitan	1.02	1.00, 1.03	0.92	0.91, 0.93 *
Hospital bed size				
Small	Reference		Reference	
Medium	1.09	1.07, 1.10 *	1.04	1.03, 1.06 *
Large	1.18	1.16, 1.20 *	1.12	1.10, 1.14 *
Hospital safety net burden				
Low burden	Reference		Reference	
Medium burden	1.28	1.26, 1.30 *	1.09	1.07, 1.10 *
High burden	1.42	1.40, 1.44 *	1.07	1.06, 1.09 *

* denotes statistical significance retained with 99% confidence interval. Hypertensive disease of pregnancy include gestational hypertension and preeclampsia diagnoses. *RR*, risk ratio; *aRR*, adjusted risk ratio; *CI*, confidence interval.

Table 3.

Unadjusted and adjusted models for 60-day postpartum readmission restricted to women with diabetes

	Unadjusted risk ratio (95% CI)		Adjusted risk ratio (95% CI)	
Diabetes				
Type 1 diabetes		Reference		Reference
Type 2 diabetes	0.87	0.82, 0.93*	0.84	0.80, 0.90*
Gestational diabetes	0.46	0.44, 0.49*	0.64	0.60, 0.67*
Unspecified diabetes	0.90	0.82, 1.00	0.98	0.89, 1.08
Maternal age in years				
15-19 years old	1.44	1.34, 1.54*	1.27	1.18, 1.36*
20-24 years old	1.19	1.14, 1.24*	1.09	1.04, 1.13*
25-29 years old		Reference		Reference
30-34 years old	0.94	0.91, 0.97*	0.98	0.95, 1.01
35-39 years old	1.00	0.60, 1.03	1.01	0.98, 1.05
40-54 years old	1.22	1.16, 1.28*	1.17	1.11, 1.23*
Payer				
Medicare	3.45	3.20, 3.72*	2.32	2.15, 2.50*
Medicaid	1.56	1.52, 1.60*	1.39	1.35, 1.43*
Private insurance		Reference		Reference
Self-pay	0.58	0.27, 1.24	1.20	1.08, 1.34*
No charge	1.11	1.02, 1.20	0.56	0.26, 1.20
Other	1.18	0.91, 1.52	1.08	0.99, 1.16
Median ZIP code income quartile				
Lowest income quartile	1.67	1.61, 1.73*	1.26	1.21, 1.31*
2nd lowest quartile	1.32	1.27, 1.37*	1.11	1.07, 1.16*
2nd highest quartile	1.19	1.14, 1.24*	1.07	1.03, 1.11*
Highest income quartile		Reference		Reference
Cesarean delivery	1.73	1.69, 1.77*	1.50	1.46, 1.54*
Delivery postpartum hemorrhage	1.28	1.21, 1.36*	1.27	1.19, 1.35*
Systemic lupus erythematosus	2.59	2.12, 3.16*	1.71	1.40, 2.09*
Multiple gestation	1.52	1.43, 1.62*	1.30	1.22, 1.38*
Asthma	1.66	1.58, 1.73*	1.38	1.32, 1.45*
Chronic kidney disease	3.48	3.18, 3.79*	1.95	1.78, 2.14*
Hypertensive diseases of pregnancy	2.39	2.32, 2.46*	1.96	1.91, 2.02*
Chronic hypertension	2.38	2.28, 2.48*	1.88	1.80, 1.96*
Hospital teaching status				
Metropolitan non-teaching		Reference		Reference
Metropolitan teaching	1.19	1.16, 1.22*	1.09	1.06, 1.12*

	Unadjusted risk ratio (95% CI)		Adjusted risk ratio (95% CI)	
Non-metropolitan	1.01	0.96, 1.06	0.88	0.84, 0.93 *
Hospital bed size				
Small	Reference		Reference	
Medium	1.10	1.05, 1.15 *	1.04	1.00, 1.09
Large	1.24	1.19, 1.29 *	1.14	1.09, 1.19 *
Hospital safety net burden				
Low burden	Reference		Reference	
Medium burden	1.36	1.31, 1.41 *	1.11	1.06, 1.17 *
High burden	1.52	1.47, 1.58 *	1.09	1.03, 1.15 *

* denotes statistical significance retained with 99% confidence interval. Hypertensive disease of pregnancy include gestational hypertension and preeclampsia diagnoses. *RR*, risk ratio; *aRR*, adjusted risk ratio; *CI*, confidence interval.

Table 4.

Unadjusted and adjusted models for 60-day postpartum readmission for specific complications

	Unadjusted risk ratio (95% CI)		Adjusted risk ratio (95% CI)	
Severe maternal morbidity				
Type 1 diabetes	3.44	3.04, 3.89	2.09	1.85, 2.37
Type 2 diabetes	2.97	2.75, 3.21	1.57	1.45, 1.70
Gestational diabetes	1.47	1.42, 1.53	1.19	1.14, 1.23
Unspecified	3.05	2.47, 3.77	1.90	1.53, 2.35
No diabetes	Reference		Reference	
Wound complications				
Type 1 diabetes	3.30	2.86, 3.82	1.39	1.20, 1.61
Type 2 diabetes	5.42	5.07, 5.80	2.13	1.99, 2.29
Gestational diabetes	1.73	1.66, 1.80	1.25	1.20, 1.30
Unspecified	4.84	3.98, 5.89	2.34	1.92, 2.85
No diabetes	Reference		Reference	
Diabetic complications				
No diabetes	0.00	0.00, 0.00	0.00	0.00, 0.00
Type 2 diabetes	0.13	0.11, 016	0.20	0.16, 0.24
Gestational diabetes	0.01	0.00, 0.01	0.01	0.01, 0.01
Unspecified	0.52	0.40, 0.66	0.73	0.50, 0.94
Type 1 diabetes	Reference		Reference	
Hypertensive diseases of pregnancy				
Type 1 diabetes	2.92	2.78, 3.07	1.77	1.69, 1.87
Type 2 diabetes	2.55	2.47, 2.63	1.46	1.42, 1.51
Gestational diabetes	1.34	1.33, 1.36	1.16	1.14, 1.17
Unspecified	2.63	2.42, 2.87	1.73	1.59, 1.89
No diabetes	Reference		Reference	
Venous thromboembolism				
Type 1 diabetes	1.10	0.68, 1.76	0.64	0.40, 1.03
Type 2 diabetes	2.15	1.77, 2.62	1.10	0.90, 1.35
Gestational diabetes	1.50	1.38, 1.62	1.19	1.10, 1.30
Unspecified	1.79	0.98, 3.27	1.08	0.59, 1.98
No diabetes	Reference		Reference	

In adjusted analyses the five study models in the table included demographic, hospital and clinical factors in Table 2. For the severe maternal morbidity analysis, patients with these outcomes during the delivery hospitalization were excluded to avoid misclassification. Similarly, for the thromboembolism analysis patients with an acute event during the delivery hospitalization were excluded; history of venous thromboembolism prior to the delivery hospitalization was accounted for in the model. Diabetic complications including diabetes including diabetic ketoacidosis, hyperglycemic hyperosmolar syndrome, and coma. Factors included in the adjusted analyses for specific morbidity outcomes included same factors in the primary adjusted analysis including patient demographics, hospital factors, and medical and obstetrical risk factors.