Effect of Hospital Setting and Volume on Clinical Outcomes in Women with Gestational and Type 2 Diabetes Mellitus

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Abstract

Objective: Efforts to improve health care outcomes in the United States have led some organizations to recommend specific hospital settings or case volumes for complex medical diagnoses and procedures. But there are few studies of the effect of setting and volume on maternal outcomes, particularly in complicated conditions, such as diabetes. Our objective was to estimate the effect of hospital setting and volume on childbirth morbidity and length of stay in pregnancies complicated by type 2 and gestational diabetes.

Methods: We analyzed Maryland hospital discharge data during 1999–2004. The dependent variables were primary cesarean delivery, episiotomy, a composite variable for severe maternal morbidity, and hospital length of stay. The independent variables were hospital setting (community, non-teaching hospitals, community, teaching hospitals, and academic medical centers) and tertiles of annual hospital diabetes delivery volume. Multivariable regression analysis was used to assess the relation of hospital setting with each outcome, adjusting for hospital volume and maternal case mix.

Results: 5,507 deliveries with type 2 (15%) and gestational (85%) diabetes were analyzed. Primary cesarean delivery rates among women with any diabetes did not vary across settings. After adjustment for volume and patient case mix, the likelihood of severe maternal morbidity was higher among deliveries at academic centers compared to community, non-teaching hospitals (odds ratio [OR], 2.1; 95% confidence interval: 1.0, 4.2). Academic centers had a protective effect (OR, 0.3; 95% CI: 0.2, 0.7) and community teaching hospitals had a borderline protective effect (OR, 0.8; 95% CI: 0.7, 1.0) on episiotomy, compared to community, non-teaching hospitals. Length of stay was greater at academic centers and community, teaching hospitals compared to community, non-teaching hospitals (5.4 days, 3.5 days vs. 2.8 days, respectively). We did not identify an independent association between hospital diabetes volume and clinical outcomes after adjustment for case mix.

Conclusions: Among women with type 2 and gestational diabetes, hospital setting is associated with a higher likelihood of severe maternal morbidity and length of stay, independent of volume. Patient case mix accounts for some of the variation across settings. The volume-outcome relationship found with other complex medical conditions or procedures was not found among diabetic pregnancies. Further investigations are needed to explain variations in outcomes across hospital settings and volumes.

Introduction

EFFORTS TO IMPROVE HEALTH CARE outcomes in the United States have led some organizations to recommend specific hospital settings or case volumes for complex medical diagnoses and procedures. The Leapfrog Group,¹ a consortium of private and public organizations that insures nearly 35 million individuals, for example, has recommended hospital setting and volume standards for complex surgical procedures.

These efforts are based on earlier works that report higher quality outcomes with specific hospital settings and volumes. Population-based studies^{2–5} report lower morbidity and mortality among patients with complicated medical conditions (e.g., diabetes, coronary disease) or those undergoing high-risk procedures (e.g., esophageal resection) at academic medical centers compared to community-based hospitals. Hospitals with higher volumes of complex patients and low-birth-weight infants have been shown to have less

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mortality and morbidity compared to those of lower-volume hospitals.^{6,7}

In contrast to the literature on medical and surgical outcomes,⁸ early studies of maternity care have reported conflicting results on the relation of hospital setting^{9,10} and volume^{9,11} on maternal outcomes. Garcia and colleagues reported less likelihood of cesarean delivery or episiotomy at teaching hospitals compared to non-teaching, community hospitals. Macones and colleagues¹² reported no association between hospital setting and maternal complications among women undergoing vaginal birth after cesarean delivery.⁹ With regard to hospital volume, Tracy and colleagues¹¹ reported less likelihood of cesarean delivery at low-volume hospitals compared to high-volume hospitals. Grobman and others¹³ reported a higher risk of maternal injury with childbirth at high-volume institutions.

While these early studies offer relevant information, the investigations were largely conducted in low-risk patients.^{9,11} There is little data on the effect of setting and volume on childbirth outcomes in medically complex pregnancies, such as those complicated by diabetes.

Gestational diabetes mellitus (GDM), defined as carbohydrate intolerance first recognized during pregnancy, is one of the most common medical complications of pregnancy¹⁴. Pre-existing diabetes includes both type 1 and type 2. Of the 4 million annual live births in the United States, an estimated 200,000 births (7%) are complicated by diabetes. While the risk of maternal morbidity in pregnancies with type 2 diabetes is greater than that of pregnancies with GDM, the number of pregnancies complicated by gestational¹⁵ and type 2 diabetes^{16,17} is expected to rise steadily over the next decade,^{14,18} potentially contributing to an increase in maternal-related complications and resource utilization.^{17,19} While there is no current setting or volume specifications for obstetrical care in women with diabetes, the increasing prevalence of this condition in pregnancy warrants an examination of the relation of hospital setting and volume with maternal outcomes. Hospital setting and volume can indicate the clinical experience of an obstetrical team with high-risk pregnancies. It would be important, therefore, to discern whether the association of setting with maternal outcomes in diabetic pregnancies is explained by setting, volume or patient case mix.

The goal of this study was to determine whether differences existed in maternal outcomes across hospital settings in pregnancies complicated by type 2 and gestational diabetes and, if differences were found, to estimate the contribution of hospital volume and patient case mix to these differences. Our hypotheses were as follows: (1) maternal cesarean delivery, episiotomy, severe maternal morbidity, and length of stay would vary across hospital settings; and (2) adjustment for hospital volume and patient case mix would account for these differences. If hospital setting is independently associated with better outcomes, obstetricians might develop guidelines for care based on the category of diabetes (type 2 versus gestational). If volume accounts for much of the variation of setting with outcomes, referrals based on both setting and volume may be indicated.

Methods

Study design

We conducted a retrospective analysis of 5,507 discharges for deliveries in pregnancies complicated by type 2 and ges-

tational diabetes during 1999–2004 in which we estimated the association of hospital setting and hospital volume on primary cesarean delivery, episiotomy, a composite variable of severe maternal morbidity, and hospital length of stay, adjusting for sociodemographic and clinical factors. The study was approved by the Institutional Review Board of the Johns Hopkins School of Medicine.

Data source

The data source was the Maryland Health Care Commission (MHCC) Database,²⁰ which has been previously used to examine perinatal⁹ and diabetes outcomes,^{5,21} as well as quality of care.²² The MHCC database is an attractive database in which to evaluate the relationship between hospital characteristics and health outcomes because comparable data is available on all discharges from the 52 non-federal hospitals in the state. Routine chart audits are conducted internally by each hospital and by the state to ensure the accuracy of the information submitted to the Health Care Commission. Requests for data are submitted to the Commission, and upon approval, data elements, devoid of patient identifiers, are distributed to investigators. Information is available on patient demographics; primary insurers; primary discharge diagnosis and up to 15 secondary diagnoses; and principal procedure and up to 15 secondary procedures. Discharge diagnoses and clinical procedures are listed as International Classification of Diseases, 9th Revision and Procedure (ICD-9) codes.²³

Identification of cases

We identified maternal hospital discharges for pregnancies complicated by diabetes that resulted in the labor and delivery of an infant using ICD-9 diagnosis codes for GDM (ICD-9 code 648.8X) and pre-gestational (ICD-9 648.0X).²³ Because the ICD-9 code of 648.0X includes both type 1 and type 2 diabetes, we cross-referenced this group of discharges with the diagnosis code for type 2 diabetes (ICD-9 code 250.0X). We assumed the diagnosis of GDM was made using the two step process: a 50-g glucose screening test followed by a 100-g 3-h oral glucose tolerance test (OGTT) to confirm the diagnosis in those with a positive glucose screening test or a 75-g OGTT. The American College of Obstetricians and Gynecologists report that the majority of obstetricians in the United States screen for GDM using the two-step process.²⁴

We excluded pregnancies complicated by type 1 diabetes because they may have a differential risk of cesarean delivery or maternal co-morbidity. Twin and higher-order gestations were also excluded because of the higher potential risk of cesarean delivery and maternal comorbidity. We limited the analysis to non-federal hospital that provided obstetrical care during the entire 6-year study period ($n = 34$ hospitals). We excluded hospitals with less than five obstetrical cases complicated by gestational or type 2 diabetes in a given year ($n = 4$ hospitals).

Justification for outcome variables

The outcomes of interest were primary cesarean delivery, episiotomy, a composite variable of severe maternal morbidity, and hospital length of stay. We chose primary cesarean delivery because of the potential surgical morbidity and the

possibility of repeat cesarean delivery in subsequent pregnancies.²⁵ Recent reports support potentially higher complication rates among women with diabetes or obesity undergoing cesarean delivery.²⁶ Episiotomy is an established measure of maternal quality of life.¹³ We used a composite variable to assess the more severe complications of childbirth and to provide comparisons with prior studies of maternal outcomes.⁹ These complications included pulmonary embolism, cardiac complications, anesthesia-related complications, hemorrhage requiring blood transfusion, operative injury (bladder, bowel or ureter), postpartum fever requiring antibiotics, and surgical wound infection. A binary composite variable for major maternal morbidity was generated for patients with at least one major delivery-related complication. Women with multiple major complications were counted once and coded as having a major complication. Primary cesarean delivery and episiotomy were identified with ICD-9 codes and modeled as dichotomous variables.²³ Length of stay was modeled as a continuous variable.

Independent variable: hospital setting

Hospitals were classified into three settings according to their degree of academic affiliation.^{9,27} Community, non-teaching hospitals were defined as hospitals without a residency program in obstetrics. Community teaching hospitals were defined as hospitals with an obstetrical residency program with or without an affiliation with a school of medicine. Academic medical centers were defined as hospitals with a residency program in obstetrics and a single, primary affiliation with a school of medicine.

Covariates

Hospital volume. We used tertiles of the distribution of annual hospital diabetes (cases/year) delivery volume (<32 cases/year, 32–50 cases/year, and >50 cases/year) as the primary covariate. Hospitals with more than 50 deliveries annually (highest volume) were designated as the reference group.

Additional hospital characteristics included level of obstetrical care (level 1, level 2 versus level 3). A level 1 hospital provides care to infants delivered at 35 weeks gestation or higher. Board-certified obstetricians or family medicine physicians supervise delivery services. Neonatal units are staffed by pediatricians. Level 2 hospitals provide delivery room and specialized care for stable infants weighing $\geq 1,500$ g or at ≥ 32 weeks gestation. Delivery services are supervised by obstetricians. Neonatal units are supervised by pediatricians. Hospitals with a level 3a designation provide care for infants weighing $\geq 1,000$ g or at ≥ 28 weeks gestation. Hospitals with a level 3b or 3c designation provide acute delivery and neonatal intensive care for infants of all gestational ages and birth weights. Maternal-fetal medicine specialists supervise the delivery units and are available continuously. Neonatal units are supervised by board-certified neonatal-perinatal medicine subspecialists and offer continuous availability of neonatologists. We re-categorized all individual level 3 hospitals into one category for the current analysis.

Sociodemographics. Sociodemographic characteristics included maternal age, race (black, white, Asian, other), payment source (commercial, health maintenance organiza-

tion (HMO), Medicaid and self-pay), marital status (single, married), and parity (one or more live births).

Clinical characteristics. Clinical covariates included category of diabetes (type 2 versus gestational), prior cesarean delivery, medical illnesses (chronic hypertension, pre-eclampsia), labor complications (premature rupture of membranes, chorioamnionitis), maternal obesity (excessive weight gain, obesity ($30\text{--}39.9\text{ kg/m}^2$), and morbid obesity ($\geq 40\text{ kg/m}^2$)). Infant birth weight was reported in grams. Clinical covariates were identified using ICD-9 diagnosis codes. Less than 2% of the independent variable or covariates were missing in the database.

Statistical analysis

We analyzed hospital characteristics using hospital level data. The distribution of characteristics across settings was compared using the chi-squared statistic for categorical variables and analysis of variance for continuous variables. Based on an alpha of 0.05, there was 80% power to detect a 25% difference in sociodemographic characteristics between the three groups. We also examined outcomes across hospitals within each setting and volume category.

Bivariate analyses, estimating unadjusted odds ratios (Ors), were conducted to examine the association of hospital setting with each outcome and individual covariates. The results of the bivariate analysis guided the selection of variables for the multivariate models. We had 80% power to detect a 10% absolute difference in rates of primary cesarean, episiotomy, maternal morbidity, and length of stay among the three hospital settings. Potential collinearity between sociodemographic variables was examined using the correlation matrix (correlation coefficient 0.4 or higher) and the variance inflation factor.²⁸

To estimate the independent effect of hospital setting on each outcome, we developed separate multivariate models. We assessed the effect of delivery at academic medical centers and community teaching hospitals on the likelihood of cesarean delivery, episiotomy, maternal morbidity, and hospital length of stay, compared to community, non-teaching hospitals. Median (quantile) regression was used to account for outliers in maternal length of stay, providing robust estimates of association. Hospitalizations were clustered by hospitals. Pregnancies were clustered within individual mothers. The ORs, regression coefficients (RCs), and 95% confidence intervals (CIs) were adjusted using multilevel analysis and the robust cluster variance estimator.²⁸ Factors were considered significant in the multivariate analysis if the probability value was <0.05 .

We adjusted for the categories of sociodemographic, clinical, and hospital factors in which there was an association with both hospital setting and the outcome of interest from the bivariate analysis or if the variable was known to be clinically associated with the outcome.²⁸ Each model was first adjusted for hospital volume. Explanatory variables were added in a stepwise fashion: sociodemographics (age, race, parity, payment source, marital status), hospital characteristic (obstetrical care level), and clinical factors. The model for primary cesarean delivery included only those women without prior cesarean delivery and was also adjusted for malpresentation of the fetus. We also conducted subgroup analyses in which

we developed multivariate models for each outcome stratified by category of diabetes (type 2 and gestational). Data analysis was conducted with STATA software (STATA release 9; Statacorp, College Station, TX).

Results

There were 6,190 singleton deliveries with type 2 or GDM out of 159,537 (3.9%) hospitalizations for any delivery in Maryland in our data set during the 6-year study period. We were able to link 5,507 (89%) of the 6,190 maternal files with an infant file. The 683 total unmatched files consisted of the following: (1) women admitted for postpartum care only after delivery outside of the hospital (12%), (2) stillbirths (10%), (3)

diagnosis of spontaneous miscarriage or miscarriage with hemorrhage (25%), and (4) deliveries of infants weighing ≤ 500 g (50%). We did not include cases in which the infant birth weight was less than 500 g because it is difficult to distinguish live births from second-trimester miscarriages. Mothers in the unmatched group were slightly younger, more likely to be white, and less likely to have had a prior cesarean delivery compared to the 5,507 mothers who matched to an infant.

Characteristics of study sample

There were 21 community-based, non-teaching hospitals, six community teaching hospitals, and three academic medi-

TABLE 1. CHARACTERISTICS OF THE STUDY SAMPLE ($N=5,507$) BY HOSPITAL SETTING ($N=30$ HOSPITALS), MARYLAND, 1999–2004

Characteristic	Hospital settings								P-value [†]
	Total sample,* n = 5,507		Community hospitals with no residency program, n = 3,771 (68%)		Community hospitals with residency program, n = 1,446 (26.2%)		Academic medical centers, n = 290 (5.2%)		
	No.	%	No.	%	No.	%	No.	%	
Total diabetes									<0.001
Type 2 diabetes	827	15	99	12	157	19	223	27	
Gestational	4,680	85	4,118	88	3,791	81	3,416	73	
Age in years, mean (SD)	31 (5.6)			31 (5)		30 (6)		30 (7)	<0.001
Race/ethnicity									<0.001
White	3139	57	2640	70	419	29	81	28	
Black	1542	28	506	15	795	55	180	62	
Asian	275	5	226	6	43	3	6	2	
Other	551	10	264	7	188	13	20	7	
Payment source									<0.001
Commercial	1995	36	1508	40	405	28	96	33	
Medicaid	1575	29	766	20	666	46	143	49	
Health maintenance organization	1791	33	1433	38	318	22	46	16	
Self-pay	66	1.2	37	<1	14	<1	3	<1	
Other	80	1.4	58	2	17	1	5	2	
Marital status									<0.001
Single	1652	30	830	22	651	45	148	51	
One or more live births	2093	38	1508	40	651	45	125	43	0.7
Level of obstetric care									0.01
Level 1	566	10	566	15	—	—	—	—	
Level 2	1189	22	1131	30	58	4	—	—	
Level 3	3752	68	2074	55	1388	96	290	100	
Prior cesarean delivery	222	4	113	3	101	7	15	5	<0.001
Chronic hypertension	245	4	158	4	73	5	14	5	0.3
Preeclampsia	133	2	93	2.5	13	2.5	4	1.3	0.5
Intrapartum infection ¹	122	2	2904	77	217	15	23	8	0.008
Maternal obesity ²	28	10	1546	27	709	29	29	10	0.003
Birth weight (g)									<0.001
<2,500	331	6	180	5	113	8	38	13	
2,500–3,999	4,418	81	3,053	82	1,150	80	215	74	
≥ 4,000	711	13	493	13	181	13	37	13	

[†]The *p*-values are from chi-squared statistics and analysis of variance (age), comparing characteristics between each hospital setting. *p* < 0.05 is considered significant.

*Includes the entire sample, regardless of hospital setting.

¹Intrapartum infection included premature rupture of membranes and chorioamnionitis.

²Maternal obesity included excessive weight gain, obesity and morbid obesity.

SD, standard deviation; data are shown as percentages unless otherwise indicated.

Percentages may not total 100% due to rounding.

cal centers providing obstetrical care during the study period. Sixty-eight percent of the deliveries occurred at community hospitals, 26% at community teaching hospitals, and 5.2% at academic medical centers. There was little variation in outcomes among hospitals within each setting or each tertile of volume. The study sample was comprised of 4,680 (85%) hospitalizations among women with GDM and 826 (15%) hospitalizations among women with type 2 diabetes. As shown in Table 1, deliveries at community teaching hospitals and academic medical centers were more likely to involve young, single, black, and Medicaid-eligible women compared to deliveries at community, non-teaching hospitals (all $p < 0.05$). The rate of chronic hypertension, pre-eclampsia,

intrapartum infection, and maternal obesity was similar across hospital settings. Thirteen percent of the infants at academic medical centers weighed less than 2,500 g. The percentage of infants weighing 4,000 g or more was similar across settings.

Relation of maternal characteristics with clinical outcomes

Because of the differences in case mix across hospital settings, we examined the association of patient characteristics with each outcome of interest (Table 2). Black race had a protective effect on episiotomy, but was associated with

TABLE 2. ADJUSTED ASSOCIATIONS OF SOCIODEMOGRAPHIC AND CLINICAL FACTORS WITH PRIMARY CESAREAN, EPISIOTOMY, MATERNAL MORBIDITY, AND LENGTH OF STAY ($N = 5,507$), MARYLAND, 1999–2004

Characteristic	Outcomes			
	Primary cesarean delivery aOR* (95% CI)	Episiotomy aOR (95% CI)	Composite maternal morbidity aOR (95% CI)	Length of stay aRC (95% CI)
Annual hospital diabetes volume ¹				
First tertile	1.3 [†] (1.0, 1.5)	1.3 [†] (1.1, 1.6)	1.2 (0.6, 2.2)	1.3* (0.8, 1.4)
Second tertile	1.1 (0.9, 1.2)	1.1 (0.9, 1.4)	0.9 (0.6, 1.5)	0.3 (0.1, 0.5)
Third tertile	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Age ² (years)	1.0 (1.0, 1.1)	0.98 (0.97, 0.99)	0.98 (0.94, 1.00)	−0.01 (−0.02, 0.007)
Race/ethnicity				
White	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Black	1.4 [†] (1.2, 1.6)	0.5 [†] (0.4, 0.6)	0.8 (0.4, 1.4)	0.4* (0.3, 0.6)
Asian	0.8 (0.6, 1.1)	1.3 [†] (1.0, 1.8)	1.9 (0.9, 3.8)	0.7* (0.4, 1.0)
Other	0.8 (0.7, 1.0)	1.0 (0.8, 1.3)	0.8 (0.5, 1.4)	0.2* (0.001, 0.5)
Multiparity ³	0.6 [†] (0.5, 0.8)	0.6 [†] (0.4, 0.9)	0.7 [†] (0.4, 0.9)	0.7* (0.4, 0.9)
Single status	1.0 [†] (0.9, 1.2)	0.8 [†] (0.7, 1.0)	1.6 (0.9, 2.5)	0.1 (−0.05, 0.3)
Payment source				
Commercial	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Medicaid	0.9 (0.8, 1.2)	0.5 [†] (0.4, 0.7)	1.3 (0.8, 2.1)	−0.04 (−0.2, 0.1)
HMO	1.1 (0.9, 1.3)	0.9 (0.7, 1.1)	0.9 (0.5, 1.4)	−0.003, (−0.1, 0.1)
Self-pay	1.2 (0.7, 2.0)	1.4 (0.8, 2.6)	0.8 (0.9, 2.5)	−0.5* (−1.2, −0.09)
Level of obstetric care				
Level 1	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Level 2	1.2 (1.1, 1.4)	1.1 (1.0, 1.3)	1.2 (1.1, 1.3)	0.9* (0.8, 1.2)
Level 3	1.3 (1.1, 1.4)	0.9 (0.8, 1.2)	1.2 (1.1, 1.4)	1.2* (1.0, 1.4)
Hypertensive disease				
Chronic hypertension	1.1 (0.8, 1.4)	0.8 (0.6, 1.8)	1.2 (0.5, 2.7)	0.7* (0.3, 1.0)
Preeclampsia	3.3 [†] (2.3, 4.8)	0.8 (0.6, 1.2)	0.6 (0.2, 2.8)	0.3 (−0.03, 0.7)
Intrapartum infection ⁴	1.8 [†] (1.2, 2.1)	0.4 [†] (0.2, 0.8)	1.6 (0.6, 4.4)	0.3 (−0.06, 0.7)
Maternal obesity ⁵	1.6 (0.8, 3.5)	0.8 (0.2, 2.6)	1.7 (0.2, 8)	−0.3 (−1.2, 0.6)
Birth weight (g)				
< 2,500	1.6 [†] (1.3, 2.0)	0.7 (0.5, 1.0)	1.5 (0.8, 2.8)	1.2* (0.9, 1.4)
2,500–3,999	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
≥ 4,000	1.9 [†] (1.6, 2.3)	0.8 (0.7, 1.1)	1.6 [†] (1.0, 2.5)	−0.06 (−0.2, 0.7)
Cesarean delivery	—	—	—	1.6* (1.5, 1.8)
Composite maternal morbidity	—	—	—	0.4* (0.08, 0.9)

[†]aOR is statistically significant because the 95% CI does not cross 1.

*Adjusted regression coefficient is statistically significant because the 95% CI does not cross 0.

¹Tertiles of the distribution of annual hospital delivery volume complicated by type 2 or gestational diabetes.

²Age was modeled as a continuous variable.

³Multiparity corresponds to one or more live births.

⁴Intrapartum infection included premature rupture of membranes and chorioamnionitis.

⁵Maternal obesity included excessive weight gain, obesity and morbid obesity.

Models for cesarean delivery, episiotomy, and maternal morbidity were adjusted for age, race, parity, payment source, hospital level of obstetrical care, volume, chronic hypertension, infection, maternal obesity, and infant birth weight.

Model for length of stay was adjusted for age, race, parity, payment source, hospital level of obstetrical care, volume, chronic hypertension, infection, maternal obesity, infant birth weight, cesarean delivery and composite variable for maternal morbidity.

aOR, adjusted odds ratio; 95% CI, 95% confidence interval; aRC, adjusted regression coefficient.

higher odds of cesarean delivery. Conversely, Asian race was associated with higher odds of episiotomy, but lesser odds of cesarean delivery. Black race (RC, 0.4; 95% CI: 0.3, 0.6) and Asian race (RC, 0.7; 95% CI: 0.4, 1.0) were associated with longer lengths of hospital stay, compared to white women. For each 1-year increase in age, there was a 1.03 times higher odds of cesarean delivery (adjusted OR [aOR], 1.03; 95% CI: 1.02, 1.1). Each 1-year increase in age was associated with a 10% reduction in the odds of episiotomy. Age had a borderline significant, protective effect on composite maternal morbidity (OR, 0.98; 95% CI: 0.94, 1.00). The diagnosis of pre-eclampsia was statistically significantly associated with higher odds of cesarean delivery. Perinatal infection was associated with an increased likelihood of cesarean delivery (OR, 1.6; 95% CI: 1.1, 2.4), but a 60% reduction in episiotomy (OR, 0.4; 95% CI: 0.2, 0.8). Cesarean delivery was the strongest predictor of hospital length of stay (RC, 1.6; 95% CI: 1.5, 1.8). Maternal obesity was positively associated with cesarean delivery and the composite variable for maternal morbidity, but these relationships did not reach statistical significance.

Effect of hospital setting on primary cesarean, episiotomy, and maternal morbidity

We compared the rate of primary cesarean delivery, episiotomy, and a composite variable for maternal morbidity across three hospital settings (Table 3). The rate of cesarean delivery was similar across settings, ranging between 34% at community, teaching hospitals to 37% at community, non-teaching hospitals. Eighteen percent of episiotomies occurred

at community, non-teaching hospitals compared to 11% and 5% at community, teaching hospitals and academic centers, respectively. Thirteen percent of the deliveries at academic hospitals were complicated by maternal morbidity compared to 9% of the deliveries at community, non-teaching and teaching hospitals.

In bivariate analysis, we estimated unadjusted ORs to show the relation of hospital setting to each outcome of interest. The bivariate analysis (Table 3) suggested that the likelihood of cesarean delivery did not vary significantly in community-teaching and academic centers compared to community, non-teaching hospitals. Bivariate analysis also suggested that community-teaching hospitals and academic medical centers are associated with a 40% and 70% reduction in episiotomy compared to community, non-teaching hospitals. After adjustment for hospital volume, deliveries at community-teaching hospitals and academic medical centers were still associated with lesser odds of episiotomy. Bivariate analysis also suggested a higher likelihood of maternal morbidity at academic centers (OR, 2.2; 95% CI: 1.2, 4.3) compared to community, non-teaching hospitals. Adjustment for volume did not attenuate this relationship (OR, 2.4; 95% CI: 1.3, 4.8).

In a final step in the analysis, we determined the independent effect of setting on each outcome. After adjustment for patient case mix, deliveries at academic medical centers were associated with a 70% reduction in episiotomy (OR, 0.3; 95% CI: 0.2, 0.5). Further adjustment for patient case mix attenuated the relation of academic centers with maternal morbidity (OR, 2.1; 95% CI: 1.0, 4.2), but the relationship had borderline statistical significance.

TABLE 3. UNADJUSTED RATE, CRUDE AND ADJUSTED ORs FOR PRIMARY CESAREAN, EPISIOTOMY, AND MATERNAL MORBIDITY (N=5,507) BY HOSPITAL SETTING (N=30 HOSPITALS), MARYLAND, 1999–2004

Outcomes of interest	Hospital settings		
	Community hospitals with no residency program, 21 hospitals (n=3,771 deliveries)	Community hospitals with residency program, 6 hospitals (n=1,446 deliveries)	Academic medical centers, 3 hospitals (n=290 deliveries)
Primary cesarean delivery			
Rate (%)	37	34	34
Unadjusted OR (95% CI)	1.0 (Reference)	1.0 (0.6–1.8)	1.1 (0.3–1.6)
Volume-adjusted OR ² (95% CI)	1.0 (Reference)	1.1 [‡] (1.0–1.3)	1.2 (0.9–1.6)
Fully adjusted OR ³ (95% CI)	1.0 (Reference)	0.9 (0.8–1.1)	1.0(0.8–1.4)
Episiotomy			
Rate (%) [*]	18	11	5
Unadjusted OR (95% CI)	1.0 (Reference)	0.6 [‡] (0.5–0.7)	0.3 [‡] (0.2–0.5)
Volume-adjusted OR (95% CI)	1.0 (Reference)	0.9 (0.7–1.0)	0.3 [‡] (0.2–0.5)
Fully adjusted OR ³ 95% CI)	1.0 (Reference)	0.8 (0.7–1.0)	0.3 [‡] (0.2–0.7)
Composite of maternal morbidity ¹			
Rate (%) [*]	4	2	4
Unadjusted OR (95% CI)	1.0 (Reference)	1.0 (0.6, 1.6)	2.4 [‡] (1.2, 3.9)
Volume-adjusted OR ² (95% CI)	1.0 (Reference)	1.0 (0.6, 1.4)	2.5 [‡] (1.3, 4.8)
Fully adjusted OR ³ (95% CI)	1.0 (Reference)	1.1 (0.7, 1.8)	2.1 [‡] (1.0, 4.2)

^{*}Rate of cesarean delivery, episiotomy, or the composite maternal morbidity in community, teaching hospitals, or academic centers is significantly different from the rate in community, non-teaching hospitals with $p < 0.05$.

[‡]Significant OR because the 95% CI does not include 1.

¹Composite maternal morbidity variable includes (1) pulmonary embolism, (2) cardiac complications, (3) anesthesia-related complications, (4) hemorrhage requiring blood transfusion, (5) bladder injury, (6) postpartum fever, and (7) surgical wound infection.

²Adjusted for tertiles of annual hospital volume of diabetes deliveries.

³Models are adjusted for maternal age, race, parity, payment source, level of obstetrical care, chronic hypertension, pre-eclampsia, infection, maternal obesity, infant birth weight, and tertiles of hospital volume.

HMO, health maintenance organization; OR, odds ratio; 95% CI, 95% confidence interval.

TABLE 4. ASSOCIATION OF HOSPITAL SETTING AND VOLUME WITH LENGTH OF STAY IN WOMEN WITH TYPE 2 AND GESTATIONAL DIABETES

<i>Length of stay</i>	<i>Hospital setting</i>		
	<i>Community hospital with no residency program, 21 hospitals (n = 3,771 deliveries)</i>	<i>Community hospitals with residency program, 6 hospitals (n = 1,446 deliveries)</i>	<i>Academic Centers, 3 hospitals (n = 290 deliveries)</i>
Length of stay (days), mean, unadjusted ¹	2.8	3.2 [†]	4.2 [†]
Volume-adjusted ²	2.8	3.7 [†]	5.6 [†]
Fully adjusted ³	2.8	3.5 [†]	5.4 [†]

¹Length of stay in days is derived from the regression coefficients (RCs) from the median regression model.

²Adjusted for tertiles of annual hospital volume of diabetes deliveries.

³Fully adjusted model included maternal age, race, parity, payment source, category of diabetes, chronic hypertension, preeclampsia, infection, maternal obesity, infant birth weight, method of delivery, and prior cesarean delivery.

[†]Denotes that the length of stay (days) is significantly different from the length of stay at hospitals with no residency program.

Effect of hospital setting on length of stay

Length of stay for community hospitals was significantly shorter compared to community-teaching hospitals and academic centers (2.8 days compared to 3.2 and 4.2 days, respectively). After adjustment for volume, average hospital length of stay at community-teaching hospitals and academic centers was significantly higher compared to community hospitals (Table 4). In the fully adjusted model, community teaching hospitals and academic centers were still significantly associated with higher average lengths of stay.

Subgroup analysis

Among type 2 diabetics, delivery at a community-teaching hospital or academic medical center was associated with a

higher likelihood of primary cesarean delivery. Conversely, delivery at teaching hospitals had a borderline protective effect on cesarean delivery among gestational diabetics. Delivery at academic medical centers was protective against maternal morbidity among type 2 diabetics. Among gestational diabetics, there was a borderline-significant positive association between delivery at academic medical centers and the likelihood of maternal morbidity (Table 5).

Discussion

Main findings

While earlier works reported a volume-outcome relationship in medically complex patients, we did not find this relationship in women with type 2 and gestational diabetes. We

TABLE 5. ASSOCIATION OF HOSPITAL SETTING WITH PRIMARY CESAREAN DELIVERY, EPISIOTOMY, AND MATERNAL MORBIDITY BY DIABETES CATEGORY

<i>Outcomes</i>	<i>Hospital settings</i>					
	<i>Community, non-teaching hospitals</i>		<i>Community-teaching hospitals</i>		<i>Academic medical centers</i>	
	<i>Rate (%)</i>	<i>OR² (95% CI)</i>	<i>Rate (%)</i>	<i>OR² (95% CI)</i>	<i>Rate (%)</i>	<i>OR² (95% CI)</i>
Primary cesarean delivery						
Type 2 DM	28*	1.0 (Reference)	38	2.1 [‡] (1.4, 3.2)	41	2.4 [‡] (1.4, 4.3)
Gestational DM	36	1.0 (Reference)	25	0.9 (0.8, 1.1)	39	0.9 (0.7, 1.3)
Episiotomy						
Type 2 DM	21*	1.0 (Reference)	8	0.4 (0.2, 0.7)	9	0.4 (0.2, 1.0)
Gestational DM	17*	1.0 (Reference)	12	0.9 (0.7, 1.2)	3	0.2 (0.1, 0.5)
Composite maternal morbidity ¹						
Type 2 DM	6	1.0 (Reference)	4	0.3 (0.1, 0.8)	8	0.7 (0.3, 2.2)
Gestational DM	5*	1.0 (Reference)	4	0.8 (0.5, 1.2)	8	1.7 [‡] (1.0, 3.2)
Hospital length of stay (days)						
Type 2 DM		5.1		6.4 [‡]		8.3 [‡]
Gestational DM		2.8		3 [‡]		3.3 [‡]

¹Composite maternal morbidity variable includes (1) pulmonary embolism, (2) cardiac complications, (3) anesthesia-related complications, (4) hemorrhage requiring blood transfusion, (5) bladder injury, (6) postpartum fever, and (7) surgical wound infection.

²ORs and 95% CIs are adjusted for tertiles of annual hospital volume of diabetes deliveries, maternal age, race, parity, level of obstetrical care, payment source, chronic hypertension, pre-eclampsia, infection, maternal obesity, and infant birth weight.

*Rate of cesarean delivery, episiotomy, or maternal morbidity in community-teaching hospitals or academic centers for a particular type of diabetes is significantly different from the rate in community, non-teaching hospitals with $p < 0.05$.

[‡]Significant OR because the 95% CI does not include 1.

DM, diabetes mellitus; OR, odds ratio; 95% CI, 95% confidence interval; rate is the rate of each procedure in the designated hospital setting.

found that hospital volume and patient case mix accounted for some of the variation in the relation of hospital setting with maternal outcomes. Even after adjustment, however, hospital setting was independently associated with episiotomy, severe maternal morbidity, and hospital length of stay.

Findings in relation to other studies

Recent studies emphasize the clinical relevance of hospital setting^{9,13} and volume^{12,29} to maternal health and pregnancy outcomes. Teaching hospitals have been linked to lower cesarean delivery and episiotomy rates.⁹ Studies of maternal morbidity and hospital volume report conflicting findings. Two studies^{30,31} found no evidence of a relationship between volume and maternal morbidity. Still, other studies^{9,29} have reported an inverse relationship between hospital volume and maternal complications.

The rate of cesarean delivery and episiotomy in our sample are similar to earlier studies among high-risk parturients. We reported a cesarean delivery rate of 34–37%, which is similar to previously reported rates among diabetic pregnancies, ranging from 30% to 45%.³² Although there is no optimal episiotomy rate based on current evidence, rates of 10–15% in general obstetric populations are considered acceptable.²⁶ The rate of episiotomy in our diabetic sample was slightly higher, ranging from 5% to 18% across settings. The rate of severe maternal morbidity (2–4%) was higher in our sample than that reported by Macones et al.¹² among women undergoing an attempt at vaginal birth after cesarean delivery, but lower than rates reported by Garcia and colleagues in a general population of parturients.⁹ Our findings suggest that women with diabetes experience rates of childbirth morbidity that parallel or exceed those of general samples of women and suggest the need for further assessment of the non-clinical factors and processes that account for these differences across settings.

Relevance of findings to maternal outcomes

We did not find support for our hypothesis that hospital volume would explain the variation in outcomes across hospital settings. For example, adjustment for volume alone did not substantially attenuate the relation of teaching hospitals with episiotomy or length of stay. There are several possible explanations for the association of setting with maternal outcomes. Organizational factors,³³ patient preferences,³⁴ physician decision-making,³⁵ and patient-physician communication³⁶ may also influence outcomes. The potential learning trajectory of resident physicians might alter length of stay. Because of the teaching environment, it may be that additional tests or management procedures are performed that necessitate a longer length of stay. Physician decisions³⁵ for procedural interventions, such as episiotomy, may be dependent upon organizational factors, such as the availability of 24-h in-house anesthesia. Management of diabetes-related childbirth complications, such as shoulder dystocia or the need for emergent cesarean delivery, might influence physicians' decisions to perform an episiotomy.³⁷ In this scenario, physicians at teaching hospitals are more likely to have access to 24-h anesthesia and, therefore, may be less likely to perform an episiotomy. Also, expectant mothers may have preferences regarding episiotomy and verbalize their desire for a conservative approach to vaginal delivery. Physicians' perception of

the complexity of a patient's presentation may also affect length of stay.¹⁹ Finally, high-risk expectant mothers in the community setting may have specific preferences for obstetrical interventions or length of stay based on perceptions of their condition or prior delivery experiences. Future studies of maternal outcomes in diabetes might adjust for individual clinician as well as hospital case volumes.

Our analysis emphasizes the importance of sociodemographic characteristics and clinical conditions on the association of hospital setting with outcomes in diabetics. Sociodemographic characteristics, such as race and payment source, have been previously linked to cesarean delivery and episiotomy.³⁸ Minority and low-income women have been shown to experience higher rates of cesarean delivery, but lower rates of episiotomy compared to white women or women with commercial insurance. Further, intrapartum complications, including pre-eclampsia and infection, are known to be a leading indication for cesarean delivery. Sociodemographic factors may also be a proxy for delayed access to prenatal care, glycemic control, and predisposition to maternal morbidity. With the potential effect of sociodemographic factors on biologic mechanisms, physicians may need to combine medical treatment for diabetes with assistance with psychosocial interventions. Parallel review of glycemic control and psychosocial circumstances might improve management and decrease maternal morbidity.

We did not find support for our hypothesis that deliveries at academic medical centers are associated with higher rates of primary cesarean delivery in the analysis of women with both type 2 and GDM. In stratified analysis, delivery at academic centers was associated with a higher likelihood of cesarean delivery among women with type 2 diabetes. It may be that women with type 2 diabetes have a higher expectation of cesarean delivery or request earlier operative intervention, independent of hospital setting.³⁹ Alternatively, physicians may have different perceptions of maternal and fetal well-being in women with type 2 diabetes.

Strengths and limitations

Our study has several strengths. We used a population-based sample to examine differences in childbirth procedures and severe maternal morbidity across hospital settings. Because we drew the study sample from a large population of women who delivered infants during 5 years in one state, we were able to examine differences among women with type 2 and gestational diabetes. Because the database contains up to seven secondary diagnosis codes, we were able to adjust for multiple co-conditions specific to diabetes in pregnancy. Few studies of diabetes in pregnancy have been able to do this. Also, the database provides information on hospital characteristics, which we were able to adjust for in the multivariable models.

In interpreting our findings, it is important to consider potential limitations. First, our results are based on administrative data which is limited by less detailed clinical information. However, prior studies support the use of administrative data in studies of maternal morbidity⁴⁰ and management of diabetes in non-pregnancy adults.⁴¹ The current study is further limited by the inability to assess neonatal morbidity in addition to maternal morbidity. This limitation is due to several design and statistical reasons. First, there can be

variation in the clinical definitions that physicians use for specific neonatal outcomes, which, in turn, would affect coding of these diagnoses on neonatal discharge records. For example, physicians use different thresholds for applying the definition of neonatal hypoglycemia. Second, due to small numbers, a composite variable for neonatal morbidity would be necessary to ensure adequate power. A composite variable, however, would be quite heterogeneous and difficult to interpret clinically. There may be an error in the ascertainment of women with GDM. Because we were unable to review glucose levels, it was not possible to confirm the diagnosis of GDM. We were unable to discern the severity of gestational diabetes (i.e., diet controlled or insulin requiring) or to adjust for glucose levels in type 2 or gestational diabetes. Adjustment for glucose levels might alter the magnitude of association of hospital setting with outcomes in our sample. Therefore, there is the possibility of residual confounding. It is possible that the prevalence of obesity (28%) was underestimated in our sample which could alter our findings. We expect little bias from the exclusion of unmatched pairs in the analysis since primary sociodemographic and clinical characteristics were not significantly different from those in our study sample. There could be errors in coding. However, prior studies show reliable coding of obstetrical diagnoses and specific obstetrical procedures, including cesarean delivery and episiotomy.⁴² Furthermore, the cesarean delivery rates in our sample were similar to those reported nationally among pregnancies with diabetes which suggests few coding errors in the Maryland database. We could not ascertain the appropriateness of procedure use or measure the quality of individual physician's decisions.

Clinical implications

While further study is warranted, our findings have important implications for childbirth and its associated morbidity in pregnancies with diabetes. Because hospital setting, rather than volume, is primarily associated with outcomes in women with diabetes, obstetricians might need to develop a tiered referral system in which women are referred to a specific hospital setting based on the category or severity of diabetes. Further study of the organizational processes of intrapartum care in different hospital settings could help clinicians to foster parity in procedure rates and reduce maternal morbidity. Our findings might also inform clinical guidelines for intrapartum care to assist with similar outcomes across settings. Finally, there is always a need to balance the care of the expectant mother with the infant. Future studies might follow the intrapartum course and delivery of diabetics prospectively to better evaluate the influence of patient demographics and physicians' decisions on outcomes.

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Disclosure Statement

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References

1. LeapFrog Group. Available at: <https://leapfrog.medstat.com>. Accessed February 28, 2009.
2. Dimick JB, Pronovost PJ, Cowan JA Jr, et al. Postoperative complication rates after hepatic resection in Maryland hospitals. *Arch Surg* 2003;138:41–46.
3. Dimick J, Cattaneo SM, Lipsett PA, et al. Hospital volume is related to clinical and economic outcomes of esophageal resection in Maryland. *Ann Thoracic Surg* 2001;72:334–339.
4. Theimann DR Coresh J, Oetgen WJ, et al. The association between hospital volume and survival after myocardial infarction in elderly patients. *N Engl J Med* 1999;340:1640–1648.
5. Steiner CA Bass E, Talamini MA, et al. Surgical rates and operative mortality for open and laparoscopic cholecystectomy in Maryland. *N Engl J Med* 1994;330:403–408.
6. Birkmeyer JD, Siewers AE, Finlayson FV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med* 2002;340:28–37.
7. Birkmeyer JD, Stukel TA, Siewers AE, et al. Surgeon volume and operative mortality in the United States. *N Engl J Med* 2003;349:2117–2127.
8. Phibbs CS, Baker LC, Caughey AB, et al. Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants. *N Engl J Med* 2007;356:2165–2175.
9. Garcia Francisco AR, Miller H, Huggins GR, et al. Effect of academic affiliation and obstetric volume on clinical outcome and cost of childbirth. *Obstet Gynecol* 2001;97:567–576.
10. Viisainen K, Gissler M, Hemminki E. Birth outcomes by level of obstetric care in Finland: a catchment area based analysis. *J Epidemiol Community Health* 1994;48:400–405.
11. Tracy S, Sullivan E, Dahlen H, et al. Does size matter? A population-based study of birth in lower volume maternity hospitals for low-risk women. *BJOG* 2006;113:86–96.
12. Chang JJ, Stamilio DM, Macones GA. Effect of hospital volume on maternal outcomes in women with prior cesarean delivery undergoing trial of labor. *Am J Epidemiol* 2008;167:711–718.
13. Grobman WA, Feinglass J, Murthy S. Are the Agency for Healthcare Research and Quality obstetric trauma indicators valid measures of hospital safety? *Am J Obstet Gynecol* 2006;195:868–874.
14. Centers for Disease Control and Prevention. Diabetes and women's health across the lifespan. 2005. Available at: www.cdc.gov/diabetes. Accessed February 27, 2009.
15. Metzger BE, Lowe LP, Dyer AR, et al. Hyperglycemia and adverse pregnancy outcomes. *N Engl J Med* 2008;358:1991–2002.
16. Lawrence JM, Contreras R, Chen W, et al. Trends in the prevalence of preexisting diabetes and gestational diabetes mellitus among a racially/ethnically diverse population of pregnant women, 1999–2005. *Diabetes Care* 2008;31:899–904.
17. Feig DS. Type 2 diabetes in pregnancy: a growing concern. *Lancet* 2002;359:1690–1692.
18. Ferrara A, Kahn HS, Quesenberry CP, et al. An increase in the incidence of gestational diabetes mellitus: Northern California, 1991–2000. *Obstet Gynecol* 2004;103:526–533.
19. Feig DS, Razzaq A, Sykora K, et al. Trends in deliveries, prenatal care, and obstetrical complications in women with pregestational diabetes: a population-based study in Ontario, Canada, 1996–2001. *Diabetes Care* 2006;29:232–235.
20. Maryland Health Care Commission hospital discharge data. Available at: www.hsrc.state.md.us/casemix. Accessed August 1, 2009.

21. Choti MA, Bowman HM, Pitt HA, et al. Should hepatic resections be performed at high-volume referral centers? *J Gastrointest Surg* 1998;2:11–20.
22. Daumit GL, Pronovost PJ, Anthony CB, et al. Adverse events during medical and surgical hospitalizations for persons with schizophrenia. *Arch Gen Psychiatry* 2006;63:267–272.
23. International Classification of diseases—clinical modification. Salt Lake City, UT: Med-Index Publications, 2002.
24. Gabbe SG, Gregory RP, Power ML, et al. Management of diabetes mellitus by obstetrician-gynecologists. *Obstet Gynecol* 2004;103:1229–1234.
25. Hartmann K, Viswanathan M, Palmieri R, et al. Outcomes of routine episiotomy: a systematic review. *JAMA* 2005;293:2141–2148.
26. Robinson HE, O'Connell CM, Joseph KS, et al. Maternal outcomes in pregnancies complicated by obesity. *Obstet Gynecol* 2005;106:1357–1364.
27. Dimick JB, Pronovost PJ, Cowan JA Jr, et al. Should older patients be selectively referred to high-volume centers for abdominal aortic surgery? *Vascular* 2004;12:51–56.
28. Hosmer DW, Lemeshow S. *Applied logistic regression*. New York: John Wiley, 1989.
29. Heaphy PE, Bernard SL. Maternal complications of normal deliveries: variation among rural hospitals. *J Rural Health* 2000;16:139–147.
30. Klein MC, Spence A, Kaczorowski J, et al. Does delivery volume of family physicians predict maternal and newborn outcome? *CMAJ* 2002;166:1257–1263.
31. LeFevre ML. Physician volume and obstetric outcome. *Med Care* 1992;30:866–871.
32. Conway DL. Obstetric management in gestational diabetes. *Diabetes Care* 2007;30(Suppl 2):S175–S179.
33. Linton A, Peterson MR, Williams TV. Clinical case mix adjustment of cesarean delivery rates in U.S. military hospitals, 2002. *Obstet Gynecol* 2005;105:598–606.
34. Horner RD, Oddone EZ, Matchar DB. Theories explaining racial differences in the utilization of diagnostic and therapeutic procedures for cerebrovascular disease. *Milbank Q* 1995;73:443–462.
35. van Ryn M, Burgess D, Malat J, et al. Physicians' perceptions of patients' social and behavioral characteristics and race disparities in treatment recommendations for men with coronary artery disease. *Am J Public Health* 2006;96:351–357.
36. Cooper LA, Roter DL, Johnson RL, et al. Patient-centered communication, ratings of care, and concordance of patient and physician race. *Ann Intern Med* 2003;139:907–915.
37. Weber AM, Meyn L. Episiotomy use in the United States, 1979–1997. *Obstet Gynecol* 2002;100:1177–1182.
38. Oleske DM, Branca ML, Schmidt JB, et al. A comparison of capitated and fee-for-service Medicaid reimbursement methods on pregnancy outcomes. *Health Serv Res* 1998;33:55–73.
39. Bettes BA, Coleman VH, Zinberg S, et al. Cesarean delivery on maternal request: obstetrician-gynecologists' knowledge, perception, and practice patterns. *Obstet Gynecol* 2007;109:57–66.
40. Taylor LK, Travis S, Pym M, et al. How useful are hospital morbidity data for monitoring conditions occurring in the perinatal period? *Aust N Z J Obstet Gynaecol* 2005;45:36–41.
41. Solberg LI, Engebretson KI, Sperl-Hillen JM, et al. Are claims data accurate enough to identify patients for performance measures or quality improvement? The case of diabetes, heart disease, and depression. *Am J Med Qual* 2006;21:238–245.
42. Yasmeen S, Romano PS, Schembri ME, et al. Accuracy of obstetric diagnoses and procedures in hospital discharge data. *Am J Obstet Gynecol* 2006;194:992–1001.

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