Published in final edited form as:

Am J Perinatol. 2017 September ; 34(11): 1160–1168. doi:10.1055/s-0037-1604414.

Increased Neonatal Respiratory Morbidity Associated With Gestational and Pregestational Diabetes: a retrospective study

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Abstract

Objective: To examine risk of neonatal respiratory morbidity associated with gestational and pregestational diabetes, accounting for the prematurity-associated risk using a propensity score analysis.

Study design: In a retrospective study including 222,978 singleton pregnancies, delivering at 24 0/7–41 6/7 weeks (2002–2008), we calculated a probability to deliver at term (< 37 weeks' gestation). Outcomes were stratified by the probability to deliver at term (>0.8 and ≤0.8). Adjusted odds ratios (aOR) with 95% confidence intervals (95%CI) were calculated.

Results: Gestational and pregestational diabetes complicated 5.1% and 1.5% of pregnancies, respectively and were associated with increased risks of neonatal respiratory morbidity compared to women without diabetes regardless of probability to deliver at term, although the risks tended to be higher with a higher probability to deliver at term: respiratory distress syndrome: aOR 1.5; 95%CI 1.3–1.7 and aOR 3.1; 95%CI 2.6–3.7; transient tachypnea of newborn aOR 1.5; 95%CI 1.3–1.6, and aOR 2.2; 95%CI 1.9–2.6; and apnea aOR 1.5; 95%CI 1.2–1.7 and aOR 3.2; 95%CI 2.6–3.9, for gestational and pregestational at term, respectively.

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Paper presentation information

Presented as an oral presentation at the SMFM 32th Annual Meeting-The pregnancy meeting, Dallas, Tx (Feb 6–11, 2012).

Conflict of interest statement

The authors report no conflicts of interest.

Institutions involved in the Consortium on Safe Labor are named in the Acknowledgments.

Conclusion: Diabetes was associated with increased risk of neonatal respiratory morbidity beyond what can be attributed to prematurity. Neonatal respiratory morbidities were increased with pregestational compared with gestational diabetes.

Keywords

Gestational diabetes; Neonatal respiratory morbidity; Pregestational diabetes; Propensity score

Introduction:

The prevalence of gestational diabetes mellitus (GDM) and pregestational diabetes mellitus (DM) has been estimated to up to 9.2% and 1% in the U.S. respectively, and has been increasing.^{1–3} GDM and pregestational DM have been studied as a risk factor for neonatal respiratory morbidity.^{4–8} Fetal hyperinsulinemia has been suggested to be associated with delayed pulmonary maturation.⁹ Pregnancies complicated by GDM and pregestational DM are associated with higher risk of preterm delivery¹⁰ and cesarean delivery^{4, 6}, both of which are also risk factors for neonatal respiratory morbidity.^{11, 12} Prior studies suggested that the risk of neonatal respiratory morbidity may differ by GDM compared to pregestational DM, but data are limited by small numbers^{4, 5, 13}, and heterogeneous groups (singletons and multiple pregnancies⁴; term and preterm^{5, 13}). Since GDM typically develops later in gestation, around 24–28 weeks¹⁴, fetuses are exposed to the risk of hyperinsulinemia for a shorter duration compared to fetuses of women with pregestational DM. However, fetal lung maturation occurs later in pregnancy, so it is unclear whether neonatal respiratory morbidity would differ by the timing of DM. When trying to understand the contribution of GDM and pregestational DM to neonatal respiratory morbidity, it is important to distinguish morbidity associated with diabetes from that associated with prematurity. The primary aim of this study was to explore the risks of neonatal respiratory morbidity associated with GDM and pregestational DM while considering the propensity of prematurity in a large, contemporary U.S. obstetric population.

Methods

This was a secondary analysis of the Consortium on Safe Labor (CSL) study, a retrospective electronic medical record study of 228,438 deliveries at 23 weeks' gestation or greater between 2002 and 2008 in 12 clinical centers with 19 hospitals across 9 ACOG districts.¹⁵ The majority of births (87%) occurred between 2005 and 2007.¹⁵ All participating institutions obtained Institutional Review Board (IRB) approval.

Data were abstracted from the electronic medical record and mapped to predefined codes at the data coordinating center. Neonatal intensive care unit (NICU) charts were linked to the newborn records. International Classification of Diseases-9 (ICD-9) codes were also obtained. Data validation was conducted for four diagnoses including cesarean delivery for non-reassuring fetal heart rate tracing, asphyxia, NICU admission due to a respiratory diagnosis and shoulder dystocia. Variables were highly concordant with the chart review (greater than 95% for 16 out of 20 variables and greater than or equal to 91.9% for all).¹⁵ Validation of the electronic medical record was specifically performed for all neonates who

delivered at 34 0/7 weeks of gestation or later requiring oxygen or ventilation in the delivery room and subsequent NICU admission for respiratory support, and concordance was 97.3–99.7% with the medical charts. We limited the current analysis to singleton gestations delivering between 24 0/7 and 41 6/7 weeks' gestation (n=222,978). GDM and pregestational DM diagnoses were derived from the medical records and supplemented by ICD-9 codes.

Our main interest was to investigate the risk of neonatal morbidity associated with the underlying pathology from GDM and pregestational DM independent of the neonatal physiologic immaturity associated with premature delivery.¹² A traditional analysis that adjusts for gestational age at delivery has been noted to induce bias in instances where the preterm delivery itself is an intermediate along the causal pathway in the presence of unmeasured confounders.^{16, 17} Of note, stratification by gestational age at delivery causes the same bias as adjusting. One solution is to stratify women based on their probability for preterm or term delivery instead of whether they actually delivered preterm or term. In order to understand the neonatal respiratory morbidity associated with GDM and pregestational DM independent of prematurity, we calculated a probability to deliver at term (< 37 weeks' gestation) using the following variables: maternal age, body mass index (BMI; kg/m²) at delivery, race, insurance, parity, marital status, smoking, precursor for delivery (spontaneous labor, rupture of membranes, indicated [including all possible indications except GDM or pregestational DM], elective, no recorded indication), cervical status at admission (effacement, dilation, station), induction, whether they had a trial of labor, age of the delivering physician, type of hospital and site. This analysis can develop groups that differ according to the exposure interest (GDM and pregestational DM), but have similar baseline characteristics.¹⁸ The estimate captured the overall effect of diabetes on neonatal respiratory disease, for those at high risk for preterm or term delivery, and can be interpreted as the risk of neonatal respiratory disease attributable to the underlying diabetes. We defined high probability of delivery at term as probability >0.8 and low probability of delivery at term as probability < 0.8 (i.e. preterm delivery). The probability of 0.8 was chosen as the cut-point to best approximate the proportion of preterm deliveries in the general population: 12.2% of pregnancies had a low probability of delivery at term with this cut-off point, which was similar to the preterm delivery rate of 12.7% in 2007, the last year of the CSL study.¹⁹

We examined pregnancy characteristics and compared within no DM, GDM, and pregestational DM. Pregnancy characteristics included maternal age, body mass index (BMI) kg/m² at delivery, birthweight, gestational age, race/ethnicity, marital status, smoking during pregnancy, alcohol use during pregnancy, parity, health insurance, chronic hypertension, pregnancy associated hypertension (gestational hypertension, preeclampsia, superimposed preeclampsia, and Hemolysis, Elevated Liver enzyme, Low Platelet [HELLP] syndrome), cesarean delivery, and antenatal corticosteroid administration.

Neonatal morbidities were examined and compared within no DM, GDM, and pregestational DM after stratifying by probability of delivery at term. Neonatal morbidities include neonatal intensive care unit (NICU) admission, and neonatal respiratory morbidity (respiratory distress syndrome [RDS], transient tachypnea of newborn [TTN], pneumonia, apnea, and mechanical ventilation).

In the CSL, detailed information on neonatal respiratory support and morbidities were obtained from chart review for all neonates who delivered at 34 0/7 weeks of gestation or later requiring oxygen or ventilation in the delivery room and subsequent NICU admission for respiratory support. Therefore, we conducted a secondary analysis after limiting to pregnancies 34 weeks' gestation. We examined NICU respiratory support and respiratory morbidity. NICU respiratory support included oxygen by nasal cannulae, oxygen by isolette/blow-by, continuous positive airway pressure (CPAP)/bilevel positive airway pressure (BiPAP)/noninvasive positive pressure, mechanical ventilator, oscillator, and surfactant administration. Respiratory morbidity included RDS/HMD (respiratory distress syndrome/hyaline membrane disease), radiography verified RDS/HMD, TTN, pneumonia (radiography verified cases), apnea and bradycardia, pulmonary hypertension, pneumothorax, meconium aspiration, pulmonary hypoplasia, and respiratory failure. These were compared within no DM, GDM, and pregestational DM after stratifying by probability of delivery at term. Due to repeated pregnancies in the data, linear and ordinal logistic regressions with Generalized Estimating Equation (GEE) were used to compare maternal characteristics and neonatal outcomes so that gestational diabetes and pregestational diabetes were compared to the no diabetes group separately. Multivariable logistic regression analysis was performed to calculate the probability of delivery at term. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for respiratory morbidity associated with GDM or pregestational DM compared to women without DM (referent group), controlling for maternal age, BMI at delivery, race/ethnicity, insurance, parity, marital status, smoking, precursor for delivery (spontaneous labor, premature rupture of membranes, indicated, elective and no recorded information) and hospital type as fixed effects. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC).

Results

Pregnancy characteristics are presented in Table 1. There were 11,327 (5.1%) women with GDM and 3,296 (1.5%) women with pregestational DM. Pregnancy characteristics were different significantly among groups. Women with GDM and pregestational DM compared to women without DM were older, more obese, Non-Hispanic black (pregestational DM only) or Hispanic, multiparous, and more likely to have chronic hypertension, pregnancy associated hypertension, and cesarean delivery, and more likely to deliver infants with birth weight >4000 gram or <2500 gram and at earlier gestation (all $P<.01$). Women with pregestational DM compared to women with GDM and without DM were more likely to be not married, and to have public insurance ($P<.01$). The rate of antenatal corticosteroid administration was higher in women with pregestational DM compared with women with GDM and without DM ($P<.01$). However, there was no statistical difference in the rate of antenatal corticosteroids among women who delivered <34 weeks' gestation ($P=.12$).

Neonatal respiratory morbidity is presented in Table 2. Women with GDM and pregestational DM compared to women without DM had higher levels of delivery room resuscitation, RDS, TTN, apnea/bradycardia, mechanical ventilation, and NICU admission (all $P<.01$). Women with pregestational DM compared to women with GDM and without DM were more likely to have pneumonia, stillbirth, neonatal death, and perinatal mortality (all $P<.01$ except pneumonia [$P=.01$])

Neonatal respiratory morbidity stratified by the probability to deliver at term is presented in Table 3. GDM and pregestational DM were associated with increased risks of neonatal respiratory morbidity compared to women without diabetes regardless of the probability to deliver at term, although the risks tended to be higher with a higher probability to deliver at term. These findings indicate that the neonatal respiratory morbidity associated with diabetes was not fully explained by greater propensity of prematurity. In addition, neonatal respiratory morbidities were increased with pregestational compared with GDM.

Information on neonatal respiratory support and morbidity from the detailed NICU chart reviews for deliveries at 34 weeks or greater are presented in Table 4. The results were similar in that GDM and pregestational DM were associated with higher levels of neonatal respiratory support and risk of neonatal respiratory morbidity compared to women without diabetes in pregnancy, and the risks were higher for pregestational DM compared with GDM. Due to the small numbers, many of the adjusted odds ratios of neonatal respiratory support and respiratory morbidity were unable to be calculated (Table S1). However, for pregestational diabetes, CPAP/BiPAP/noninvasive positive pressure support and RDS/HMD were increased with a higher probability to deliver at term, again indicating that these morbidities were not fully explained by a greater propensity of prematurity.

Comment

In this large, multi-institutional cohort of women, the risk of neonatal respiratory morbidity was higher for women with GDM or pregestational DM compared to women without diabetes in pregnancy, and these risks were increased beyond what can be attributed to prematurity. In addition, neonatal respiratory morbidity appeared higher in women with pregestational DM compared with GDM.

Previous studies have suggested that GDM and pregestational DM are associated with an increased risk of neonatal respiratory morbidity.^{4–8} However, it was unclear whether the respiratory morbidity was due to diabetes versus the physiologic immaturity associated with earlier delivery. Stratifying by actual gestational age at delivery can be confounded by the indication for delivery since more complicated pregnancies might be delivered earlier, and the underlying reason for delivery itself can be associated with an increased risk of neonatal respiratory morbidity. Our analysis using propensity scores analyzed the association of GDM and pregestational DM with neonatal respiratory morbidity in pregnancies with otherwise similar baseline characteristics (either high or low probability to deliver at term).¹⁸ In our study, stronger associations between diabetes and neonatal respiratory morbidity were found in women with a high probability to deliver at term. These findings indicate that the neonatal respiratory morbidity associated with diabetes was not fully explained by the physiologic immaturity associated with prematurity and support the concept that diabetes itself is a risk factor. However, the cause of increased risks of neonatal respiratory morbidity associated with diabetes is unclear. Fetal hyperglycemia and hyperinsulinemia have been suggested mechanisms of increased neonatal respiratory morbidity.⁹ In a study of fetal lung tissue, insulin has been found to decrease the expression of surfactant protein A (SP-A) and SP-B.^{20, 21} A previous study found poor glycemic control (defined by mean blood glucose >105 mg/dl) was associated with delayed appearance of phosphatidylglycerol in

pregestational DM, which may suggest maternal hyperglycemia is associated with neonatal respiratory morbidity.²² Increased risk of cesarean delivery^{4, 6} in women with GDM and pregestational DM may also be contributing the increased risk of neonatal respiratory morbidity.^{11, 12}

Data regarding neonatal respiratory morbidity comparing GDM and pregestational DM have been limited and conflicting.^{4, 5, 13} Mallah et al in 1997 (972 GDM and 71 pregestational DM at all gestational age) and Bental et al in 2011 (825 GDM and 120 pregestational DM between 24 and 33 weeks' gestation) found no difference in neonatal respiratory morbidity between GDM and pregestational DM.^{4, 5} However, Akhlaghi et al in 2004 (21 GDM and 73 pregestational DM at all gestational age) found that pregestational DM was associated with increased risk of neonatal respiratory morbidity compared with GDM.¹³ Conflicting results may be due to small sample size, and heterogeneous groups (singletons and multiple pregnancies⁴; term and preterm^{5, 13}). Our study demonstrated higher neonatal respiratory morbidity associated with pregestational DM compared with GDM. The cause of higher risk is unclear, but we postulate that hyperglycemia at earlier gestational age and increased risks of other morbidities such as hypertensive disease, renal disease, and infection²³ may be associated with increased risk of neonatal respiratory morbidity in women with pregestational DM. Considering the propensity of preterm delivery helped to determine the risk of neonatal respiratory morbidity associated with GDM and pregestational DM compared with no DM beyond what can be attributed to prematurity.

Limitations of the present study should be noted. Our study did not have information on treatment of GDM and pregestational diabetes. However, we think our findings are still clinically relevant because they are somewhat representative of the population risk of neonatal respiratory disease with general management of a large number of women from multiple institutions across the U.S. Although mapping data of key variables from electronic medical records were highly concordant with chart review, data on GDM and pregestational DM were not explicitly validated. Although we controlled for a number of covariates, we cannot exclude the possibility of impact from residual confounding. Also despite the large sample size compared to previous studies,⁴⁻⁸ our study may be underpowered to analyze uncommon outcomes. The major strength of this study is the large cohort with detailed neonatal outcomes and chart review on a subset of neonates, enabling us to provide the most conclusive evidence to date that respiratory morbidity was higher in pregnancies complicated by pregestational DM compared with GDM.

We found increased risk of neonatal respiratory morbidity in women with GDM and pregestational DM compared to women without DM. Neonatal respiratory morbidity was especially higher in women with pregestational DM. The optimal timing of delivery in women with GDM and pregestational DM whose serum glucose is poorly controlled is unclear.^{24, 25} Since infants of women with GDM and pregestational DM are especially vulnerable to neonatal respiratory morbidity, the timing of delivery should be carefully considered.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgment:

The Consortium on Safe Labor was funded by the Intramural Research Program of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, National Institutes of Health, through Contract No. HHSN267200603425C.

ACKNOWLEDGEMENTS: This research was supported by the Intramural Research Program of the National Institutes of Health, Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD). The Consortium on Safe Labor was funded by the Intramural Research Program of the NICHD, through Contract No. HHSN267200603425C.

Institutions involved in the Consortium include, in alphabetical order: Baystate Medical Center, Springfield, MA; Cedars-Sinai Medical Center Burnes Allen Research Center, Los Angeles, CA; Christiana Care Health System, Newark, DE; Georgetown University Hospital, MedStar Health, Washington, DC; Indiana University Clarian Health, Indianapolis, IN; Intermountain Healthcare and the University of Utah, Salt Lake City, Utah; Maimonides Medical Center, Brooklyn, NY; MetroHealth Medical Center, Cleveland, OH.; Summa Health System, Akron City Hospital, Akron, OH; The EMMES Corporation, Rockville MD (Data Coordinating Center); University of Illinois at Chicago, Chicago, IL; University of Miami, Miami, FL; and University of Texas Health Science Center at Houston, Houston, Texas.

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Table 1.

Pregnancy characteristics by diabetes group.

	No diabetes n=208,355	Gestational diabetes n=11,327	Pregestational diabetes n=3,296	P-value ^a
Maternal age	27.4 ± 6.1	30.8 ± 6.0	30.2 ± 6.1	<.01
<18	3.4	0.7	1.2	<.01
18-34	82.5	70.3	72.0	
35+	14.0	28.9	26.6	
missing	0.1	0.1	0.2	
BMI ^b at delivery, kg/m ²	30.6 ± 6.1	34.1 ± 7.5	35.8 ± 8.3	<.01
<25	12.0	5.6	4.9	<.01
25-29	30.6	19.8	18.1	
30+	36.4	51.5	62.8	
missing	21.0	23.1	14.2	
Birthweight, grams	3,246 ± 589	3,310 ± 647	3,187 ± 836	0.04
<2500	8.0	8.7	16.3	<.01
2500-4000	84.9	79.8	69.8	
4000+	7.1	11.6	13.8	
Gestational age (wk)	38.4 ± 2.3	37.8 ± 2.2	36.6 ± 3.0	<.01
Delivered at term, ≥ 37 weeks	89.1	83.7	67.7	
Delivered preterm, < 37 weeks	10.9	16.3	32.3	
Race/Ethnicity				
Non-Hispanic white	50.1	43.9	31.6	<.01
Non-Hispanic black	22.5	18.9	34.4	
Hispanic	17.1	21.7	24.0	
Asian/ Pacific Islander	3.9	7.9	4.1	
Other/Unknown	6.4	7.5	5.9	
Marital status				
Not married	38.3	31.8	41.1	<.01
Married	58.5	64.8	53.7	
Missing	3.2	3.4	5.1	
Smoking	6.7	6.4	8.3	0.09
Alcohol use	1.9	1.3	2.3	0.09
Parity				
0	40.2	34.6	32.4	<.01
1	30.6	31.5	31.2	
2+	29.2	33.9	36.5	
Health Insurance				
Private	56.0	58.3	47.3	<.01
Public	32.1	31.1	44.8	
Self pay	1.2	1.3	1.2	
Other	10.7	9.3	6.6	

	No diabetes n=208,355	Gestational diabetes n=11,327	Pregestational diabetes n=3,296	P-value ^a
Chronic hypertension	7.1	15.2	29.6	<.01
Pregnancy associated hypertension ^c	7.2	11.7	14.1	<.01
Cesarean delivery	26.8	42.6	55.9	<.01
Antenatal corticosteroids ^d	3.5	4.3	10.3	<.01
Antenatal corticosteroids for delivery <34 weeks ^d	50.5	51.6	56.9	.12

Number shown as % or mean $\pm$ standard deviation. The unit of analysis was pregnancy.

^aP-values were obtained from linear and ordinal logistic regressions using generalized estimating equations to account for correlated data with no diabetes as comparison group.

^bBMI, body mass index

^cPregnancy associated hypertension include gestational hypertension, preeclampsia, superimposed preeclampsia, and Hemolysis, Elevated Liver enzyme, Low Platelet [HELLP] syndrome.

^d4 sites were excluded due to lack of report

Table 2.

Neonatal respiratory morbidity by diabetes group.

Variables	No Diabetes n=208,355	Gestational Diabetes n=11,327	Pregestational Diabetes n=3,296	P-value ^a
Delivery room resuscitation				<.01
Oxygen	21.0	19.4	22.4	
Bag and mask	2.0	2.3	4.9	
CPAP ^b	0.3	0.5	0.3	
Intubation	1.3	1.6	3.3	
Chest compressions	0.1	0.1	0.2	
Epinephrine	0.1	0.1	0.2	
No/Unknown	75.3	76.1	68.7	
RDS ^c	3.0	4.0	10.0	<.01
TTN ^d	3.4	5.1	8.3	<.01
Pneumonia	0.8	0.8	1.3	.06
Apnea/bradycardia	2.0	2.7	6.7	<.01
Mechanical ventilation	2.2	2.7	7.0	<.01
Stillbirth	0.4	0.4	1.3	<.01
Neonatal death	0.3	0.2	0.9	<.01
Perinatal mortality	0.7	0.6	2.2	<.01
NICU Admission ^e	11.5	17.2	31.6	<.01
NICU length of stay Days	26.8	24.5	28.9	.23

Number shown as % or mean $\pm$ standard deviation.^aP-values were obtained from linear and ordinal logistic regressions using generalized estimating equations to account for correlated data with no diabetes as comparison group.^bContinuous positive airway pressure^cRespiratory distress syndrome^dTransient tachypnea of newborn^eNeonatal intensive care unit

Table 3.**Neonatal Respiratory Morbidity with High or Low Probability to Deliver at Term**

High Probability to Deliver at Term (P >0.8; N=195,837 [87.8%])					
Neonatal Respiratory Morbidity	No diabetes n=183,582 (Referent)		GDM^a n=9,829	Pregestational Diabetes n=2,426	
	%	%	aOR^b (95% CI)^c	n (%)	aOR^b (95% CI)^c
NICU Admission ^d	9.6	14.9	1.7 (1.6, 1.8)	27.3	3.3 (3.0, 3.7)
RDS ^e	2.1	2.9	1.5 (1.3, 1.7)	6.8	3.1 (2.6, 3.7)
TTN ^f	3.0	4.5	1.5 (1.3, 1.6)	7.7	2.2 (1.9, 2.6)
Pneumonia	0.7	0.7	1.0 (0.8, 1.3)	1.1	1.6 (1.1, 2.4)
Apnea ^g	1.4	2.0	1.5 (1.2, 1.7)	4.9	3.2 (2.6, 3.9)
Mechanical ventilation	1.5	1.7	1.2 (1.0, 1.4)	4.5	2.6 (2.1, 3.2)

Low Probability to Deliver at Term (P ≤ 0.8; N=27,141 [12.2%])					
Neonatal Respiratory Morbidity	No diabetes n= 24,773 (Referent)		GDM^a n=1,498	Pregestational Diabetes n=870	
	%	%	aOR^b (95% CI)^c	n (%)	aOR^b (95% CI)^c
NICU Admission ^d	25.4	32.3	1.5 (1.3, 1.7)	43.4	2.5 (2.1, 2.8)
RDS ^e	10.0	11.4	1.2 (1.0, 1.5)	18.9	2.2 (1.8, 2.7)
TTN ^f	6.4	9.0	1.3 (1.1, 1.6)	10.1	1.5 (1.2, 1.9)
Pneumonia	1.7	1.9	-	2.1	-
Apnea ^g	6.3	7.5	1.3 (1.0, 1.6)	11.7	2.0 (1.6, 2.5)
Mechanical ventilation	7.4	8.7	1.3 (1.1, 1.6)	14.0	2.0 (1.6, 2.5)

Significant findings are Bolded.

Some analyses had too few observations to calculate adjusted odds ratios.

^aGestational diabetes

^b Adjusted Odds ratio. Multivariable logistic regression analysis using generalized estimating equations to account for correlated data was performed to calculate the probability of delivery at term. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for respiratory morbidity associated with GDM or pregestational DM compared to women without DM (referent group) controlling for maternal age, BMI at delivery, race, insurance, parity, marital status, smoking, precursor for delivery (spontaneous labor, premature rupture of membranes, indicated, elective and no recorded information) and hospital site.

^cConfidence interval^dNeonatal intensive^eRespiratory distress syndrome^fTransient tachypnea of newborn^gOne site that did not report apnea was excluded.

Table 4.

Neonatal respiratory support and morbidity from detailed NICU chart reviews for deliveries at 34 weeks or greater.

Neonatal respiratory support and morbidity.	High Probability Deliver at Term (P >0.8)				
	No Diabetes n=179,567 (Referent)	Gestational Diabetes n=9,541	Pregestational Diabetes n=2,233		
	%	%	aOR	%	aOR
Oxygen by nasal cannulae	0.7	1.1	1.6 (1.3, 2.0)	2.2	2.9 (2.2, 4.0)
CPAP/BiPAP/noninvasive positive pressure	0.5	0.7	1.5 (1.1, 2.0)	1.1	2.5 (1.6, 3.8)
Ventilator	0.8	1.0	1.5 (1.2, 1.8)	1.9	2.5 (1.8, 3.4)
Surfactant administration	0.4	0.6	1.7 (1.3, 2.3)	1.2	3.6 (2.4, 5.4)
RDS/HMD	0.9	1.2	1.6 (1.3, 1.9)	2.2	2.7 (2.0, 3.7)
Radiography-verified cases	0.3	0.6	2.2 (1.6, 2.9)	1.0	3.2 (2.0, 5.0)
Pulmonary hypertension	0.1	0.1	0.9 (0.4, 2.0)	0.3	2.9 (1.2, 6.8)
Pneumothorax	0.1	0.1	1.0 (0.5, 2.1)	0.1	1.1 (0.2, 4.6)

Neonatal respiratory support and morbidity.	Low Probability Deliver at Term (P ≤0.8)				
	No Diabetes n=21,344 (Referent)	Gestational Diabetes n=1,269	Pregestational Diabetes n=673		
	%	%	aOR	%	aOR
CPAP/BiPAP/noninvasive positive pressure	1.2	2.3	1.9 (1.3, 3.0)	1.6	1.4 (0.7, 2.6)
RDS/HMD	2.0	2.0	1.0 (0.7, 1.5)	4.5	2.3 (1.5, 3.4)

Abbreviations: aOR (adjusted odds ratio), CI (confidence interval), NICU (neonatal intensive care unit), RDS (respiratory distress syndrome)/HMD (hyaline membrane disease), CPAP (continuous positive airway pressure), BiPAP (biphasic positive airway pressure)

Significant findings are Bolded.

Some analyses had too few observations to calculate adjusted odds ratios. The rates of these outcomes are presented in Table S1.

* Multivariable logistic regression analysis using generalized estimating equations to account for correlated data was performed to calculate the probability of delivery at term. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for respiratory morbidity associated with GDM or pregestational DM compared to women without DM (referent group) controlling for maternal age, BMI at delivery, race, insurance, parity, marital status, smoking, precursor for delivery (spontaneous labor, premature rupture of membranes, indicated, elective and no recorded information) and hospital site.