

Risk Factors for a Primary Cesarean Delivery in Pregnancies Complicated by Pregestational Diabetes

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Objective: The Cesarean delivery risk is increased in pregnancies complicated by pregestational diabetes. Our study aim is to identify risk factors and predictors for a primary Cesarean delivery in women whose pregnancy is complicated by pregestational diabetes.

Methods: This is a retrospective study of women with pregestational diabetes and singleton pregnancies managed with uniform treatment plans and strict control of their blood glucose levels at an academic medical center. Maternal demographics and clinical characteristics were collected and evaluated. Logistic regression was used to analyze the association of risk factors on primary Cesarean rates.

Results: There were 252 women evaluated. Group 1 consisted of 117 women delivered by primary Cesarean (45.4%). Group 2 consisted of women delivered vaginally (53.6%). The best predictors for a cesarean delivery were the maternal BMI in the 1st trimester (BMI > 40, Relative Risk (RR) 60.3% (95% 47.7–71.97) and hypertensive disorders of pregnancy (RR, 55.39% (95%, Confidence Interval (CI) 47.87–63.71)). Maternal weight gain, elevated hemoglobin A1c levels in the 3rd trimester, and ratio of head circumference to abdominal circumference (HC/AC) on a 3rd trimester ultrasound were other significant contributors for an elevated primary cesarean rate.

Conclusion: In pregestational diabetes overseen by a dedicated diabetic pregnancy management team with uniform treatment plans, and strict blood glucose control, chronic hypertension and maternal weight gain were the primary contributors for a primary cesarean. Other contributors included maternal hemoglobin A1c levels, HC/AC ratios on ultrasound, and maternal weight gain during pregnancy. These results highlight the importance of actively managing maternal weight and hypertension prior to pregnancy and focusing on maternal glucose control and weight gain during pregnancy.

Keywords: cesarean section, diabetes mellitus, gestational weight gain, glycosylated hemoglobin, hypertension, obesity

Introduction

The management of women with pre-existing diabetes during pregnancy has become a global problem. In the United States, 1–2% of pregnancies are complicated by pregestational diabetes mellitus (PGDM).¹ PGDM is associated with numerous adverse pregnancy outcomes including preterm delivery, hypertensive complications, large for gestational age infants, and cesarean deliveries.² Not surprisingly, previous studies have reported the rate of Cesarean deliveries among patients with PGDM to be as high as 57–60%.^{3,4} Proposed contributors for the higher c-section rate in PGDM are physician bias on the mode of delivery, labor dystocia, failed induction, and fetal indications.^{4,5} Although a common confounding factor for PGDM is obesity, diabetes has been found to be an independent risk factor for a cesarean delivery.⁶

There have been nationwide efforts to decrease the primary Cesarean rate in the United States. While reasons vary as to why cesarean deliveries are unavoidable, such as the significant risk of fetal macrosomia, fetal intolerance of labor, and fetal malpresentation, studies have suggested many of these cesarean deliveries among this population are due to failed inductions or labor arrests following prolonged attempts at an induction of labor.³ Unlike a vaginal delivery, cesarean delivery poses an increased risk of infection, bleeding with possible need for blood or blood products, wound

complications, risk for uterine rupture, and abnormal placentation in future pregnancies.⁷ PGDM has been reported to be associated with a 2.5-fold increase in wound complications following cesarean delivery.^{8–10} In an attempt to decrease these morbidities, it is important to expand the investigation of the pregestational diabetic population and determine if certain patients are at greater risk due to coexisting variables such as their demographic profile, social factors, pre-pregnancy and pregnancy blood glucose control, pre-pregnancy weight, weight gain during the pregnancy, and preexisting medical conditions.

The purpose of this study is to identify risk factors and predictors for a primary Cesarean delivery in women whose pregnancy is complicated by pregestational diabetes. This could lead to initiation of pre-pregnancy lifestyle modifications that optimize maternal health and lead to a decrease in the Cesarean rate.

Methods

Data and Study Design

We performed a retrospective study of 252 pregnancies managed by the UAMS Obstetrical Center for the Management of Hyperglycemia in Pregnancy between October 17, 2018 and May 16, 2023. This is a Diabetes Education Accredited Program (DEAP) with a multidisciplinary diabetes management program for pregnant patients in Little Rock, Arkansas and the surrounding region composed of maternal fetal medicine specialists, pharmacists, diabetic educators, and registered dietitians (Figure 1).

The University of Arkansas Institutional Review Board approved study #133969 on 3/26/2018 using expedited review procedures under category 5, as referenced in Title 45 CFR 46.110, paragraph (a) with a waiver of informed consent. This study complies with the Declaration of Helsinki.

Patient data was collected and entered into a database by a single team member in charge of data collection and tabulation for our program. Our PGDM women are managed in a special clinic by a multidisciplinary team consisting of maternal fetal medicine physicians, a clinical pharmacist, a registered dietitian, and certified diabetic educators for the duration of their pregnancy. All women had blood drawn for a hemoglobin A1c (HbA1c) and had an ultrasound to evaluate fetal growth each trimester. The patients' blood glucose logs are reviewed every 1–2 weeks in the clinic via a phone call or by telemedicine visits. Insulin is the first line treatment for all patients except for those refusing insulin or when metformin is needed to optimize glycemic control. Goals for therapy include a fasting blood sugar <95 mg/dl, 1 hour post prandial glucose <140 mg/dl, and a two hour post prandial glucose <120 mg/dl. Indications for delivery follow American College of Obstetricians and Gynecologists (ACOG) guidelines.¹ Fetal surveillance is started at 32 weeks with weekly or twice weekly non stress testing unless the testing is indicated sooner in pregnancy.

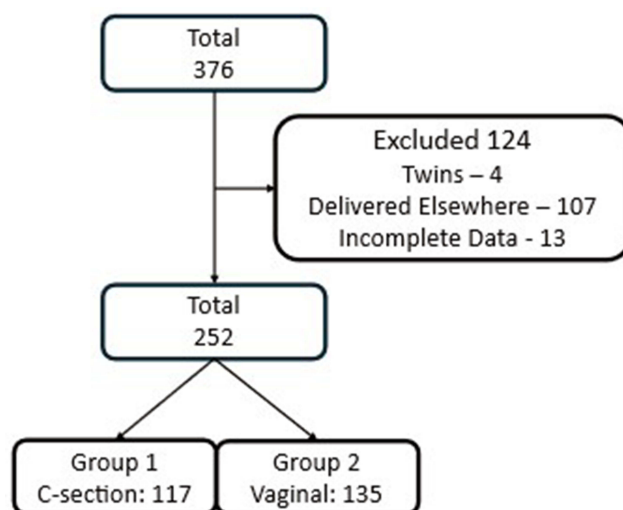


Figure 1 Inclusion and exclusion criteria.

The study included all patients managed by the high-risk team in this program. All patients were enrolled in the database created for this program. Exclusions were absence of clinic-determined weight in the first trimester, as it was important to calculate maternal weight gain accurately based on actual clinic weight records and not maternal recall, delivery at another institution since it was not possible to collect an accurate indication for the Cesarean, and twin gestation because most are delivered by patient elected Cesarean. Patients who had two deliveries in the study period were included as two separate events.

Independent Variables

We analyzed demographic characteristics of mothers with pregestational diabetes to determine the associated factors for the elevated cesarean rate in our population. These studied variables include maternal age, maternal race/ethnicity, health insurance carrier, median household income of the patient's county of residence, and percentage of rural population of their county. We also analyzed characteristics of the patients' pregnancies including BMI in the first trimester; weight gain during pregnancy; development of a hypertensive disorder during pregnancy; HbA1c in the first, second, and third trimester; expected fetal weight in the 3rd trimester greater than 90th percentile; and abdominal circumference (AC) of fetus in the 3rd trimester greater than 95th percentile on ultrasound. Hypertensive disorders of pregnancy for this study were defined to include chronic hypertension, gestational hypertension, preeclampsia, and eclampsia and preeclampsia superimposed on chronic hypertension.

Outcome: Primary C-Section Rate

We defined a primary cesarean rate as the rate of a cesarean delivery in all singleton pregnancies at any gestational age in women without a previous cesarean. Characteristics about the mode of delivery, indications for a cesarean delivery, medical complications before and during the pregnancy, and delivery period were collected. Cesarean delivery indications were grouped into four categories: non-reassuring fetal heart rate (FHR) tracing, labor abnormalities (arrest of dilation, arrest of descent, failed induction), severe hypertensive disorders, and other (malpresentation, cord prolapse, history of shoulder dystocia, macrosomia, and cardiac arrest).

Analyses

The descriptive statistics for maternal demographic and clinical characteristics of the study patients were computed for the entire sample and stratified by the primary delivery mode (cesarean vs vaginal deliveries). (Tables 1 and 2) For continuous variables, these statistics include the mean, (standard deviation), and median [Q1-Q3] where Q1 and Q3 stand for the first and third quartiles, respectively. Categorical variables were summarized with frequencies and percentages. The percentage of the Cesarean deliveries within each category of a categorical variable was determined. Confidence intervals for the percentages were calculated using the Wilson score approach or Exact Binomial approach when appropriate. We performed the Shapiro–Wilk test for normality assumption of the distribution of a numeric variable. The comparison of a continuous variable across multiple groups was initially conducted using ANOVA approaches. If the normality of the residuals was not rejected, ANOVA results were reported (for Maternal age and Ratio of Head Circumference/Abdominal Circumference (HC/AC) in Table 3). Otherwise, Kruskal–Wallis tests were applied, and the corresponding results were reported (for Body Mass Index (BMI), Weight gain, HbA1c in Table 4). The Chi-squared test was used for two-way tables in which the column variable had more than 2 categories (ie the Cesarean delivery having 4 categories in Table 4). Simulated p-values were obtained in the consideration of small cell counts. Logistic regressions were utilized to explore both unadjusted and adjusted effects of study variables in relation to the odds of cesarean delivery. When examining unadjusted effects, each logistic regression included only one study variable as the sole explanatory variable. Several model selection procedures were performed before studying the adjusted effects, including significance-based stepwise and forward selection, as well as penalized likelihood-derived lasso regression. The Schwarz Bayes Criterion (SBC) was used as the measure for finding the best fitted models. The procedures essentially reached the same consensus on the final working model, which includes hypertensive disorder of pregnancy (yes, no), BMI numerical value, weight gain in pounds, A1c value in the third trimester, maternal age at delivery, maternal race/ethnicity, and ratio of HC/AC on ultrasound as the explanatory variables. A multivariable logistic regression was fitted in, assessing the

Table 1 Distribution of Maternal Demographic Characteristics of the Pregnancies Affected by PGDM, Delivered in UAMS Arkansas, Oct. 2018–May 2023

Variable	Total (N = 252)	Cesarean Delivery (Group 1 N = 117)	Vaginal Delivery (Group 2 N = 135)	% Cesarean Delivery and 95% CI
	n (Column %), Otherwise as Indicated			Row % (95% CI), or Difference in Means (95% CI)
Maternal age in years				
19 or less	20 (7.9)	12 (10.3)	8 (5.9)	60 (36.05, 80.88)
20-29	116 (46)	55 (47)	61 (45.2)	47.4 (38.07, 56.89)
30-34	61 (24.2)	25 (21.4)	36 (26.7)	41 (28.55, 54.32)
35+	55 (21.8)	25 (21.4)	30 (22.2)	45.5 (31.97, 59.45)
Mean (SD)	28.8 (6.8)	28.3 (6.7)	29.3 (6.9)	−1.04 (−2.72, 0.64)
Median [Q1 – Q3]	29 [23–34]	28 [23–33]	29 [23.5–34]	
Maternal race/ethnicity				
Caucasian	81 (32.1)	41 (35)	40 (29.6)	50.6 (39.27, 61.92)
African American	130 (51.6)	60 (51.3)	70 (51.9)	46.2 (37.38, 55.11)
Hispanic	34 (13.5)	12 (10.3)	22 (16.3)	35.3 (19.75, 53.51)
Other	7 (2.8)	4 (3.4)	3 (2.2)	57.1 (18.41, 90.1)
Health insurance				
Medicaid or Government program	145 (57.5)	61 (52.1)	84 (62.2)	42.1 (33.93, 50.54)
Private insurance	104 (41.3)	54 (46.2)	50 (37)	51.9 (41.91, 61.83)
Self-pay	3 (1.2)	2 (1.7)	1 (0.7)	66.7 (9.43, 99.16)
Median household income of the county pregnant women living in				
≤ \$50,000	82 (32.7)	42 (36.2)	40 (29.6)	51.2 (39.92, 62.42)
> \$50,000	169 (67.3)	74 (63.8)	95 (70.4)	43.8 (36.18, 51.62)
Missing	1	1	0	
Mean (SD)	52,325.3 (7037.4)	51,788.9 (7566.4)	52,786.1 (6542.4)	−997.2 (−2771.23, 776.74)
Median [Q1 – Q3]	53,597 [47,315–53,597]	53,597 [46,949.5–53,597]	53,597 [48,289.5–53,597]	
Percentage of rural population of the county pregnant women living in				
≤ 30%	114 (45.4)	50 (43.1)	64 (47.4)	43.9 (34.58, 53.46)
> 30%	137 (54.6)	66 (56.9)	71 (52.6)	48.2 (39.56, 56.87)
Missing	1	1	0	
Mean (SD)	32.8 (23.3)	33.6 (23.8)	32.1 (22.9)	1.4 (−4.39, 7.27)
Median [Q1 – Q3]	30.9 [12.3–44.8]	31.5 [12.3–48.1]	30.9 [12.3–44.8]	

Notes: For % calculation, the category of missing values for a variable was not included. Maternal race/ethnicity: “Others” includes Asian, Native American, Native Hawaiian/Pacific Islander, and others.

Abbreviations: Q1, First Quartile; Q3, Third Quartile.

Table 2 Distribution of Clinical Characteristics of the Pregnancies Affected by PGDM, Delivered in UAMS Arkansas, Oct. 2018–May 2023

Variable	Total (N = 252)	Cesarean Delivery (Group 1 N = 117)	Vaginal Delivery (Group 2 N = 135)	% Cesarean Delivery and 95% CI
	n (Column %), Otherwise as Indicated			Row % (95% CI), or Difference in Means (95% CI)
BMI in the 1st trimester				
18.5 - <25	21 (9.6)	6 (5.9)	15 (12.8)	28.6 (11.28, 52.18)
25 - <30	25 (11.4)	9 (8.8)	16 (13.7)	36 (17.97, 57.48)
30 - <35	53 (24.2)	25 (24.5)	28 (23.9)	47.2 (33.3, 61.36)
35 - <40	52 (23.7)	21 (20.6)	31 (26.5)	40.4 (27.01, 54.9)
40+	68 (31.1)	41 (40.2)	27 (23.1)	60.3 (47.7, 71.97)
Missing	33	15	18	
Mean (SD)	36.9 (10.1)	38.7 (10.3)	35.3 (9.7)	3.4 (0.69, 6.05)
Median [Q1 – Q3]	35.9 [30.6–41.5]	37 [31.8–43.8]	34.6 [29.6–39.1]	
Weight gain				
Mean (SD)	20.8 (17)	24.6 (16.4)	17.4 (16.9)	7.3 (2.78, 11.72)
Median [Q1 – Q3]	19 [9.8–31]	22.5 [13–34.8]	16 [6.3–27.5]	
Hypertensive disorder of pregnancy				
Yes	161 (63.9)	90 (76.9)	71 (52.6)	55.9 (47.87, 63.71)
No	91 (36.1)	27 (23.1)	64 (47.4)	29.7 (20.55, 40.16)
Hgb A1C value in the 1st trimester				
<5.7	23 (11.9)	10 (10.8)	13 (13)	43.5 (23.19, 65.51)
5.7–6.4	23 (11.9)	9 (9.7)	14 (14)	39.1 (19.71, 61.46)
6.5+	147 (76.2)	74 (79.6)	73 (73)	50.3 (41.98, 58.68)
Missing	59	24	35	
Mean (SD)	8.2 (2.1)	8.3 (2.1)	8.2 (2.2)	0.1 (–0.48, 0.73)
Median [Q1 – Q3]	8 [6.5–9.7]	8 [6.6–9.7]	8 [6.4–9.7]	
Hgb A1C value in the 2nd trimester				
<5.7	53 (26.1)	24 (24.5)	29 (27.6)	45.3 (31.56, 59.55)
5.7–6.4	42 (20.7)	17 (17.3)	25 (23.8)	40.5 (25.63, 56.72)
6.5+	108 (53.2)	57 (58.2)	51 (48.6)	52.8 (42.94, 62.46)
Missing	49	19	30	
Mean (SD)	6.8 (1.4)	6.9 (1.4)	6.7 (1.5)	0.2 (–0.19, 0.59)
Median [Q1 – Q3]	6.6 [5.6–7.7]	6.8 [5.7–7.8]	6.3 [5.6–7.6]	
Hgb A1C value in the 3rd trimester				
<5.7	53 (26.1)	25 (26.3)	28 (25.9)	47.2 (33.3, 61.36)
5.7–6.4	54 (26.6)	22 (23.2)	32 (29.6)	40.7 (27.57, 54.97)

(Continued)

Table 2 (Continued).

Variable	Total (N = 252)	Cesarean Delivery (Group 1 N = 117)	Vaginal Delivery (Group 2 N = 135)	% Cesarean Delivery and 95% CI
	n (Column %), Otherwise as Indicated			Row % (95% CI), or Difference in Means (95% CI)
6.5+	96 (47.3)	48 (50.5)	48 (44.4)	50 (39.62, 60.38)
Missing	49	22	27	
Mean (SD)	6.5 (1.2)	6.7 (1.2)	6.4 (1.1)	0.3 (−0.07, 0.58)
Median [Q1 – Q3]	6.4 [5.6–7.3]	6.5 [5.6–7.6]	6.2 [5.6–7]	
Expected fetus weight in the 3rd trimester greater than 90th percentile				
Yes	77 (30.6)	36 (30.8)	41 (30.4)	46.8 (35.29, 58.48)
No	175 (69.4)	81 (69.2)	94 (69.6)	46.3 (38.73, 53.97)
Abdominal circumference of fetus in the 3rd trimester greater than 95th percentile				
Yes	90 (35.7)	40 (34.2)	50 (37)	44.4 (33.96, 55.3)
No	162 (64.3)	77 (65.8)	85 (63)	47.5 (39.64, 55.51)
Ratio of HC/AC on ultrasound				
Mean (SD)	1 (0.1)	1 (0.1)	1 (0.1)	0 (−0.02, 0.02)
Median [Q1 – Q3]	1 [1–1.1]	1 [1–1.1]	1 [1–1.1]	

Notes: For % calculation, the category of missing values for a variable was not included.

Abbreviations: Q1, First Quartile; Q3, Third Quartile; Hgb, hemoglobin; BMI, Body mass index; HC/AC, head circumference/abdominal circumference.

Table 3 Adjusted Effects of Study Variables on the Association with Cesarean Delivery

Variable	OR (95% CI)	p-value
Hypertensive disorder of pregnancy Yes vs No	3.566 (1.695, 7.5)	≤0.001
BMI in the 1st trimester 1 unit increase	1.077 (1.032, 1.124)	0.001
Weight gain 1 pound increase	1.04 (1.016, 1.065)	0.001
HbA1c in the 3rd trimester 1 unit increase	1.695 (1.208, 2.378)	0.002
Maternal age in years 1 year increase	1.012 (0.953, 1.076)	0.253
Maternal race/ethnicity Caucasian African American Hispanic Other	ref 0.352 (0.149, 0.833) 0.586 (0.161, 2.141) 0.294 (0.034, 2.576)	0.119
Ratio of HC/AC on ultrasound 0.01 increase	1.057 (1.003, 1.113)	0.04

Abbreviation: OR, Odd Ratio.

Table 4 Distribution of Identified Risk Factors by Cesarean Delivery Indicatory Categories

Variable	Total (N = 117)	NRFHT (N = 38)	Labor Abnormalities (N = 39)	Severe Hypertensive Disorder (N = 14)	Others (N = 26)	P-value
	n (Column %), or n, Mean (SD)					
Hypertensive disorder of pregnancy						
Yes	90 (76.9%)	30 (78.9%)	28 (71.8%)	14 (100%)	18 (69.2%)	0.115
No	27 (23.1%)	8 (21.1%)	11 (28.2%)	0 (0%)	8 (30.8%)	
BMI in the 1st trimester						
18.5 - <25	6 (5.9%)	3 (9.4%)	2 (5.7%)	0 (0%)	1 (4.8%)	0.878
25 - <30	9 (8.8%)	1 (3.1%)	5 (14.3%)	1 (7.1%)	2 (9.5%)	
30 - <35	25 (24.5%)	7 (21.9%)	9 (25.7%)	2 (14.3%)	7 (33.3%)	
35 - <40	21 (20.6%)	7 (21.9%)	7 (20%)	3 (21.4%)	4 (19%)	
40+	41 (40.2%)	14 (43.8%)	12 (34.3%)	8 (57.1%)	7 (33.3%)	
Missing	15	6	4	0	5	
N, Mean (SD)	102, 38.7 (10.3)	32, 39.8 (10.8)	35, 37.8 (10.4)	14, 39.9 (7.3)	21, 37.4 (11.4)	0.44733
Weight gain						
N, Mean (SD)	102, 24.6 (16.4)	32, 24.4 (14.7)	35, 24.2 (15.6)	14, 28.3 (21.1)	21, 23.2 (17.6)	0.9228
HbA1c value in the 3rd trimester						
Mean (SD)	95, 6.7 (1.2)	31, 7.1 (1.3)	35, 6.3 (1.1)	10, 6.6 (1.1)	19, 6.7 (1.2)	0.046*
Maternal age in years						
19 or less	12 (10.3%)	3 (7.9%)	6 (15.4%)	1 (7.1%)	2 (7.7%)	0.449
20-29	55 (47%)	20 (52.6%)	19 (48.7%)	7 (50%)	9 (34.6%)	
30-34	25 (21.4%)	5 (13.2%)	10 (25.6%)	2 (14.3%)	8 (30.8%)	
35+	25 (21.4%)	10 (26.3%)	4 (10.3%)	4 (28.6%)	7 (26.9%)	
N, Mean (SD)	117, 28.3 (6.7)	38, 28.8 (6.4)	39, 26.2 (6.4)	14, 29.1 (7.3)	26, 30 (6.8)	0.102
Maternal race/ethnicity						
Caucasian	41 (35%)	12 (31.6%)	15 (38.5%)	4 (28.6%)	10 (38.5%)	0.941
African American	60 (51.3%)	21 (55.3%)	19 (48.7%)	8 (57.1%)	12 (46.2%)	
Hispanic	12 (10.3%)	3 (7.9%)	5 (12.8%)	1 (7.1%)	3 (11.5%)	
Other	4 (3.4%)	2 (5.3%)	0 (0%)	1 (7.1%)	1 (3.8%)	
Ratio of HC/AC on ultrasound						
N, Mean (SD)	115, 1 (0.1)	38, 1 (0.1)	39, 1 (0.1)	14, 1 (0.1)	24, 1 (0.1)	0.263

adjusted effects of those variables in the final model. The statistical significance level for all analyses was set at 5%. The analyses were performed using R version 4.2.3 and SAS version 9.4 statistical software programs.

Results

In total, 252 patients met the inclusion criteria for this study. Of these patients, Group 1: 117 were delivered by primary cesarean section (45.4%), and Group 2: 135 patients delivered vaginally (53.6%). Listed below are the nonmodifiable, modifiable, and social variables selected for comparison (Tables 1 and 2). In terms of the characteristics of the population studied, 51.6% were African American, 32.1% were Caucasian, 46% were 20–29 years old, and 46% were greater than 30 years old. Most patients had Medicaid insurance (57.5%). Most of the sampled patients (67.3%) lived in counties with a median household income over \$50,000 annually (Table 1).

There was an increased primary Cesarean rate in patients aged 19 years old or less (60%). However, in later adjusted and unadjusted analyses, age did not appear to have a statistically significant effect. There were no significant differences among primary Cesarean rates when compared with other variables including race (Caucasian, African American, Hispanic, and other) or the other social variables, ie health insurance, median household income, or if the patient was labeled as living in a rural area.

Of note, in patients with a BMI in the first trimester of 40 or greater, there was a 60% rate of primary Cesarean section. If a hypertensive disorder of pregnancy was present, there was also a high rate of Cesarean (55%) compared to 29% without. If the HbA1c was greater than 6.5% in any trimester, the rate of Cesarean was 50% or greater. If the estimated fetal weight was greater than 90% (weight for gestational age) or the abdominal circumference greater than 95%, the rate of Cesarean only differed slightly (EFW 46.8% versus 46.3%, AC 44.4% versus 47.5%) (Table 2).

Table 3 demonstrates adjusted effects of study variables on the association with Cesarean delivery. After variable selection procedure, hypertensive disorder in pregnancy, BMI, weight gain, A1C in the 3rd trimester, maternal age, race/ethnicity, and HC/AC were included in this working model. Significant associations (based on p-value <0.05) were with BMI, weight gain, HbA1c in the third trimester, and ratio of HC/AC on ultrasound. The most noteworthy associations with an increased rate of Cesarean delivery were hypertension disorder of pregnancy and elevated BMI (p-values 0.0008 and 0.0006, respectively). A one-pound increase in weight gain from baseline also had a significantly increased association with a p-value of 0.001.

With regard to diabetic control, most patients had a HbA1c of 6.5 or greater in the first and second trimester (76% in first, 53% in second), but the majority of patients had a HbA1c less than 6.5 in the third trimester (53%). The patients with an HbA1c greater than 6.5 in each trimester were more likely to have a delivery via primary Cesarean than those under 6.5 and this was statistically significant when the comparison was made in the third trimester as demonstrated in Table 2 (P-value < 0.002).

Additionally, there were no significant differences found in the Cesarean delivery rate between maternal race/ethnicity or maternal age groups. There was a significant association with an increasing ratio of HC/AC on ultrasound and Cesarean delivery with p-value 0.04.

Table 4 demonstrates the distribution of the variables used in the final regression model stratified by the indication for c-sections. Among these variables, only the HbA1c value in the third trimester was observed to be distributed significantly between the indications, with labor abnormalities as the most common risk factor for c-section. Among all other variables, indication for c-section was evenly distributed.

Discussion

In women, with PGDM who become pregnant, the most significant predictors that the patient would have a primary Cesarean delivery were the BMI in the first trimester and if the patient had a hypertensive disorder during pregnancy. An elevated first trimester BMI is particularly important because women with a normal BMI (18.5–<25) in the first trimester have a Cesarean rate of 28.6% compared with women who have an elevated BMI (≥ 40) who have a Cesarean rate of 60.3%. Women who do not have a hypertensive disorder of pregnancy have a Cesarean rate of 29.7% compared with women who do have a hypertensive disorder of pregnancy who have a 55.9% Cesarean rate (Figure 2).

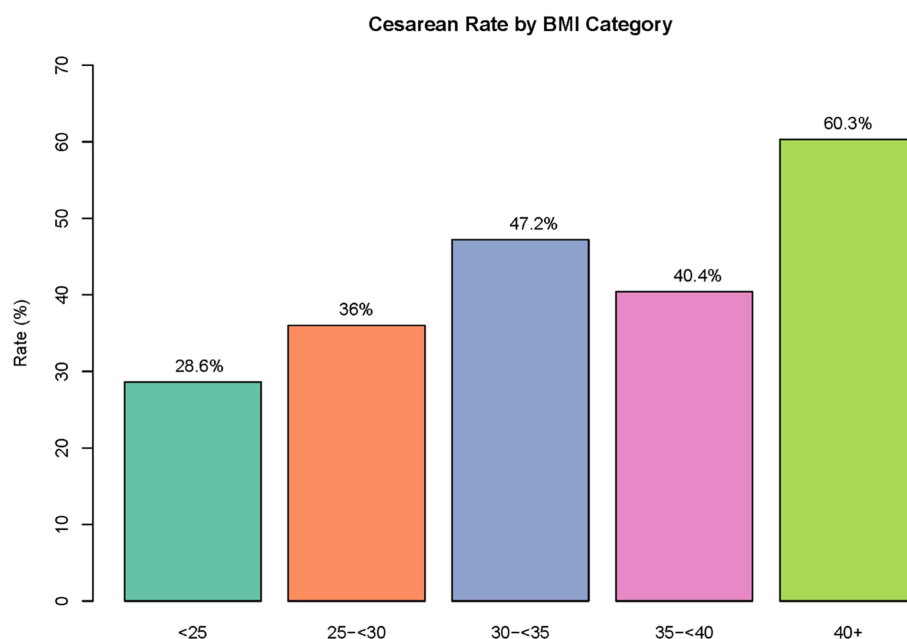


Figure 2 Cesarean Rate by BMI Category.

Our data is consistent with other reported rates in the literature highlighting the effect of maternal BMI as they enter pregnancy. There is a generalized lack of epidemiologic population studies of the topic of Cesarean delivery for PGDM. Rates of Cesarean deliveries reported in the literature vary widely from 26 to 74%.⁴ The wide range of Cesarean rates for PGDM is likely due to non-standardized data collection with some studies reporting the total Cesarean delivery rate (not distinguishing between primary and repeat deliveries), and others reporting specific rates for each category of patients using the Robson Ten Group Classification system.⁴ According to 2020 data from the Center for Disease Control and Prevention (CDC), Cesarean rate not confined to diabetes is higher for patients with class III obesity (BMI ≥ 40 at 52.3%).¹¹

Our program recommends the lifestyle modification of maternal weight gain between 0–20 lbs. in view of the obesity associated with PGDM. The mean weight gained in our sample was 20.8 lb. overall, with significantly higher gain in the Cesarean section group 1 (24.6 lb.) compared to the vaginal delivery group 2 (17.4 lb.). Although the Institute of medicine recommendations of weight gain in the obese BMI 30+ is 11–20 lbs,¹² this study specifically identified the impact of each pound gained to increase an OR of primary Cesarean delivery by 1.04 suggesting a potential benefit from limiting maternal weight gain for PGDM. This has been suggested in other publications where weight gain below current guidelines in the obese pregnant women have not resulted in adverse pregnancy outcome leading to a recommendation to remove the lower limits of weight gain in the obese group.¹³

In addition, our results highlight the importance of strict glycemic control in PGDM. One unit increase of HbA1c in the third trimester led to an odds ratio (OR) of 1.695 on the primary Cesarean section. This is consistent with other publications where HbA1c is reported as an independent risk factor for adverse pregnancy outcomes and c-section with an adjusted odds ratio of 1.47, predictive of Cesarean birth per HbA1c 1% increase.¹⁴ In a retrospective study, Finneran et al investigated the prognostic ability of longitudinal HbA1c assessments to predict obstetric outcomes based on degree of glycemic control in early and late pregnancy.¹⁵ They concluded antenatal hemoglobin HbA1c values are useful for objective risk stratification of patients with pregestational diabetes, and that strict glycemic control throughout pregnancy with a late pregnancy HbA1c target of $<6.5\%$ leads to reduced rates of obstetric adverse outcomes independent of early glucose control.¹⁵ A study by Chen et al analyzed 2860 cases of diabetes in pregnancy. In this study, they used Hgb A1C $>6.0\%$ to define “poor control” and found that those with poorly controlled PGDM had a statistically significant higher rate of a Cesarean compared to women with gestational diabetes or well-controlled pregestational diabetes.¹⁶ Our

findings support the importance of monitoring A1c levels, as A1c in the third trimester had the second greatest likelihood of Cesarean delivery among the covariates examined.

Hypertensive disorders can result in non-reassuring fetal heart rate during labor or non-reassuring antenatal testing if placental blood flow is compromised, and indications for Cesarean delivery may arise. Fisher et al, in their study, observed that fetal distress comprised 58% of the indications for emergency Cesarean delivery in women with diabetes.¹⁷ Another study reported an increased risk of intrapartum Cesarean delivery for fetal indications in patients with PGDM but not in patients with gestational diabetes.⁴ The authors speculated that this was due to an alteration in placental vasculature, the same mechanism leading to an increased stillbirth rate in these pregnancies.⁴ The present study's findings further underscore the relationship of hypertensive disorders of pregnancy, PGDM, and risk of Cesarean delivery and suggest optimizing blood pressure control may decrease the rate of primary Cesarean delivery. Cardiovascular disorders are also known to increase the risk of fetal growth restriction leading to rising HC/AC ratios with asymmetrical growth restriction and intolerance of labor. The negative impact of hypertensive disorders with OR 3.56 (95% CI 1.695–7.5) is consistent with a larger population-based study from Ohio of 1,463,506 live births where the adjusted RR of primary c-section in pregnancies complicated by multiple medical problems was reported at 1.34–3.87.¹⁸

Other factors analyzed included maternal age, race, type of health insurance, household income, the patient's residence (rural vs urban), weight gain during pregnancy, BMI in the second and third trimester of pregnancy, and estimated fetal weight >90% or abdominal circumference >95% in the third trimester of pregnancy. None of these other factors were significant predictors of a primary Cesarean delivery.

Upon investigating the reported indications for Cesarean delivery, we noted an almost equal distribution of labor abnormalities (33%) and non-reassuring FHR (32%). This rate is consistent with other reports but differs in that none are the primary driver for Cesarean delivery. Labor dystocia has been reported as one of the leading indications for unscheduled Cesarean section in PGDM, implicated in 48%, in a retrospective cohort study by Krut et al.¹⁹ Studies have suggested one reason to explain the higher c-section rate in patients with PGDM is its association with impairment of uterine contractility, observed in mice and humans with diabetes.^{20,21} Studies have also shown diabetes is independently associated with exposure to higher doses of oxytocin.²² This data helps in understanding the high incidence of labor arrest in these patients leading to a Cesarean delivery, especially when combined with additional factors that may impair uterine contractility such as magnesium sulfate for preeclampsia. There is a potential need for a higher maximum of Pitocin dosing in labor inductions for these patients to reduce risk of a Cesarean.²² It is possible that the high rate of hypertensive disorders may have led to higher Non-Reactive Fetal Heartrate (NRFHR) tracing leading to Cesarean delivery prior to the full manifestation of labor dystocia. Additionally, our data does not support accelerated fetal growth as a major contributor to primary Cesarean rate in PGDM. Thus, a larger fetus commonly implicated in labor abnormalities, may not be the major contributor to failed vaginal deliveries.

Strengths and Limitations

The main limitation of our study was the limited number of patients included, which restricted our ability to subcategorize each indication for a Cesarean delivery for a more detailed analysis. Another limitation is that our study was only conducted at a single institution where patients are managed by the same multidisciplinary team. Our findings may not be applicable to other practices with a different mix of health care providers and different thresholds for managing PGDM patients.

The strength in the data includes uniformity of data entry and pregnancy management. The data also comes from a state included in the top three states in USA with an obesity prevalence rate of 40% or greater according to the Center for Disease Control obesity maps for 2023.²³ These results may jump start programs in the state for obesity control.

Conclusions

The primary Cesarean delivery rate in women with PGDM without an elevated BMI in the first trimester and without a hypertensive disorder of pregnancy was 28.6% and 29.7%, respectively. If the patient's BMI was >40 and if a hypertensive disorder of pregnancy was present, then the primary Cesarean delivery rate increased to 60.3% and 55.9%, respectively. Other factors that contributed to an increased Cesarean delivery rate were increased weight gain and

an increased third trimester HbA1c. This suggests that despite rigorous management of hypertension, diabetes, and weight gain during pregnancy, contributing factors may not be modifiable during prenatal care and other lifestyle modifications prior to pregnancy may be helpful in decreasing the primary Cesarean rate.

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