

Comparison of Birth Outcomes by Gestational Diabetes Screening Criteria

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Abstract

Objectives This study is to examine the association between different diagnostic criteria for gestational diabetes mellitus (GDM) and adverse birth outcomes.

Study Design A retrospective cohort study of 5,937 women with a singleton pregnancy was conducted, who completed GDM screening between 24 to 32 weeks gestational age. Four nonoverlapping groups of women defined as: 1) Normal: glucose challenge test (GCT) <130 mg/dL, 2) elevated GCT + normal oral glucose tolerance test (OGTT): abnormal 1 hour GCT + normal 3 hour OGTT, 3) GDM/International Association of Diabetes in Pregnancy Study Group (IADPSG): abnormal 3 hour OGTT by the IADPSG criteria, and 4) GDM/Carpenter-Coustan (CC): diagnosis per CC criteria. We used logistic regression to examine the association between GDM group classification and main outcome of macrosomia and secondary birth outcomes.

Results Prevalences were GDM/CC 4.6%, GDM/IADPSG 3.0, and 7.6% overall. GDM/IADPSG group was associated with increased macrosomia (adj OR [odds ratio] 1.87; 95% CI [confidence interval]: 1.08–3.25; $p = 0.02$), while GDM/CC group was associated with increased preterm birth (adj OR 1.75; 95% CI: 1.05–2.80; $p = 0.03$).

Conclusion Little difference in birth outcomes was found between the two criteria, GDM/CC and GDM/IADPSG. Randomized controlled trials are needed to clarify the risks and benefits of these screening paradigms before their incorporation into clinical practice.

Keywords

- ▶ screening strategies
- ▶ gestational diabetes
- ▶ fetal growth
- ▶ pregnancy outcomes

Treatment of gestational diabetes mellitus (GDM) reduces the risk of adverse perinatal outcomes, such as preterm labor, macrosomia, severe perineal lacerations, birth trauma, neonatal hypoglycemia, and stillbirths.¹ However, there is con-

trovery about the best way to screen for GDM among pregnant women. The two currently used methods, the International Association of Diabetes in Pregnancy Study Group Criteria (IADPSG) and the Carpenter-Coustan (CC) diagnose

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GDM at different thresholds, use different glucose loads (75 vs. 100 grams), use one versus two step screening, and require one versus two abnormal values resulting in different rates of women being treated for GDM. Consequently, it is important to consider the differences between these two diagnostic criteria on birth outcomes.

Currently in the United States, GDM is diagnosed by a two-step approach using the Carpenter-Coustan criteria. However, the hyperglycemia adverse pregnancy outcome study (HAPO) demonstrated a linear relationship between maternal hyperglycemia and adverse perinatal outcomes in women undergoing a fasting 75 grams oral glucose tolerance test (OGTT).² The threshold values for the 75 grams OGTT identified a subset of women with mild hyperglycemia who would have been considered normal under the current two-step screen but who had an increased incidence of pregnancy complications. These findings prompted the IADPSG to propose GDM diagnostic criteria that use one-step 75 grams OGTT testing for all women and make the diagnosis of GDM based on one abnormal value with a slightly lower diagnostic threshold.^{3,4} This approach would increase the prevalence of GDM in the U.S. from 5 to 7% to 16 to 18%.⁵

One prior study demonstrated that infants of women who would have been treated for GDM by the IADPSG criteria had higher birth weights than either the offspring of women with normal GCT or those with GDM by CC Criteria.⁶ This study, however, only included term births and did not adjust for maternal body mass index (BMI) or weight gain during pregnancy in their analyses, both of which are associated with fetal overgrowth.⁷ Recently, a panel of experts recommended continued use of the two-step approach until there was evidence of improved outcomes associated with the proposed lower diagnostic threshold.⁸

In our study, we hypothesized that women with mild hyperglycemia who did not meet the current diagnostic criteria for GDM would be at risk for the following adverse perinatal outcomes: macrosomia, large for gestational age (LGA), preterm birth, hypertensive disorders of pregnancy, birth trauma, and caesarean delivery.

Methods

Sample Selection

This is a retrospective cohort study of 7,819 pregnant women with singleton pregnancies who delivered at a large women's academic hospital between January 2006 and December 2010. Clinical and demographic patient data were abstracted from the hospital's clinical data repository that combines data from the electronic medical record and the administrative claims database. Our sample consisted of women universally screened with a random 50 grams GCT for GDM with the majority screened between 24 to 28 weeks gestational age (GA).

To be included in this study, participants had to have a 1 hour 50 grams GCT < 130 mg/dL, or \geq 130 mg/dL and < 180 mg/dL, and a clinically indicated 3 hours 100 grams OGTT; 755 women did not meet these criteria. An additional 202 women who had a 50 grams GCT between 130 and 135 mg/dL did not have a confirmatory 100 grams OGTT because some physicians

used a cutoff of 135 mg/dL to order a 100 grams OGTT. These women differed from the normal group on several clinical characteristics and delivery outcomes (data not shown) and thus were excluded from the main analyses.

Many physicians considered a 50 grams GCT greater than 200 mg/dL diagnostic of GDM and as such, women with these values were included in the GDM/CC group. We identified 41 women with a 50 grams GCT value between 180 and 200 mg/dL and without a confirmatory 100 grams OGTT, four of whom had a diabetes medication ordered. These women were considered to have GDM based on their elevated 50 grams GCT result and clinical judgment and thus included those in the GDM/CC group after a sensitivity analysis demonstrated that the overall results with and without them were unchanged.

Women were excluded if they had multiple gestations, pre-existing diabetes, or delivered at another hospital. Women were also excluded if they were missing key independent variables, such as glucose values or date of last period ($n = 645$), had out of range GAs < 0, or > 43 weeks ($n = 234$), or did not have glucose testing done ($n = 46$). This resulted in a final sample size of 5,937. **►Fig. 1** shows the sample derivation for these analyses.

GDM Group Classification

To test our hypothesis we compared four nonoverlapping groups of women based on their routine second trimester GDM test results: 1) normal: GCT < 130 mg/dL, 2) mild elevated GCT + normal OGTT hyperglycemia: abnormal 1 hour GCT + normal 3 hours 100 grams OGTT, 3) GDM/IADPSG: abnormal 100 grams OGTT based on the IADPSG criteria (normal based on Carpenter-Coustan, thus untreated), and 4) GDM/CC: GDM diagnosed using the Carpenter-Coustan criteria (**►Fig. 1**). The IADPSG have endorsed the use of a single step GDM testing strategy using a fasting 2 hours 75 grams OGTT in which only one elevated value (fasting \geq 92 mg/dL, 1 hour \geq 180 mg/dL or 2 hour \geq 153 mg/dL) is required to diagnose GDM^{3,4}; this definition has not been widely adopted in the U.S. We approximated these diagnostic criteria with the approach listed in **►Fig. 1**.

The covariates were self-defined race/ethnicity, highest education level completed, marital status, smoking status, gravidity, parity, prepregnancy weight, mother's age at delivery, number of prenatal visits, GA at delivery, and total maternal weight gain (TMWG). TMWG defined as last weight prior to delivery minus measured prepregnancy weight was classified according to the Institute of Medicine 2009 guidelines as insufficient, appropriate, or excessive.⁹ Adjusted TMWG (aTMWG) or net maternal weight gain, was defined as the TMWG minus the infant birth weight. This continuous variable was used in the multivariable models to allow for removal of the part versus whole correlation. Prepregnancy weight was used in our models instead of prepregnancy BMI because height was not available for 366 women. We defined gestational diabetes treatment as receiving metformin, insulin, or glyburide within the prenatal period.

The primary outcome, LGA birth weight was defined as birth weight > 90th percentile for GA based on U.S. birth weight standards.¹⁰ Secondary outcomes included: 1)

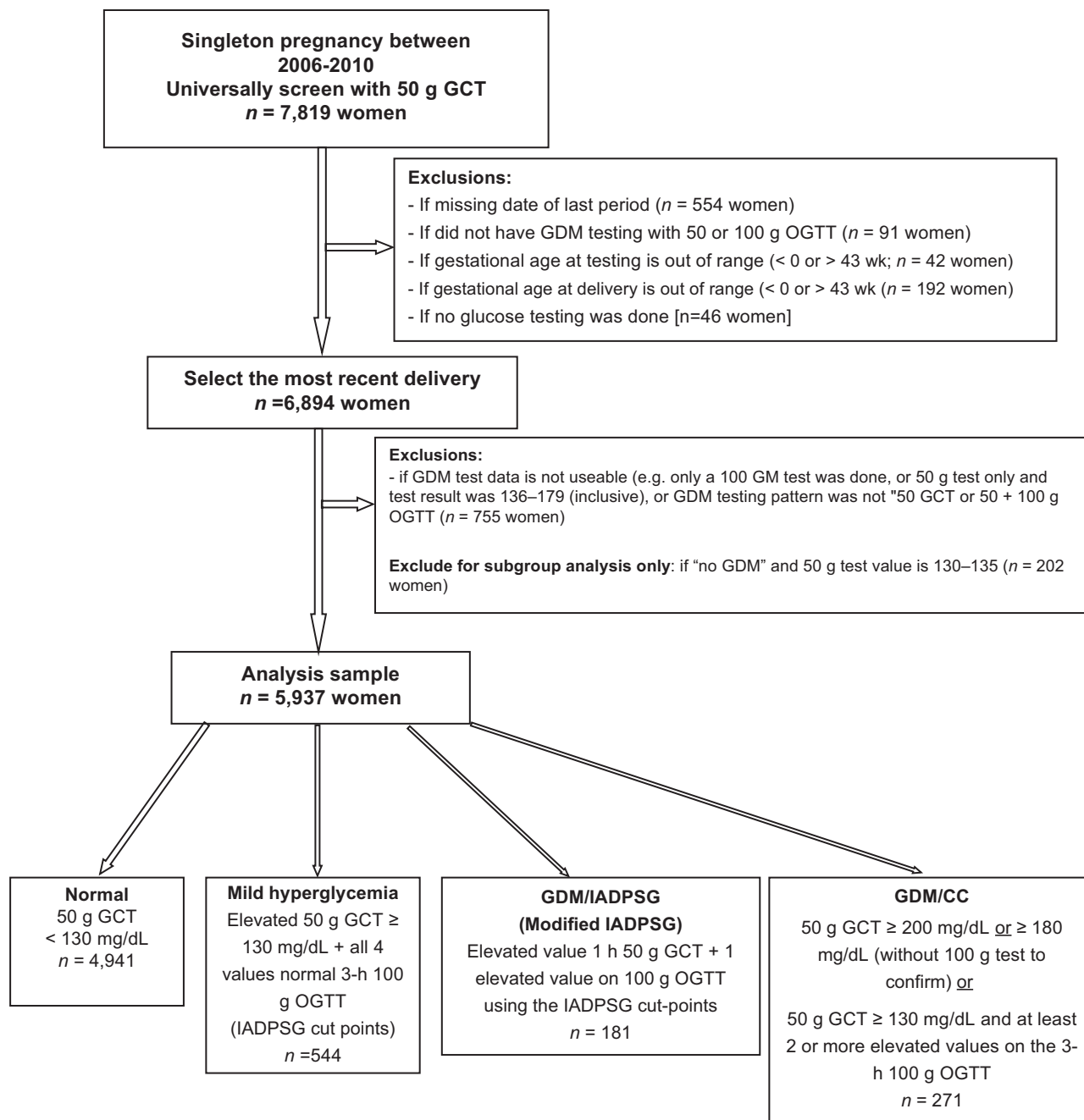


Fig. 1 Sample derivation shows the sample derivation for these analyses. CC, Carpenter-Coustan; GDM, gestational diabetes mellitus; IADPSG, international association of the study of diabetes in pregnancy group; OGTT, oral glucose tolerance test; GCT, glucose challenge test.

macrosomia birth weight $\geq 4,000$ grams as defined in the prior GDM treatment trials^{1,11}; 2) *primary cesarean delivery* defined using procedure current procedural terminology (CPT) codes 74, 74.1, 74.9; 3) *hypertensive disorders of pregnancy* was a composite variable that included either having pre-eclampsia or gestational hypertension as defined by the International Classification of Diseases (ICD) 9 codes 642.41, 642.31, 642.51, 642.71, 642.6 (this composite does not contain code 642.01 for chronic hypertension which was analyzed separately); 4) *preterm delivery* was defined as a delivery < 37 weeks of gestation; 5) *severe vaginal lacerations* (3rd/4th degree lacerations (664.21, 664.31); and 6) *shoulder dystocia* (660.41).

Statistical Analyses

Basic descriptive statistics (including Chi-squared or ANOVA [analysis of variance]) were used to summarize demographic and clinical data and assess differences across the four GDM groups. If significant differences were apparent, post hoc comparisons using a Bonferroni's adjustment were conducted. Logistic regression was used to investigate the relationship between GDM group and the primary and secondary outcomes. Unadjusted associations with the GDM group were fit for each outcome and regression models were run including covariates significantly related to GDM group at the 0.10 significance level. Because of the hypothesis-generating nature of this study, all statistical analyses were conducted without

adjustment for multiplicity. Regarding sample size, we had sufficient numbers to conduct our analyses; with nearly 6,000 women, we had 80% power to detect an odds ratio of approximately 1.19 between the “normal” group and the “GDM by IADPSG criteria” group (e.g., the group with the smallest sample size) on the primary outcome of LGA after accounting for covariate adjustment. In other words, this effect represents a 19% increased risk in the odds of LGA to the “GDM by IADPSG criteria” group. The other comparisons (“Normal” vs. “elevated GCT + normal OGTT” and “Normal” vs. “GDM by CC Criteria”) would have greater power to detect the same effects due to the larger collective sample sizes. This research study was conducted according to the prevailing ethical principles and was approved by the University’s Institutional Review Board.

Results

GDM prevalence in this population was 4.6% using GDM/CC criteria; an additional 3.0% was detected using the GDM/IADPSG for a total of 7.6%. The mean GA when the 50 grams test was performed was 26.67 (SD [standard deviation] 3.39)

weeks; 75% of women were within a range of 24 to 28 weeks. The mean 50 grams glucose values were significantly different across the four groups and increased across the groups from normal to mild, GDM/IADPSG, and GDM/CC.

The four groups varied by socioeconomic and clinical characteristics (► **Table 1**). Those in the mild and GDM/IADPSG were more like to be white, the normal were more likely to be black, and the GDM/CC group was more likely to be other. A larger proportion of the normal group had at least a high school education. The normal group was also less likely to be married and younger. Across groups there were no significant differences by number of prenatal visits, gravidity, or parity.

Women in the normal, elevated GCT + normal OGTT, and GDM/IADPSG groups had similar distributions of prepregnancy BMI categories: 50 to 60% of these women had a normal prepregnancy BMI compared with 36.5% in the GDM/CC group. The overall mean aTMWG was 24.6 ± 13.4 lbs. Women who were overweight (−1.8 lbs.; *p* = 0.002) or obese prepregnancy (−10.0 lbs, *p* < 0.001) had a lower total net maternal weight gain compared with women in the normal prepregnancy weight group. Across the four groups, women

Table 1 Study sample demographic and clinical characteristics

Maternal characteristics, <i>n</i> (%) or mean ± SD	<i>n</i>	Total cohort <i>n</i> = 5,937	Normal <i>n</i> = 4,941	Elevated GCT + NL OGTT <i>n</i> = 544	GDM by IADPSG criteria <i>n</i> = 181	GDM by CC criteria <i>n</i> = 271	χ ² <i>p</i> -value	Post hoc comparisons ^a (adjusted <i>p</i> -value)
Race/ethnicity	5,937						0.0186	5: (<i>p</i> = 0.0275)
White		4,222 (71.1)	3,500 (70.8)	409 (75.2)	134 (74.0)	179 (66.1)		
Black		1,049 (17.7)	942 (19.1)	51 (9.4)	23 (12.7)	33 (12.2)		
Other		479 (8.1)	348 (7.0)	65 (11.9)	17 (9.4)	49 (18.1)		
Unknown		187 (3.1)	151 (3.1)	19 (3.5)	7 (3.9)	10 (3.7)		
Education level	5,241						< 0.0001	1: (<i>p</i> < 0.0001) 3: (<i>p</i> = 0.0274)
HS graduate/GED or less		959 (18.3)	862 (19.7)	50 (10.4)	17 (11.6)	30 (12.3)		
Some college/ associate degree		1,034 (19.7)	877 (20.1)	77 (16.0)	30 (20.4)	50 (20.6)		
Bachelor’s degree		1,568 (29.9)	1,263 (28.9)	167 (34.6)	59 (40.1)	79 (32.5)		
Master’s degree and higher		1,680 (32.1)	1,367 (31.3)	188 (39.0)	41 (27.9)	84 (34.6)		
Married	5,877	4,143 (70.5)	3,365 (68.8)	431 (79.5)	145 (81.0)	202 (75.4)	< 0.0001	1: (<i>p</i> < 0.0001) 2: (<i>p</i> = 0.0032)
Any smoking during pregnancy	5,937	424 (7.1)	367 (7.4)	30 (5.5)	15 (8.3)	12 (4.4)	0.1046	NS
Maternal age at delivery (y)	5,937	30.6 ± 5.6	30.3 ± 5.7	31.9 ± 5.1	32.1 ± 5.2	32.9 ± 5.0	< 0.0001	1: (<i>p</i> < 0.0001) 2: (<i>p</i> < 0.0001) 3: (<i>p</i> < 0.0001)
Prenatal visits:	5,937	11.1 ± 4.5	11.1 ± 4.5	11.1 ± 4.5	10.4 ± 5.2	11.2 ± 4.4	0.2033	NS
Gravida (number of pregnancies)	5,932						0.9511	NS
1		1,930 (32.5)	1,606 (32.5)	181 (33.3)	58 (32.0)	85 (31.4)		
2		1,957 (33.0)	1,630 (33.0)	187 (34.4)	53 (29.3)	87 (32.1)		
3+		2,045 (34.4)	1,701 (34.4)	175 (32.1)	70 (38.7)	99 (36.5)		
Parity (number of live births > 20 wk)	5,932						0.1513	NS

(Continued)

Table 1 (Continued)

Maternal characteristics, n (%) or mean \pm SD	n	Total cohort n = 5,937	Normal n = 4,941	Elevated GCT + NL OGTT n = 544	GDM by IADPSG criteria n = 181	GDM by CC criteria n = 271	χ^2 p-value	Post hoc comparisons ^a (adjusted p-value)
Nulliparous		2,618 (44.1)	2,150 (43.5)	251 (46.2)	82 (45.3)	135 (49.8)		
Primiparous		2,235 (37.7)	1,880 (38.1)	202 (37.2)	65 (35.9)	88 (32.5)		
Multiparous (2+ or more)		1,079 (18.2)	907 (18.4)	90 (16.6)	34 (18.8)	48 (17.7)		
Prepregnancy weight (lbs)	4,554	148 \pm 34.9	146.9 \pm 33.9	148 \pm 34.3	157.2 \pm 40.9	163.7 \pm 44.1	< 0.0001	2: ($p = 0.0039$) 3: ($p < 0.0001$) 5: ($p < 0.0001$)
Prepregnancy BMI (kg/m ²)	4,188						< 0.0001	3: ($p < 0.0001$) 5: ($p < 0.0001$) 6: ($p = 0.0018$)
Underweight		170 (4.1)	155 (4.4)	10 (2.9)	1 (0.9)	4 (2.2)		
Normal weight		2,458 (58.5)	2,124 (59.9)	204 (58.5)	58 (52.3)	66 (36.5)		
Overweight		908 (21.7)	759 (21.4)	72 (20.6)	33 (29.7)	44 (24.3)		
Obese		637 (15.7)	509 (14.4)	63 (18.1)	19 (17.1)	67 (37.0)		
IOM pregnancy weight gain	3,909						0.0006	3: ($p = 0.0056$) 6: ($p = 0.0013$)
Insufficient		636 (16.3)	528 (15.9)	57 (18.0)	8 (7.6)	43 (25.6)		
Appropriate		1,391 (35.6)	1,191 (35.9)	112 (35.3)	34 (32.4)	54 (32.1)		
Excessive		1,882 (48.1)	1,600 (48.2)	148 (46.7)	63 (60.0)	71 (42.3)		
Total maternal weight gain (lbs)	4,256	32.1 \pm 13.6	32.5 \pm 13.5	30.5 \pm 14.1	33.9 \pm 12.7	26.3 \pm 14.4	< 0.0001	1: ($p = 0.0248$) 3: ($p < 0.0001$) 5: ($p = 0.0026$) 6: ($p < 0.0001$)
Total maternal weight gain (adjusted for baby's birth weight; lbs)	4,246	24.6 \pm 13.4	25.1 \pm 13.3	22.9 \pm 13.9	26.2 \pm 12.6	18.7 \pm 14.3	< 0.0001	1: ($p = 0.0156$) 3: ($p < 0.0001$) 5: ($p = 0.0020$) 6: ($p < 0.0001$)
50 g GCT value (mg/dL)	5,937	108.2 \pm 27.1	99.0 \pm 17.1	147.0 \pm 11.9	150.6 \pm 13.9	170.2 \pm 28.0	0.0001	1: ($p < 0.0001$) 2: ($p < 0.0001$) 3: ($p < 0.0001$)
Chronic hypertension	5,937	76 (1.3)	54 (1.1)	9 (1.7)	4 (2.2)	9 (3.3)	0.007	3: ($p = 0.065$)

Abbreviations: BMI, body mass index; CC, Carpenter-Coustan; GDM, gestational diabetes mellitus; GCT, glucose challenge test; IADPSG, international association of the study of diabetes in pregnancy group; NL, normal; NS, nonsignificant; OGTT, oral glucose tolerance test; SD, standard deviation.

^aPost hoc comparisons are indicated by the following: 1 = normal vs. elevated GCT + NL OGTT; 2 = normal vs. GDM by IADPSG criteria; 3 = normal vs. GDM by CC criteria; 4 = elevated GCT + NL OGTT vs. GDM by IADPSG criteria; 5 = elevated GCT + NL OGTT vs. GDM by CC criteria; 6 = GDM by IADPSG criteria vs GDM by CC criteria.

in the normal group had the highest pregnancy weight gain (25.1 \pm 13.3 lbs), while women in the GDM/CC group had the lowest aTMWG (18.7 \pm 14.3 lbs.).

Birth Outcomes: LGA differed significantly across groups and was highest in the GDM/IADPSG group (18.9%) followed by the GDM/CC group (14.8%), elevated GCT + normal OGTT (12.1%), and normal groups (10.8%; $p = 0.005$; \blacktriangleright **Table 2**). The Bonferroni-corrected pairwise comparisons revealed that the primary difference was between the normal (10.8%) and GDM/IADPSG (18.9%) groups ($p = 0.0038$). However, in the multivariable analyses (\blacktriangleright **Table 3**), there no longer was a significant relationship between group and LGA. Macrosomia was also significantly different from the normal group in the GDM/IADPSG group on both unadjusted and adjusted analyses. Similarly, preterm birth was significantly higher in the GDM/CC group ($p = 0.031$) in multivariable analyses. There were no group differences in the outcomes of primary caesarean delivery, hypertensive disorder of preg-

nancy, vaginal lacerations, and shoulder dystocia after adjustment for covariates.

High prepregnancy weight and adjusted maternal weight gain were independent predictors of LGA, macrosomia, C-section, gestational hypertension/preclampsia adjusting for GDM screening group (e.g., normal, elevated GCT + normal OGTT, GDM/IADPSG, GDM/CC) and other covariates ($p < 0.05$, data not shown). Prepregnancy weight and maternal weight gain were not associated with risk of perinatal trauma and preterm delivery.

While the majority of our women were screened between 24 to 28 weeks of GA, 25% were screened either before or after this timeframe. Because women screened early in pregnancy may have different risk factors for GDM compared with those women screened later in pregnancy, we conducted a series of sensitivity analyses to examine this issue. We compared demographic and clinical characteristics across 50 grams GCT GA timeframes (less than 24 weeks,

Table 2 Perinatal outcomes by GDM Screening Group

Perinatal outcomes <i>n</i> (%) or mean \pm SD	<i>n</i>	Total cohort <i>n</i> = 5937	Normal <i>n</i> = 4941	Elevated GCT + NL OGTT <i>n</i> = 544	GDM by IADPSG criteria <i>n</i> = 181	GDM by CC criteria <i>n</i> = 271	χ^2 <i>p</i> -value	Post hoc comparisons (adjusted <i>p</i> -value) ^a
Infant birth weight (lbs)	5,923	7.4 \pm 1.1	7.4 \pm 1.1	7.5 \pm 1.1	7.7 \pm 1.2	7.5 \pm 1.1	0.0012	2: (<i>p</i> = 0.0010)
Birth weight category	5,921						0.0015	2: (<i>p</i> = 0.0038)
SGA		507 (8.6)	436 (8.9)	42 (7.7)	13 (7.2)	16 (5.9)		
AGA		4,744 (80.1)	3,960 (80.4)	436 (80.1)	133 (73.9)	215 (79.3)		
LGA		670 (11.3)	530 (10.8)	66 (12.1)	34 (18.9)	40 (14.8)		
Macrosomia \geq 4,000 g	5,923	574 (9.7)	455 (9.2)	59 (10.8)	32 (17.8)	28 (10.3)	0.0014	2: (<i>p</i> = 0.0008)
Gestational age at delivery (wk)	5,937	39.3 \pm 2.0	39.3 \pm 2.0	39.3 \pm 2.0	39.4 \pm 1.9	38.8 \pm 2.0	0.0001	3: (<i>p</i> < 0.0001) 5: (<i>p</i> = 0.0044) 6: (<i>p</i> = 0.0076)
Preterm birth (GA < 37 wk)	5,937	559 (9.4)	455 (9.2)	51 (9.4)	15 (8.3)	38 (14.0)	0.0640	NS
Cesarean delivery	5,937	1,588 (26.7)	1,267 (25.6)	175 (32.2)	51 (28.2)	95 (35.1)	0.0001	1: (<i>p</i> = 0.0062) 3: (<i>p</i> = 0.0036)
Hypertensive disorder of pregnancy	5,937	546 (9.2)	442 (8.9)	51 (9.4)	22 (12.2)	31 (11.4)	0.2700	NS
Lacerations (3rd or 4th degree)	5,864	252 (4.3)	203 (4.2)	30 (5.5)	12 (6.7)	7 (2.6)	0.0865	NS
Dystocia	5,864	127 (2.2)	104 (2.1)	11 (2.0)	6 (3.4)	6 (2.3)	0.7363	NS

Abbreviations: AGA, appropriate for gestational age; CC, Carpenter-Coustan; GA, gestational age; GCT, glucose challenge test; GDM, gestational diabetes mellitus; IADPSG, international association of the study of diabetes in pregnancy group; LGA, large for gestational age; NL, normal; NS, nonsignificant; OGTT, oral glucose tolerance test; SGA, small for gestational age.

^aPost hoc comparisons are indicated by the following: 1 = normal vs. elevated GCT + NL OGTT; 2 = normal vs. GDM by IADPSG criteria; 3 = normal vs. GDM by CC criteria; 4 = elevated GCT + NL OGTT v GDM by IADPSG criteria; 5 = elevated GCT + NL OGTT vs. GDM by CC criteria; 6 = GDM by IADPSG criteria v GDM by CC criteria.

24 to 28 weeks, greater than 28 weeks GA). While there were differences in baseline characteristics across GA screening timeframes (data not shown), there was no relationship between GA timing and the distribution of GDM classifications (i.e., normal, elevated, IADPSG, CC). We next restricted our analysis to only those women with screening between 24 and 28 weeks and we found a similar pattern of baseline demographic characteristics, GDM classification, and delivery outcomes among those women screened at 24 to 28 weeks and the overall cohort (data not shown).

Discussion

The overall prevalence of GDM in our study was 7.6% which was lower than the combined prevalence reported in the HAPO study (17.8%) and within the range 9.3 to 25.5% of GDM prevalences reported for 15 HAPO study centers, and similar to prevalences of 7.3% found by Ethridge et al and 10.3% found by Mayo et al.^{5,7,12} The variation in the GDM prevalence across the studies may be due to the differences in the glucose measures for the diagnosis of GDM, the use of the two-step versus one step screening approach, the rates of maternal obesity and prevalence of impaired glucose metabolism in the general population of the study sites.

Women who met the GDM/IADPSG criteria were significantly more likely than the Normal group and GDM/CC group to have babies with macrosomia. This finding was consistent

with the association reported from the Mayo et al study in their untreated GDM/IADPSG group.¹² Treatment of women with GDM diagnosed by the Carpenter-Coustan criteria is known to result in lower birth weight and reduced risk for macrosomia and LGA.^{1,11} Women in the GDM/IADPSG group in our study were not treated for GDM; this may explain the higher prevalence of macrosomia in this group and differences from the study by Feldman et al which found that the screening according to the IADPSG criteria group was not associated with lower rates of macrosomia or LGA.¹³

We did not find a significant increase in the proportion of cesarean deliveries in the GDM/CC group compared with the GDM/IADPSG group in our study. Our results differed from previous study findings which reported an increase in the IADPSG groups.¹²⁻¹⁴ The prospective diagnosis and treatment of the IADPSG group in the study by Duran et al that showed a decrease in cesarean rate,¹⁴ and the untreated IADPSG group in the studies by Feldman¹³ and Mayo¹² showing an increase in cesarean rates may explain these discrepancies in the study findings.^{12,13}

Women in the GDM/CC criteria were significantly more likely to deliver prematurely which was consistent with reports from Mayo et al and Duran et al^{12,14} However, this finding differed from the results by Ethridge et al who similarly compared GDM diagnostic criteria because they only included terms births.⁷ Whether iatrogenic preterm birth, based on the diagnosis of GDM, contributes to the increased risk for preterm

Table 3 Multivariable models of GDM testing group predictor of perinatal outcomes

Predictor	Elevated GCT + normal OGTT n = 544			GDM by IADPSG criteria n = 181			GDM by CC criteria n = 271		
	Unadjusted OR, CI	p-Value	Adjusted OR, CI	Unadjusted OR, CI	p-Value	Adjusted OR, CI	Unadjusted OR, CI	p-Value	Adjusted OR, CI
Outcomes									
LGA	1.145 (0.87, 1.50)	0.3297	0.938 (0.64, 1.37)	1.932 (1.32, 2.84)	0.0008	1.466 (0.85, 2.53)	1.436 (1.01, 2.03)	0.0412	1.229 (0.76, 1.97)
Macrosomia	1.196 (0.90, 1.59)	0.2217	0.988 (0.66, 1.48)	2.126 (1.43, 3.15)	0.0002	1.876 (1.08, 3.25)	1.133 (0.76, 1.69)	0.5442	1.022 (0.57, 1.84)
Cesarean delivery	1.375 (1.14, 1.66)	0.0011	1.181 (0.91, 1.52)	1.138 (0.82, 1.58)	0.4440	0.810 (0.51, 1.29)	1.565 (1.21, 2.03)	0.0006	1.268 (0.90, 1.79)
HTN disorder of pregnancy	1.053 (0.78, 1.43)	0.7396	1.080 (0.70, 1.66)	1.409 (0.89, 2.22)	0.1406	1.215 (0.63, 2.35)	1.315 (0.89, 1.94)	0.1649	1.269 (0.75, 2.14)
Lacerations (3rd or 4th degree)	1.352 (0.91, 2.01)	0.1336	1.024 (0.59, 1.78)	1.655 (0.91, 3.02)	0.1012	0.925 (0.33, 2.58)	0.622 (0.29, 1.34)	0.2237	0.290 (0.07, 1.20)
Dystocia	0.953 (0.51, 1.79)	0.8798	0.540 (0.19, 1.50)	1.592 (0.69, 3.68)	0.2760	1.294 (0.40, 4.21)	1.059 (0.46, 2.44)	0.8921	0.990 (0.30, 3.24)
Preterm birth	1.020 (0.75, 1.38)	0.8990	1.243 (0.83, 1.86)	0.891 (0.52, 1.52)	0.6730	1.423 (0.75, 2.71)	1.608 (1.13, 2.30)	0.0090	1.715 (1.05, 2.80)

Abbreviations: CC, Carpenter-Coustan; CI, confidence interval; GDM, gestational diabetes mellitus; GCT, glucose challenge test; HTN, hypertensive; IADPSG, international association of the study of diabetes in pregnancy group; LGA, large for gestational age; OGTT, oral glucose tolerance test; OR, odd ratio.

Note: Reference group is normal group. Models for LGA, macrosomia, primary C-section, gestational HTN/preeclampsia, and perinatal trauma were adjusted for race, marital status, maternal education, mother's age at delivery, gestational age at delivery, prepregnancy weight and adjusted total maternal weight gain. The model for preterm birth did not include gestational age at delivery.

birth in this group that requires further exploration. We used ICD9 and CPT codes and were unable to determine whether the preterm births were spontaneous or indicated. Finally, none of the birth outcomes were significantly different among the women in the elevated GCT + normal OGTT compared with the normal group after adjustment. In summary, the association between adverse perinatal outcomes and the IADPSG criteria for diagnosing GDM reported across several studies remains varied.^{7,12-14} The disparity in this finding across the studies may be attributed to differences in study design (largely retrospective), glucose testing strategy, treatment (or not) of the IADPSG group, and in the prevalence of obesity and GDM in the population at the study institutions. Only future investigation with a prospective and/or randomized control trial that directly compares the IADPSG criteria and CC criteria will elucidate the association with adverse perinatal outcomes.

Women with an elevated 50 grams GCT ≥ 130 mg/dL and a normal 3-hour OGTT had similar perinatal outcomes in this study as the women with a normal 50 grams GCT (< 130 mg/dL). This differs from prior work that demonstrated that women with an elevated 50 grams GCT and normal 3-hour OGTT may still be at risk for adverse outcomes but the difference may be related to use of a comparison group with a 50 grams GCT less than 120 mg/dL in prior studies.¹⁵ The overall low risk of complications among women with a normal 50 grams GCT or abnormal 50 grams GCT and normal 3-hour OGTT suggests only a very small proportion of women would have had a normal 50 grams GCT and significantly elevated 3-hour OGTT with downstream adverse outcomes.

Women in the GDM/IADPSG group had the highest proportion of excessive weight gain during pregnancy while the GDM/CC group, elevated 50 grams + normal 100 OGTT group and normal group were lower and similar. This is likely because women in the GDM/CC group would have received dietary counseling whereas those in the GDM/IADPSG group likely did not. Excess weight gain during pregnancy is a major risk factor for weight retention postpartum and long-term metabolic risks.¹⁶ Limited weight gain in obese women with GDM perhaps is one important health benefit of GDM diagnosis as the increased detection allows for interventions that may reduce the metabolic dysfunction that leads to type 2 diabetes.¹⁷

Several limitations deserve mention. Since our institution does not routinely use the one-step 75 grams testing strategy, all women received a 100 grams OGTT and we were unable to compare the one-step and two-step strategies directly. However, the largest study comparing maternal glucose values after a 100 versus 75 grams oral glucose load at 24 to 28 weeks found that results were similar at 1 hour after the glucose load and both the one and two-hour values were significantly correlated.¹⁸ While our approach is not an exact representation of the IADPSG diagnostic criteria because women underwent a 100 grams OGTT rather a 75 grams OGTT, these data allowed us to estimate birth outcomes in women with these levels of hyperglycemia. Additionally, we may have underestimated the proportion of women who would have screened positive for GDM using

the one-step IADPSG approach because some women with a normal 50 grams GCT may have had an abnormal 75 grams OGTT. We also separated the women with a normal 50 grams GCT from those with an elevated 50 grams GCT but normal 100 grams OGTT to analyze the outcomes associated with each of these groups. There are variations in GDM screening patterns and we included women with GDM screening before 37 weeks. Our sensitivity analyses demonstrated that inclusion of these women did not affect our overall results. There were also women who could not be included because of irregular GDM screening approaches. Women diagnosed with GDM at our institution routinely receive dietary education, self-blood glucose monitoring, and medications as per clinical recommendations.¹⁹ We do not have specific information on lifestyle interventions or adherence to treatment. We had limited data on neonatal outcomes and were unable to classify preterm births into spontaneous or indicated, so the neonatal implications of preterm birth in our study are incompletely understood. Finally, we used ICD 9 and CPT procedure codes to identify outcomes and potentially underestimated the prevalence of these outcomes due to potential miscoding.

Despite these limitations, this was a large cohort of pregnant women from a clinical setting that provided sufficient perinatal variables to examine the association of GDM screening classification and fetal growth and other secondary outcomes. An important and unique feature of these analyses was that the GDM/IADPSG group was untreated and had rates of adverse birth outcomes similar to those observed in HAPO. Under the current testing strategy (two-step CC approach), this group would have been considered normal. However, if the one-step IADSPG strategy was implemented, this group and a portion of the elevated GCT + normal OGTT group most likely would have been identified as GDM and treated. The potential benefit of treating women with mild hyperglycemia should be confirmed by a randomized clinical trial designed to directly compare the two screening approaches. Findings from two NIH funded randomized controlled trials currently underway will better delineate the risks and benefits of expanding the GDM diagnostic criteria.

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Conflicts of Interest Statement

The authors report no conflicts of interest.

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