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Markedly different rates of incident insulin treatment based on universal gestational diabetes mellitus screening in a diverse HMO population

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Abstract

OBJECTIVE—We sought to evaluate population gestational diabetes mellitus (GDM) screening results and risk for incident insulin treatment.

STUDY DESIGN—Among 64,687 pregnant women universally screened for GDM from 1995 through 2010 in 2 regions of a large US health plan, we stratified women requiring insulin treatment during their pregnancy by GDM screening results (50-g glucose challenge test [GCT]), followed by a 3-hour, 100-g oral glucose tolerance test if GCT was positive. Women with GCT >200 mg/dL were evaluated separately.

RESULTS—Overall, 2% of all pregnant women required insulin treatment, ranging from 0.1% (normal GCT) to 49.9% (GCT >200 mg/dL; *P* for trend <.0001). Women with GCT >200 mg/dL had a much higher rate of insulin treatment than women with GDM (odds ratio, 3.7; 95% confidence interval, 3.1–4.4). Risk factors for higher insulin treatment rates with GDM or GCT >200 mg/dL included obesity, race/ethnicity, and diagnosed ≤16 weeks' gestation.

CONCLUSION—Our results indicate women with GCT >200 mg/dL could be reasonably treated as GDM without requiring additional oral glucose tolerance test for diagnosis.

Keywords

diagnosis; gestational diabetes; insulin; screening

Gestational diabetes mellitus (GDM), defined as carbohydrate intolerance that begins or is first recognized during pregnancy, is associated with increased maternal, fetal, and neonatal risks.[1,2] Although the clinical debate about the best screening approach for GDM diagnosis is increasingly heated, in the United States the 2-step approach (50-g glucose challenge test [GCT], followed by an oral glucose tolerance test [OGTT] if GCT is positive) is both the

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most common approach and the only GDM screening approach currently recommended by American Congress of Obstetricians and Gynecologists (ACOG).[1,2] The ACOG's rationale for 2-step screening is that current randomized clinical trial (RCT) evidence for improved outcomes with GDM treatment is based on 2 recent RCTs, both of which utilized 2-step screening.[1,3,4] Both of these 2 recent RCTs provided important evidence about treatment of mild GDM—because it was unethical to randomize women with significant hyperglycemia to no treatment. However, when making decisions about screening and diagnosis in a population, it is important to consider the entire spectrum of disease, including women with the most severe disease (in the case of GDM, women requiring insulin treatment because medical nutrition therapy has failed[2]). Among a diverse HMO population of 64,687 women universally screened for GDM from 1995 through 2010, we evaluated the proportion of women requiring incident insulin treatment based on initial GDM screening results.

Materials and Methods

Research setting

The study population was drawn from a combined membership of >650,000 at 2 regions: Kaiser Permanente Hawaii (KPH) and Kaiser Permanente Northwest (KPNW). Both regions' memberships are ~20% of the areas' general populations and reflect their demographic/sociographic characteristics.[5–9] Overallat KPH, the majority (75%) of members are non-white compared to 74% for state census.[6] For KPNW membership, 16% overall are non-white compared to 15% in the states of Oregon and Washington.[7,8] In Hawaii, low-income individuals enroll under the state health insurance plan for Medicaid, > 12% of KPH population. KPNW serves ~8% of Medicaid members through the Oregon Health Plan, a population demographically similar to the area population.[10,11] All members in both regions have access to medically necessary services from Kaiser Permanente or by referral from their primary care physician.

Both regions maintain administrative and clinical electronic databases on inpatient admissions and deliveries, outpatient visits, laboratory tests, pharmacy dispenses, chronic-disease registries, and outside claims/referrals. Institutional review boards of both Kaiser Permanente regions and the State of Hawaii Department of Health approved this study.

Sample selection

Inclusion criteria were women 18 years and older, members at KPH or KPNW through their entire pregnancy, who delivered singleton live births during 1995 through 2010 (n = 73,016). Mothers with preexisting diabetes would not be eligible for GDM screening, and were excluded from analysis when known (n = 675 [1%], based on prior diabetes diagnosis in the EMR or if listed as a medical risk factor on the birth certificate), resulting in 72,341 women potentially eligible for screening. EMR data were not available to determine preexisting diabetes status in the earlier years for both regions, and for most of the study years for KPH, so it was not possible to exclude all women with preexisting diabetes (who would be reflected in "untested"). Based on US data for women of childbearing age,[12,13] we estimate there were ≥1500 women with preexisting diabetes we could not identify (who would thus not be screened for GDM). Both regions universally screen for GDM, and among the 72,341

women, we had available GDM screening laboratory measurements on 64,687. Reasons for not screening include history of GDM in previous pregnancy (n = 624) and thus presumably treated directly without testing, preterm birth (n = 1313), and an estimated 1500 women with preexisting diagnosed diabetes we could not identify by EMR. The final study sample was 64,687.

Glucose testing and GDM diagnosis

Both KPH and KPNW universally screen for GDM, initially using a 50-g, 1-hour GCT. For those who failed the GCT (>140 mg/dL); a 100-g, 3-hour OGTT is performed to diagnose GDM. We stratified GDM screening by gestation (<24, 24–28, and >28 weeks); there were 4073 (6.3%) women who had repeat GDM screening (screened in 2 different gestational periods), and 62 women who had repeat GDM screening in all 3 gestational periods. Reasons for repeat GDM screening would be individualized but would include borderline screening the first time (eg, 1 of 4 positive OGTT glucose values), and/or later identification of conditions that may accompany GDM such as macrosomia, polyhydramnios, or persistent glucosuria. For women screenedmore than once during pregnancy, we only used 1 screening test in our analysis. We prioritized the included screening test for analysis as follows: (1) 24–28 weeks' gestation; (2) <24 weeks' gestation (some high-risk women have earlier screening and if positive are treated/not retested); and (3) >28 weeks' gestation. The average gestational age of GDM screening was 27.5 weeks' gestation (Table 1).

Both the National Diabetes Data Group (NDDG) and Carpenter and Coustan (C&C) criteria for GDM diagnosis require that ≥2 of the 4 possible glucose concentrations measured with the 100-g OGTT are positive, although they have different threshold cutoffs. The NDDG require the ≥2 values to exceed these thresholds (in mg/dL): fasting ≥105 mg/dL; 1-hour ≥190 mg/dL; 2-hour ≥165 mg/dL; and 3-hour ≥145 mg/dL The more recent C&C criteria have lower thresholds: fasting ≥95 mg/dL; 1-hour ≥180 mg/dL; 2-hour ≥155 mg/dL; and 3-hour ≥140 mg/dL.[14–16] Currently, both regions use C&C criteria. However, as our evaluation began in 1995, when both regions were using NDDG criteria, we have calculated GDM using both criteria sets. Additionally, as women with a very high initial GCT (>200 mg/dL) are typically treated clinically in our practice as presumed GDM without further OGTT,[17–19] we also evaluated this group separately. We stratified maternal glucose screening results into mutually exclusive categories: (1) normal GCT (referent group); (2) positive GCT, normal OGTT; (3) 1 abnormality on the OGTT by C&C criteria (≥2 abnormalities are required to diagnose GDM); (4) GDM by the lower C&C criteria but not by NDDG; (5) GDM by NDDG criteria; (6) women with a GCT >200 mg/dL (these women were not included in any OGTT category even if performed). For subgroup analyses, glucose screening was collapsed into 3 mutually exclusive categories: (1) no GDM (ranging from normal GCT to 1 abnormality on OGTT); (2) GDM by either C&C or NDDG criteria; (3) GCT >200 mg/dL.

Classification of incident gestational insulin use

ACOG recommends treatment with insulin when dietary management fails to maintain glycemic targets.[2] Treatment for all GDM patients in both regions is by protocol: a referral to a registered dietician for dietary counseling, instruction in home blood glucose monitoring and insulin administration (if needed), weekly review of blood sugar logs with one of our

GDM nurse case managers, and modifications to treatment regimens as determined by the supervising obstetrician. Regional protocols are similar, but also region specific. Both regions currently use the following whole blood (capillary) glucose target ranges to determine when medication initiation, or further titration, is needed: fasting glucose <95 mg/dL; either 1-hour postprandial <140 mg/dL or 2-hour postprandial glucose <120 mg/dL. If dietary intervention does not achieve glycemic goals (eg, >2 self-monitored blood glucose values exceed target range or <75% self-monitored blood glucose values in target range), GDM women in both regions receive medication treatment (insulin). Oral hypoglycemic medications are infrequently used for GDM treatment in either region. Among the 64,687 women, only a total of 99 (0.15%) women received oral hypoglycemic medications. Use was split evenly among metformin (0.08%) and sulfonylureas (0.07%). Ten women who received oral agents also received insulin. Distribution of oral hypoglycemic therapy by glucose testing group was similar to insulin therapy.

To classify incident insulin use in pregnancy, we reviewed each individual woman's entire history of pharmaceutical dispensing of insulin in our pharmacy databases, as well as with outside claims and referrals. Women for whom their first dispense of insulin occurred during the pregnancy were classified as incident insulin users.

Classification of ethnicity and other covariates

Ethnicity classification was based on the mother's reported race on the states' official birth certificates. As per state algorithms for classifying race, if the mother reported being any part Native Hawaiian, ethnicity is classified as Native Hawaiian. If she did not list Native Hawaiian, but a non-Caucasian race, then we classified the woman into that group. Race was classified as white only if no other race/ethnicity was reported. Maternal age, maternal prepregnancy weight, baby gender, and baby birth weight were recorded in the electronic medical records. State birth-certificate records were used to validate baby birth weight and also provided mother's reported parity and weight gain in pregnancy. Maternal prepregnancy measured weight was available in the EMR in a subsample of 27,017 women from both regions (the outpatient EMR was phased in at KPH starting in 2004 and at KPNW starting in 1995).

Statistical analyses

We conducted all statistical analyses using the SAS Statistical Analysis System version 9.2 (SAS Institute, Cary, NC).

We conducted all initial analyses for KPH and KPNW separately and overall. We used Pearson χ^2 and Fisher exact tests to compare incident insulin use between glucose levels. We tested increasing need for insulin treatment based on GDM screening category using the Mantel-Haenszel test for trend. All the statistical tests that we report are 2-sided; the term statistically significant implies a P value < .05.

Results

Table 1 presents characteristics of the 64,687 multiethnic pregnant women universally screened for GDM. Consistent with the overall population of the respective regions, the

Hawaii region had a minority of women who were white (16.7%), whereas white women were the majority (83.5%) in the NW region. Among the 64,687 women screened with GCT in both regions, there were 11,243 (17.4%) women who had a GCT >140 mg/dL, and 595 women (0.9%) overall who had a GCT >200 mg/dL.

Incident insulin use during pregnancy, based on maternal GCT and OGTT results

Table 2 presents the prevalence of incident insulin use during pregnancy based on maternal GDM screening results for each region separately, and combined. Consistent with a greater prevalence of high-risk racial groups for GDM in Hawaii, the overall prevalence of GDM (by C&C criteria) was 6% in Hawaii and 4.4% in the KPNW region. Moreover, the overall need for insulin use among all pregnant women was double in Hawaii vs KPNW (2.97% vs 1.25%, $P < .001$).

In both regions, women with only 1 of 4 abnormal values on OGTT (ie, not diagnostic for GDM), were >4 times as likely to need insulin if the FPG was ≥95 mg/dL, compared to an isolated postprandial (1-, 2-, or 3-hour OGTT) abnormality ($P < .0001$) (Table 2). For diagnosed GDM (2 of 4 glucose values [fasting, 1 hour, 2 hour, 3 hour] positive on OGTT), women who met NDDG-GDM criteria were more than twice as likely to need insulin compared to the “mild” GDM by C&C criteria alone (odds ratio [OR], 2.8; 95% confidence interval [CI], 2.3–3.4). Notably, women with an initial GCT >200 mg/dL were the highest-risk group for needed incident insulin use during pregnancy, with a rate that was >3 times greater than women with any diagnosed GDM (OR, 3.7; 95% CI, 3.1–4.4). Overall in both regions, 50% of women with a GCT >200 mg/dL required insulin treatment during their pregnancy (Table 2).

Sensitivity analyses in subgroups

There are several risk factors for GDM, including obesity, race/ethnicity, and obstetrical history.[2] We found that women who were obese or overweight had a much higher rate for needing insulin treatment than women with normal prepregnancy weight (Table 3). The population in general has become more obese, and we also found a small cohort effect of increased incident insulin for GDM in more recent years (Table 3). There were 610 women screened who had a known history of GDM in prior pregnancies from the EMR; the rate of insulin treatment in the current pregnancy was 35% with a history of GDM by either C&C or NDDG criteria. Moreover, women with GDM by C&C criteria in a previous pregnancy were more likely to have more severe GDM (ie, meet NDDG criteria vs C&C criteria in the current pregnancy; $P < .0001$).

The rate of insulin treatment without GDM (which includes “1 abnormal” on the OGTT) was similar among different racial/ethnic groups (Table 3). However, all high-risk racial/ethnic groups had a much higher rate of needing incident insulin treatment with GDM or GCT >200 mg/dL compared to Caucasians (Table 3). For a GCT ≥140 mg/dL, the rate of needing incident insulin treatment for Hawaiians, Filipinos, Japanese, blacks, and Chinese was 14.2%, 14.7%, 11.7%, 11.6%, and 11.2%, respectively, compared to only 7.1% for Caucasians. For a screening GCT <140 mg/dL, incident insulin treatment was similarly low in all groups (0.1–0.3%; Caucasians, 0.2%).

Women screened and diagnosed ≤16 weeks' gestation ("early GDM") had a very high rate of incident insulin use: 35% of these women with GDM required insulin treatment and 68% of these women with GCT >200 mg/dL required incident insulin treatment (Table 3). The risk of incident insulin use for women diagnosed with GDM ≤16 weeks was more than double the risk of women diagnosed with GDM 24–28 weeks' gestation (OR, 2.5; 95% CI, 2.1–3.1).

Comment

Among our population of 64,687 pregnant women universally screened for GDM, we found a significant trend for incident insulin use based on initial GDM screening results overall in the population, as well as in subgroups. Although the absolute rates of incident insulin use varied based on risk factors, women with initial GCT >200 mg/dL consistently had the highest rates of incident insulin use in all analyses—even higher than women diagnosed with GDM by a 100-g, 3-hour OGTT by either C&C or NDDG criteria.

To our knowledge, ours is the first study to evaluate the need for insulin use based on screening GCT/OGTT results in a large diverse population universally screened for GDM. A few prior studies have evaluated risk factors for needing insulin treatment for GDM, and have found fasting plasma glucose, HbA1c, earlier diagnosis in pregnancy, prepregnancy body mass index (BMI), family history of diabetes, and ethnicity were strong risk factors for need for insulin treatment for GDM.[20–23] In fact, in our population, we found higher rates of incident insulin treatment were required in women diagnosed with GDM or GCT >200 mg/dL among high-risk racial/ethnic groups, based on obesity, or earlier diagnosis in pregnancy. For women with only 1 abnormality on the OGTT, they were more likely to require insulin treatment if that abnormality was an elevated fasting glucose. However, women with GDM (>2 abnormalities) had an even higher rate of insulin than an isolated fasting abnormality so glucose values after OGTT add additional value in risk stratification.

O'Sullivan et al[24] proposed 2-step screening (initial GCT screening prior to a diagnostic OGTT) in 1973 as the preferred approach. In 1982, Carpenter and Coustan[17] published work evaluating the sensitivity and specificity of this approach in 381 women (all screened with a GCT, and an OGTT was performed if the GCT was >130 mg/dL). Based on their results, they suggested that only the middle "zone of uncertainty" on the GCT should require further OGTT.[17] Specifically, based on their results in 381 women they identified 3 diagnostic zones: a zone <135 mg/dL with <1% probability of diabetes (no further testing); a zone > 182 mg/dL, with >95% probability of diabetes (treat without further testing); and a zone of uncertainty (135–182 mg/dL) where further (OGTT) testing is required.[17]

There has been much research and debate since on the proper GCT lower cutoff to define as normal (with no further testing). However, only a few studies since have evaluated the issue of whether a high GCT could be diagnostic for GDM without further testing, with most using OGTT performance, not clinical outcomes, as the reference.[18,19,25–27] Landy et al[18] evaluated 514 women with GCT > 140 mg/dL who had OGTT (312 with normal OGTT and 202 with GDM) and identified an optimal diagnostic cutpoint of GCT >186 mg/dL, chosen based on high specificity (95.9%) and low false-positive rate (4.1%) for GDM diagnosis,

that was also associated with a significantly greater proportion of large-for-gestational-age infants compared to women with GCT 140–185 mg/dL. In contrast, Lanni and Barrett[27] evaluated 16,898 women (1972 women with GCT >140 mg/dL who also had OGTT), and concluded GCT >200 mg/dL should not be diagnostic because it predicted only 47–54% of their cases (by OGTT) correctly using either C&C or NDDG criteria, and could lead to overdiagnosis. They did not evaluate GCT screening in relation to clinical outcomes.[27] In 2006, Cheng et al[19] published an important evaluation of 14,771 pregnant women based on GCT ≥200 mg/dL (stratified by presence of GDM), and found that irrespective of GDM diagnosis, GCT ≥200 mg/dL was associated with a much higher risk of adverse maternal and perinatal outcomes. Women not diagnosed with GDM but with GCT ≥200 mg/dL, compared to women with GCT <200 mg/dL, has a higher risk of cesarean delivery (adjusted OR [aOR], 4.18), preterm delivery <32 weeks (aOR, 8.05), and shoulder dystocia (aOR, 15.14), and their neonates were more likely to have a 5-minute Apgar score <7 (aOR, 6.41).[19] These results, combined with our current population results of the profound increased rate of needed incident insulin use in women with a GCT >200 mg/dL confirm the C&C suggestion that it is reasonable to treat a markedly elevated GCT without further OGTT.

Our results do not negate the importance of GDM diagnosed by OGTT. For about 15–25% of women who fail the GCT (depending on whether the GCT cutoff used is 140 or 130 mg/dL[28]) but do not have a frankly abnormal GCT >200 mg/dL, our results also show that performing a full OGTT does help further risk stratify need for insulin treatment (as there was clearly a linear trend for proportion needing insulin treatment based on OGTT results). Moreover, with 2-step testing, only 25% of women (or less) would need a full OGTT for this risk stratification[28] (what Carpenter and Coustan[17] called the “zone of uncertainty”).

Current evidence (and clinical debate) is primarily focused on typical GDM screening at 24–28 weeks’ gestation. There is little evidence about how women diagnosed with GDM in early pregnancy differ from those diagnosed 24–28 weeks’ gestation.[29] Screening can identify previously unrecognized type 2 diabetes and the transient abnormality of glucose tolerance during pregnancy—both currently defined as gestational diabetes.[29] One Spanish study found that women diagnosed with GDM early in pregnancy had higher rates of insulin use and worse maternal and perinatal outcomes.[30] Both KPH and KPNW regions began a new quality improvement project in 2008 through 2009 to universally screen all high-risk obese women in the first trimester (with 2-step GCT/OGTT screening). Other high-risk women are also screened in the first trimester (eg, prior GDM, history of macrosomia). Among >2000 women screened ≤16 weeks’ gestation by 2010, we observed a profound increased risk of incident insulin use for women with diagnosed GDM (35%) and GCT >200 mg/dL (68%) (Table 3). Thus, our results also suggest that the practice of early GDM screening for high-risk women may be beneficial.

For GDM screening overall from 1995 through 2010, we found a significant trend for increasing insulin treatment associated with increasing hyperglycemia ($P < .0001$) (Table 2). There were 265 of the 64,687 women (0.4%) who neither had GDM nor GCT >200 mg/dL who still required insulin treatment. Why would any woman not meeting diagnostic criteria for GDM (even with a normal GCT) receive insulin treatment? First, we only analyzed 1 GDM screening result in each woman’s pregnancy. As would be expected in clinical

practice, some women had repeat GDM screening (4073 women [6.3%] in our study), and may have been diagnosed with GDM on repeat testing. Also, women with "borderline" OGTT (1 of 4 values positive) have increased risks for some GDM-associated outcomes,[9,31] and in some cases were likely followed by their providers more closely for development of hyperglycemia than women with a normal GCT. Finally, clinicians may choose to have some women start checking their blood sugars when they are diagnosed with GDM-associated conditions such as macrosomia or polyhydramnios; high blood sugars identified in this scenario are likely to be treated as they would for women with a laboratory diagnosis of GDM. Importantly, universal population GDM screening did stratify risk of incident insulin treatment, and in particular identified a high-risk group (GCT >200 mg/dL) in which half of women would require insulin.

Our study has important strengths. The population is a large multiethnic US sample of 64,687 pregnant women with universal maternal GDM screening and follow-up through birth to collect incident maternal insulin use. Our universal 2-step GDM screening program (50-g GCT; if positive, then a diagnostic OGTT) allows us to evaluate the effects of a large range of glucose levels, from normal GCT to meeting diagnostic criteria for GDM, as well as women with presumed GDM based on the first step of screening (GCT >200 mg/dL). Because the overall population rate of incident insulin use is so low (2% overall), a diverse population of our magnitude is needed to evaluate the rates of insulin use based on GDM screening results, and in subgroups. In addition to universal screening, it is also a strength for this analysis that treatment of GDM (including initiation of insulin) is per protocol in both our regions. Finally, our population also offers the design advantage of evaluating incident insulin rates in a real-world clinical setting in which the entire broader population is studied, including vulnerable ethnic and socioeconomic sectors that typically do not volunteer to participate in clinical trials, but are at great risk for GDM.

Our study also has limitations. We evaluated incident insulin use based on medication dispenses from our pharmacy, and it is possible some participants could have utilized non-Kaiser Permanente pharmacies for insulin purchases. However, any misclassification for this reason would be random, and would only result in underestimation of incident insulin rates. Because the outpatient electronic medical record was just beginning for KPNW during the study period and was not fully in place at KPH until ~2005, prepregnancy weights were available only on a subset of half of women (but still 36,671). In both regions, there was a significant trend for increasing rates of incident insulin use, with increasing maternal prepregnancy BMI: normal weight (BMI <25 kg/m^2), overweight (BMI 25–29 kg/m^2), and obese (BMI ≥30 kg/m^2). Thus, we combined results for Table 3. Because both regional protocols changed to treat women with GDM by C&C criteria in the latter years of our study, it is possible we are underestimating the need for insulin use in the GDM C&C group. However, this protocol change would neither impact insulin treatment rates for women with GDM by NDDG criteria (who were treated in all years), nor findings that women with GCT >200 mg/dL had the highest rates of requiring insulin incident treatment.

In summary, we found that there was a significant trend with hyperglycemia level at the time of GDM screening and need for incident insulin treatment. Women with GCT >200 mg/dL had the highest risk of requiring insulin, and >3 times the risk of women diagnosed with

GDM. This was true in the entire population, as well as stratified subgroups based on prepregnancy obesity, and across racial/ethnic groups. Our results indicate women with GCT >200 mg/dL could be reasonably treated as GDM without requiring additional OGTT for diagnosis. Moreover, as women diagnosed with GDM or GCT >200 mg/dL earlier in pregnancy had a much higher rate of insulin treatment, more research is needed to evaluate if "early GDM" is more severe than GDM diagnosed at 24–28 weeks' gestation.

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TABLE 1

Characteristics of study sample

Characteristic	KPH (n = 26,498) Mean (SD)	KPNW (n = 38,189) Mean (SD)	Total (n = 64,687) Mean (SD)
Maternal age, y	28.9 (5.9)	28.7 (5.5)	28.8 (5.7)
Prepregnancy BMI, kg/m^2 [a]	26.4 (6.3)	26.7 (6.4)	26.6 (6.4)
Birthweight, g	3332 (538)	3465 (542)	3411 (544)
GCT, mg/dL [b]	119.2 (29.5)	111.8 (28.5)	114.8 (29.1)
Gestational age at GCT, wk	27.7 (4.0)	27.3 (4.0)	27.5 (4.0)
Race, n (%)			
Native Hawaiian	8650 (32.6)	35 (0.1)	8685 (13.4)
White	4435 (16.7)	31,874 (83.5)	36,309 (56.1)
Japanese	2672 (10.1)	120 (0.3)	2792 (4.3)
Filipino	5571 (21.0)	254 (0.7)	5825 (9.0)
Chinese	999 (3.8)	274 (0.7)	1273 (2.0)
Other Asian/Pacific Islander	2933 (11.1)	3209 (8.4)	6142 (9.5)
Black	262 (1.0)	1645 (4.3)	1907 (3.0)
American Indian/Alaskan Native	288 (1.1)	371 (1.0)	659 (1.0)
Other	682 (2.6)	43 (0.1)	725 (1.1)
Unknown	6 (0.0)	364 (1.0)	370 (0.5)
Hispanic, n (%)			
No	22,645 (85.5)	34,221 (89.6)	56,866 (87.9)
Yes	3853 (14.5)	3968 (10.4)	7821 (12.1)
Parity, n (%)			
0	10,422 (39.3)	13,141 (34.4)	23,563 (36.4)
1	8521 (32.2)	13,258 (34.7)	21,779 (33.7)
2	4573 (17.3)	6694 (17.5)	11,267 (17.4)
≥3	2980 (11.3)	5092 (13.3)	8072 (12.5)
Baby sex, n (%)			

Characteristic	KPH (n = 26,498) Mean (SD)	KPNW (n = 38,189) Mean (SD)	Total (n = 64,687) Mean (SD)
Female	12,795 (48.3)	18,692 (49.0)	31,487 (48.7)
Male	13,703 (51.7)	19,497 (51.0)	33,200 (51.3)

BMI, body mass index; *GCT*, glucose challenge test; *KPH*, Kaiser Permanente Hawaii; *KPNW*, Kaiser Permanente Northwest.

[a] Not available prior to electronic medical record—we have BMI for 9655 (KPH) and 27,016 (KPNW) for combined total of 36,671;

[b] n = 82 women did not have GCT but had oral glucose tolerance test.

TABLE 2

Prevalence of women who newly need insulin treatment, stratified by maternal GDM screening with 2-step

KPH

Mother's glucose screening results	n	n with insulin	%
Overall	26,498	788	2.97
Normal GCT (<140 mg/dL)	20,716	11	0.05
+GCT, normal OGTT	2820	54	1.91[a]
+GCT, 1 abnormal OGTT by C&C (1 hr, 2 hr, or 3 hr, post OGTT)	931	22	2.36[a]
+GCT, 1 abnormal OGTT by C&C (Fasting ≥95 mg/dL)	109	13	11.93[a,b]
+GCT, GDM-C&C (but no GDM-NDDG)	636	123	19.34[a,b]
+GCT, GDM-NDDG	967	375	38.78[a,b]
GCT >200 mg/dL	319	190	59.56[a,b]
P value for trend[c]			< .0001

KPNW

Mother's glucose screening results	n	n with insulin	%
Overall	38,189	477	1.25
Normal GCT (<140 mg/dL)	32,023	54	0.17
+GCT, normal OGTT	2888	91	3.15[a]
+GCT, 1 abnormal OGTT by C&C (1-, 2-, or 3-h post-OGTT)	1112	9	0.81[a,b]
+GCT, 1 abnormal OGTT by C&C (fasting ≥95 mg/dL)	178	11	6.18[a,b]
+GCT, GDM-C&C (but no GDM-NDDG)	690	35	5.07[a,b]
+GCT, GDM-NDDG	1022	170	16.63[a,b]
GCT >200 mg/dL	276	107	38.77[a,b]
P value for trend[c]			< .0001

KPH and KPNW

Mother's glucose screening results	n	n with insulin	%
Overall	64,687	1265	1.96

Normal GCT (<140 mg/dL)	52,739	65	0.12
+GCT, normal OGTT	5708	145	2.54[a]
+GCT, 1 abnormal OGTT by C&C (1-, 2-, or 3-h post-OGTT)	2043	31	1.52[a,b]
+GCT, 1 abnormal OGTT by C&C (fasting	287	24	8.36[a,b]
+GCT, GDM-C&C (but no GDM-NDDG)	1326	158	11.92[a,b]
+GCT, GDM-NDDG	1989	545	27.40[a,b]
GCT > 200 mg/dL	595	297	49.92[a,b]
*P*value for trend[c]			< .0001

Excludes preexisting diabetes mellitus and multiple fetuses. Note that, as these are mutually exclusive categories for this table, GDM-C&C means "mild GDM" values that exceed C&C but did not meet GDM-NDDG (total prevalence of GDM is 2 GDM categories combined). Moreover, if woman had GCT >200 mg/dL, she was not additionally included in GDM category even if she met criteria.

C&C, Carpenter and Coustan criteria; *GCT,* glucose challenge test; *+GCT,* 1-h, 50-g GCT >*7.7* mmol/l (140 mg/dL); *GDM,* gestational diabetes mellitus (≥2 values exceed threshold by C&C or NDDG criteria); *KPH,* Kaiser Permanente Hawaii; *KPNW,* Kaiser Permanente Northwest; *NDDG,* National Diabetes Data Group criteria; *OGTT,* 100-g oral glucose tolerance test.

[a] Statistically different from normal GCT at $P < .05$ by χ^2 or Fisher exact text;

[b] Statistically different from +GCT, normal OGTT at $P < .05$ by χ^2 or Fisher exact test;

[c] *P*value for trend across all glucose groups based on Mantel-Haenszel χ^2.

TABLE 3

Relationship of glucose to incident insulin treatment in subgroups

	Glucose group			
	No GDM	**C&C GDM**	**GCT >200 mg/dL**	***P* value for trend**
Prepregnancy BMI[a]				
Normal (>18.5 but <25 kg/m^2)				
N	17,376	619	75	
Treated with insulin, %	0.1	9.5	29.3	<.0001
Overweight (25–29 kg/m^2)				
N	9050	529	102	
Treated with insulin, %	0.4	18.2	49.0	<.0001
Obese (≥30 kg/m^2)				
N	7978	799	143	
Treated with insulin, %	1.7	29.3	56.6	<.0001
Race[b]				
White				
n	34,641	1445	223	
Treated with insulin, %	0.4	14.1	39.5	< .0001
Hawaiian				
n	8137	454	94	
Treated with insulin, %	0.5	36.6	64.9	< .0001
Filipino				
n	5231	489	105	
Treated with insulin, %	0.4	27.2	58.1	< .0001
Japanese				
n	2561	200	31	
Treated with insulin, %	0.4	29.5	41.9	< .0001
Black				
n	1827	61	19	

	Glucose group			
	No GDM	C&C GDM	GCT >200 mg/dL	*P* value for trend
Treated with insulin, %	0.4	21.3	47.4	< .0001
Chinese				
n	1139	118	16	
Treated with insulin, %	0.7	23.7	62.5	< .0001
Other Asian/Pacific Islander				
n	5584	459	99	
Treated with insulin, %	0.3	17.4	51.5	< .0001
Hispanic				
No				
n	53,498	2863	505	
Treated with insulin, %	0.4	20.9	49.9	<.0001
Yes				
n	7278	452	90	
Treated with insulin, %	0.6	23.0	50.0	< .0001
Cohort				
1995 through 2002				
n	28,205	1426	285	
Treated with insulin, %	0.2	18.6	47.4	< .0001
2003 through 2010				
n	32,572	1889	310	
Treated with insulin, %	0.6	23.2	52.3	< .0001
Gestational age at screen				
≤16 wk				
n	1774	435	112	
Treated with insulin, %	5.5	34.9	67.9	< .0001
24–28 wk				
N	42,027	1860	276	

	Glucose group			
	No GDM	**C&C GDM**	**GCT >200 mg/dL**	***P* value for trend**
Treated with insulin, %	0.2	18.6	44.6	<.0001

BMI, body mass index; *C&C,* Carpenter and Coustan criteria; *GCT,* 1-h, 50-g glucose challenge test; *GDM,* gestational diabetes mellitus (≥2 values on 3-h, 100-g oral glucose tolerance test exceed threshold by C&C: fasting >95 mg/dL; 1 h >180 mg/dL; 2 h >155 mg/dL; 3 h >140 mg/dL).

[a]Only available in subset of 36,671 (27,016 Kaiser Permanente Northwest; 9655 Kaiser Permanente Hawaii) for which EMR prepregnancy weights were measured (Kaiser Permanente Hawaii did not implement EMR until 2004 through 2005);

[b]Race groups including American Indian/Alaskan Native (n = 288), other (n = 682), and unknown (6) are not included—when they are categorized according to glucose groups, cell sizes become too small for stable estimation.