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Risk stratification of women with gestational diabetes mellitus using mutually exclusive categories based on the International Association of Diabetes and Pregnancy Study Groups criteria for the development of postpartum dysglycaemia: a retrospective cohort study

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ABSTRACT

Objectives Women with gestational diabetes mellitus (GDM) are more predisposed to develop postpartum diabetes mellitus (DM). This study aimed to estimate the relative risk (RR) of postpartum dysglycaemia (prediabetes and DM) using mutually exclusive categories according to the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria cut-off points in patients with GDM, so as to establish a risk-stratification method for developing GDM management strategies.

Design, setting and participants In this retrospective cohort study, 942 women who had been diagnosed with GDM (IADPSG criteria) at 24–28 weeks of gestation from November 2016 to April 2018 underwent a 75 g oral glucose tolerance test (OGTT) at 6–12 weeks postpartum in a tertiary hospital of Singapore. Seven mutually exclusive categories (three one timepoint positive categories (fasting, 1 hour and 2 hours), three two timepoint positive categories (fasting+1 hour, fasting+2 hours and 1 hour+2 hours) and one three timepoint positive category (fasting+1 hour+2 hours)) were derived from the three timepoint antenatal OGTT according to the IADPSG criteria. To calculate the RRs of postpartum dysglyceamia of each mutually exclusive group, logistic regression was applied.

Results 924 mothers with GDM, whose mean age was 32.7±4.7 years, were mainly composed of Chinese (45.4%), Malay (21.7%) and Indian (14.3%) ethnicity. The total prevalence of postnatal dysglycaemia was 16.7% at 6–12 weeks postpartum. Stratifying subjects into seven mutually exclusive categories, the RRs of the one-time, two-time and three-time positive groups of the antenatal OGTT test were 1.0 (Ref.), 2.0 (95% CI=1.3 to 3.1; p=0.001) and 6.7 (95% CI=4.1 to 10.9; p<0.001), respectively, which could be used to categorise patients with GDM into low-risk, intermediate-risk and high-risk group.

Conclusions Mutually exclusive categories could be useful for risk stratification and early management of patients with prenatal GDM. It is plausible and can be easily translated into clinical practice.

Strengths and limitations of this study

- The study population comprised multiethnic mothers with gestational diabetes mellitus (GDM) with a 16.7% prevalence of postnatal dysglycaemia at 6–12 weeks postpartum.
- The value of this study lies in the layout of a new possible risk-stratification method for women with GDM based on a large cohort size.
- Seven mutually exclusive categories were formed based on possible combinations of positive results from the antenatal oral glucose tolerance test using International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria, which avoided the overlapping of diagnosed indicators and selection bias.
- The categorisation method was only suitable for diagnosing patients with GDM using IADPSG criteria and may not extend to other populations.

INTRODUCTION

Defined as 'glucose intolerance with onset or first recognition during pregnancy after exclusion of cases with overt diabetes',[1] gestational diabetes mellitus (GDM) has become an emerging global epidemic with significant public health burden. The prevalence of GDM has risen by more than a third within the last two decades.[2 3] Literature has shown that GDM is not only associated with significant

obstetric complications[4 5] but also substantial short-term and long-term adverse health outcomes for the mothers and infants.[4 6 7] Previous studies have demonstrated much of this risk is related to the degree of glycaemic control during the pregnancy[8] and early interventions can ensure better health outcomes.

Although glucose homoeostasis is restored back to prepregnancy levels shortly after delivery, women with GDM still remain at a high risk of developing type 2 diabetes mellitus (T2DM) in the future.[9 10] Notably, the risk of developing T2DM after GDM tended to increase linearly with the duration of follow-up, with a linear rise in risk of 9.6 per 1000 for every additional year of follow-up after GDM.[11] Therefore, women with a history of GDM are recommended to be tested 6–12 weeks postpartum to determine their postnatal glycaemic status.[12] It serves as an ideal timepoint to provide early interventions that can aid achieving better future health outcomes.[11] However, a systematic review revealed disappointingly low rates (35.0%) of attendance for postnatal follow-up 12 weeks after delivery.[13] Some evidence underlines the importance of early identification of GDM and its subsequent treatment to promote maternal–foetal health.[14 15] Thus, patients with antenatal GDM may be a key target population in efforts to prevent the future development of diabetes as mothers with GDM access antepartum care more readily than postpartum care, which illustrates that more effective management strategies are necessitated for them at the antenatal stage.

In 2013, the WHO adopted the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria, which are now widely used around the world.[16] As a corollary, the lower glucose cut-off values and inclusive diagnosis criteria (crossing the threshold for one of the three timepoints is sufficient for diagnosis) have led to higher prevalence and heterogeneity of GDM among pregnant women. Thereby, a greater proportion of patients with GDM are identified as high risk and treated with a one-size-fits-all management plan that includes additional education, lifestyle modification and pharmacologic therapy. However, intervening in a greater proportion of women with GDM has not resulted in an overall reduction in pregnancy complications,[17–19] yet has expanded the overall costs of GDM care[17] and the psychosocial burden on affected women.[20] The STRONG Study[21] assessed the risk of adverse neonatal outcomes in women with GDM by identifying subgroups of women at higher risk to recognise the characteristics most associated with an excess of risk. It concluded that a deep investigation of the factors associated with adverse neonatal outcomes requires a risk stratification to identify subgroups of women at higher risk. This could lead to an improvement in the level of care with cost reduction and better resource allocation.[21] In the same way, research should be done to develop risk stratification of mothers with early GDM and determine the priority, cost effectiveness and acceptability in clinics and in public health for preventing T2DM in the future.

Recently, numerous studies have been increasingly performed to determine if there are effective predictive indicators of mothers with GDM for postpartum hyperglycaemia, for example, HbA1c, fasting plasma glucose (FPG) and 2-hour plasma glucose (2hPG). Due to the overlap between group-specific distributions of the multiple blood glucose values, these studied results showed large heterogeneity.[22–24] A current Canada study categorised mothers with GDM into two subtypes (GDM-sensitivity and GDM-secretion) to evaluate the incident prediabetes/diabetes in the first year postpartum. However, these subtypes of GDM do not differ in their identification of future risk of diabetes.[25] This retrospective cohort study aimed to estimate the relative risk (RR) of postpartum dysglycaemia using mutually exclusive categories according to the IADPSG criteria thresholds for the three timepoints in the antenatal oral glucose tolerance test (OGTT). This enables us to establish a risk-stratification method for delivering graded management and individualised interventions for patients with GDM.

METHODS

Study design

The retrospective cohort study included pregnant women who underwent GDM screening when offered at KK Women's & Children's Hospital (KKH), a tertiary hospital in Singapore providing obstetrics and gynaecology services, including approximately 11 000 deliveries per year.

Of the 17 486 women who gave birth from November 2016 to April 2018 in the tertiary hospital of Singapore, 13 169 women (75.3%) underwent a 75 g OGTT at 24–28 weeks of gestation and 16.8% of them (2215 cases) were diagnosed with GDM using the IADPSG criteria.[26] Overall, 1000 (45.1%) mothers with GDM, who were followed up and investigated with a 75 g OGTT at 6–12 weeks postpartum in KKH, were included in our cohort study. All patients with GDM were given a 6-week postnatal appointment to perform an OGTT and for a review after. No significant difference was observed in the characteristics of the women with GDM (age, ethnicity and body mass index (BMI) at first visit) between those who attended and who did not attend the follow-up at 6–12 weeks postpartum. After exclusion of women with a history of prediabetes or pre-existing diabetes mellitus (DM) and multiple gestations, the overall sample size derived was 942.

Data collection and criteria

PG levels were measured by means of enzymatic methods, after samples were spun down using a centrifuge. The type of analyser was Abbott Alinity c (Abbott, USA). Demographic and clinical features of patients, such as mother's age (years), ethnicity, height at first visit (m), weight at first visit (kg), parity, gestational age at delivery (weeks), gender of child and birth weight (g), were extracted from the Outpatient Admission System and Electronic Health

Table 1 The venous plasma glucose cut-off points (mmol/L) of IADPSG criteria and WHO criteria

Timepoint (hour)	IADPSG (GDM)*	WHO (DM)*	WHO (IFG)†	WHO (IGT)†
0 (fasting)	≥5.1	≥7.0	6.1–6.9	<7.0
1	≥10.0	–	–	–
2	≥8.5	≥11.1	<7.8	7.8–11.0

*Diagnoses were determined when any one value met its threshold.
†Diagnoses were determined when both values met their thresholds.
DM, diabetes mellitus; GDM, gestational diabetes mellitus; IADPSG, International Association of Diabetes and Pregnancy Study Groups; IFG, impaired fasting glucose; IGT, impaired glucose tolerance.

Intelligence System databases. BMI was calculated as weight in kg divided by the square of height in m. Considering BMI data missing rate was over 20%, the comparison of GDM women's characteristics were made between those with and without BMI data in order to estimate the impact on the results of this study. During extraction, all data were anonymised with no patient identifiers.

The diagnoses of GDM through the antenatal OGTT was determined using modified IADPSG criteria.[26] DM and prediabetes, including impaired fasting glucose (IFG) and impaired glucose tolerance (IGT), in the postnatal OGTT were established using the glycaemic thresholds from the WHO criteria (table 1).[27]

Statistical analyses

Seven mutually exclusive categories were formed based on possible combinations of positive results from the antenatal OGTT. Overall, there were three one timepoint positive categories (fasting, 1 hour and 2 hours), three two timepoint positive categories (fasting+1 hour, fasting+2 hours and 1 hour+2 hours) and one three timepoint positive category (fasting+1 hour+2 hours).

The data are presented as means with SD for continuous variables and as numbers with percentages for categorical variables. While the χ^2 test was used to compare categorical variables, Student's t-test and ANOVA were used for the comparison of continuous variables. The Mann-Whitney U test and Kruskal-Wallis test were employed to analyse non-normally distributed data. To calculate the RR of postpartum prediabetes and DM and 95% CIs of each mutually exclusive group, logistic regression was applied. Factors with a p value<0.2 on the univariate analysis were used as adjusted factors in a multivariate logistic regression analysis. The single fasting timepoint positive category was set as the reference in the analysis as this group was related to the lowest incidence of postpartum dysglycaemia. P values<0.05 were considered statistically significant. Analyses were performed using IBM SPSS Statistics for Windows, V.24.0 (IBM Corp., Armonk, New York, USA).

Patient and public involvement

No patients involved.

RESULTS

Overview of patient characteristics

In this present study, the mean age of the 924 mothers with GDM was 32.7±4.7 years. The ethnicity of most women was Chinese (45.4%), followed by Malay (21.7%) and Indian (14.3%). For the antenatal GDM cases, the mean FPG was 4.7±0.8 mmol/L, 1hPG was 10.6±1.6 mmol/L and 2hPG was 8.5±1.7 mmol/L. Demographic and clinical features of patients were as depicted in table 2.

Overview of antenatal GDM and prevalence of postnatal dysglycaemia

The total prevalence of postnatal dysglycaemia was 16.7% (157/942). Of all the mothers with GDM, 7 (0.7%) women developed IFG, 117 (12.4%) developed IGT and 33 (3.5%) developed type 2 diabetes.

As illustrated in table 3, the proportion of women who met the glycaemic thresholds for one, two or three timepoints of the antenatal OGTT on the basis of IADPSG criteria were 56.5% (532/942), 31.6% (298/942) and 11.9% (112/942), respectively.

Among the women diagnosed with postnatal dysglycaemia through the postpartum OGTT 6–12 weeks after the delivery, 35.0% (55/157), 36.3% (57/157) and 28.7% (45/157) of them were derived from the abovementioned groups, respectively. Similarly, the prevalence of postnatal dysglycaemia were 10.3%, 19.1% and 40.2% in those respective categories.

Univariate and multivariate analysis

In comparison with the women with postnatal euglycemia, those diagnosed with postnatal dysglycaemia had a significantly higher mean age (t=−2.054, p=0.04) and proportion of primiparous mothers (χ^2=9.046, p=0.011). However, no significant difference was discernible in terms of ethnicity, BMI at first visit, gestational age at delivery, gender of infants and birth weight between the two aforementioned groups (table 4).

Logistic regression models were constructed for mutually exclusive antenatal GDM groups, as illustrated in table 5. In model 1, the group of women with isolated fasting timepoint abnormality was used as the reference and the RR of postpartum glucose abnormality of the other categories ranged from 6.8 to 44.5 (p=0.000–0.065). The RRs of the one-time, two-time and three-time positive groups of the antenatal OGTT test were 1.0 (Ref.), 2.0 (95% CI=1.3 to 3.1; p=0.001) and 6.7 (95% CI=4.1 to 10.9; p<0.001), respectively. Factors with a p value of <0.2 on the univariate analysis were used as adjusted factors, namely age (continuous), ethnicity and parity.

According to the level of RRs of postpartum glucose abnormality, the one-time, two-time and three-time positive groups were assigned as low-risk, intermediate-risk and high-risk groups (table 6). Except for mother's

Table 2 Characteristics of the patient cohort of 942 mothers with GDM

Characteristics of mothers with GDM	Number	Mean±SD or % for Ethnicity*
Age (years)	942	32.7±4.7
Ethnicity		
Chinese	417	45.4
Indian	131	14.3
Malay	199	21.7
Others	171	18.6
Missing	24	2.5
BMI at first visit (kg/m^2)	701	27.4±5.6
<18.5	15	2.1
18.5–24.9	245	34.9
25–29.9	235	33.5
≥30	206	29.4
Missing	241	
Parity		
1	419	45.6
2	307	33.4
≥3	192	20.9
Missing	24	2.5
Gestational age at delivery (weeks)	918	37.8±1.8
Gender of infants		
Male	473	51.6
Female	443	48.4
Missing	26	2.8
Birth weight (g)	918	3073.0±519.5
Missing	24	
Antenatal OGTT (mmol/L)		
FPG	942	4.7±0.8
1hPG	942	10.6±1.6
2hPG	942	8.5±1.7
Postnatal OGTT (mmol/L)		
FPG	942	4.8±0.8
2hPG	942	6.4±2.1

*Valid percentages were calculated and missing data were excluded.
BMI, body mass index; FPG, fasting plasma glucose; GDM, gestational diabetes mellitus; 1hPG, 1-hour plasma glucose; 2hPG, 2-hour plasma glucose; OGTT, oral glucose tolerance test.

age and parity, there were significant gradient increases in the risk factors of postnatal dysglycaemia (including Indian ethnicity, BMI at first visit and three antenatal OGTT timepoints) in women with GDM among low-risk, intermediate-risk and high-risk groups (p=0.001–0.014).

DISCUSSION

In our cohort of women diagnosed with GDM, postpartum diagnoses of prediabetes and T2DM were drawn in 13.2% and 3.5%, respectively. Categorised by the number of positive timepoints for the antenatal OGTT test based on IADPSG criteria, the women with GDM can be stratified into low-risk, intermediate-risk and high-risk groups, according to the RR of postpartum dysglycemia 6–12 weeks after delivery. It was found that higher risk groups were significantly predominated by patients with GDM who were of Indian ethnicity, possessed higher BMI or had higher antepartum OGTT values at all three timepoints (p=0.000–0.014). Given that Asian Indians have worse insulin resistance and glucose tolerance than Chinese and Malays[28] and that higher BMI and higher antepartum OGTT values are well-established risk factors for glycaemic abnormalities,[29] the results suggest that the risk-stratification method was effective. Although there were no significant differences in mother's age and parity, which were reported to be risk factors for glycaemic abnormalities in previous studies,[29] among the three risk-stratified groups, potential complexity of inter-related factors in this study's multiracial cohort may underlie this finding.

A systematic review covering 54 studies from 1990 to 2011 reported that the average follow-up rate for patients with GDM up to 12 weeks after delivery in usual care was only 35.0%. Even in active care, the average follow-up rate was still relatively modest at 64.8%.[13] In addition to the reasons associated with clinicians and healthcare system, the mothers' paucity of time to perform the glucose test and lack of knowledge that they are at higher risks of postpartum dysglycemia aggravate the poor uptake rate of follow-up after delivery.[30 31] Therefore, it may be more ideal and feasible, at an antepartum stage, to educate women with GDM about their future risk for T2DM to enhance their healthcare awareness and health management. On the other hand, early risk stratification spares low-risk patients from unnecessary medical care while ensuring knowledge of diabetes and preventative interventions are delivered adequately to women in high-risk categories.[32] In this study, it was observed that the greater the number of positive antenatal OGTT timepoints, the higher the RR, concordant with a large retrospective cohort study conducted in Canada.[33] Based on our results, patients with antenatal GDM could be stratified into high-risk, intermediate-risk and low-risk groups according to the risk levels (RR=6.7, 2.0 and 1.0 (Ref.) in three, two and one timepoint positive OGTT test groups, respectively) of postpartum dysglycaemia. In this case, even if only the 43.5% of patients with antenatal GDM (high-risk and intermediate-risk groups) are closely followed up on, 65% of postnatal dysglycaemia can be tracked. The follow-up rate (65%) of postnatal dysglycaemia was similar to the active care results (64.8%) of the systematic review mentioned above,[13] and this form of stratified management strategy for patients with GDM is likely to be more cost-effective. A recent study[34] documented that

Table 3 Proportions of antenatal GDM and prevalence of postnatal dysglycaemia by mutually exclusive categories

	Antenatal GDM		Postnatal dysglycaemia		
Antenatal OGTT	n	Proportion (%)	n	Proportion (%)	Prevalence (%)
One timepoint positive group	532	56.5	55	35.0	10.3
Fasting	61	6.5	1	0.6	1.6
1 hour	302	32.1	36	22.9	11.9
2 hours	169	17.9	18	11.5	10.7
Two timepoint positive group	298	31.6	57	36.3	19.1
Fasting+1 hour	71	7.5	10	6.4	14.1
Fasting+2 hours	7	0.7	2	1.3	28.6
1 hour+2 hours	220	23.4	45	28.7	20.5
Three timepoint positive group	112	11.9	45	28.7	40.2
Fasting+1 hour+2 hours	112	11.9	45	28.7	40.2
Total	942	100	157	100	16.7

GDM, gestational diabetes mellitus; OGTT, oral glucose tolerance test.

a set of known risk factors could identify subgroups of GDM women with a from twofold to fivefold higher risk of developing dysglycemia compared with the reference class, which was similar to our current study. However, comparing their collections of a set of risk factors (including OGTT value, insulin treatment, prepregnancy BMI and family history of diabetes), it could be easier for clinicians to distinguish risk levels by judging whether the IADPSG thresholds of the three timepoints are attained in our study.

Recently, numerous studies have been increasingly performed to determine if there are effective predictive indicators for postpartum hyperglycaemia. In a Swedish study,[22] the HbA1c and FPG values during pregnancy

Table 4 Comparison of the characteristics of women with GDM diagnosed with postnatal dysglycaemia versus postnatal normoglycaemia

	Postnatal prediabetes+DM		Postnatal normoglycaemia			
Maternal characteristics	N	Mean±SD or %	N	Mean±SD or %	Statistics*	P value
Age (years)	157	33.4±4.3	785	32.6±4.8	−2.054	0.040
Ethnicity						
Chinese	80	53.0	337	43.9	4.705	0.195
Indian	21	13.9	110	14.3		
Malay	28	18.5	171	22.3		
Others	22	14.6	149	19.4		
BMI at first visit (kg/m^2)	116	28.1±6.1	585	27.3±5.4	−0.170	0.284
Parity						
1	79	52.3	340	44.3	9.046	0.011
2	54	35.8	253	33.0		
≥3	18	11.9	174	22.7		
Gestation Age (GA) of delivery (weeks)	151	37.7±2.0	767	37.9±1.8	−0.725	0.469
Babies gender						
Male	85	56.3	388	50.7	2.298	0.317
Female	66	43.7	377	49.2		
Birth weight (g)	151	3074.4±562.9	765	3072.7±510.9	−0.274	0.784

*Student's t-test was employed for comparing continuous variables, while the χ^2 test was used to compare categorical variables. The Mann-Whitney U test was performed to analyse non-normally distributed data.
BMI, body mass index; DM, diabetes mellitus; GDM, gestational diabetes mellitus.

Table 5 The relative risk (RR) of postpartum dysglycaemia and 95% CIs of each mutually exclusive group*

	Model 1*			Model 2†			
Antenatal GDM group	**RR**	**95% CI**	**P value**	**RR**	**95% CI**	**P value**	**Risk grade**
One timepoint positive group							
Fasting (n=61)	**1.0**	**Ref.**					
1 hour (n=302)	8.2	1.1 to 61.1	0.041	**1.0**	**Ref.**		Low risk
2 hours (n=169)	6.8	0.9 to 52.6	0.065				
Two timepoint positive group							
Fasting+1 hour (n=71)	10.3	1.3 to 83.8	0.025				
Fasting+2 hours (n=7)‡	31.0	2.3 to 423.6	0.010	2.0	1.3 to 3.1	0.001§	Intermediate risk
1 hour+2 hours (n=220)	14.5	1.9 to 107.9	0.009				
Three timepoint positive group							
Fasting+1 hour+2 hours (n=112)	44.5	5.9 to 335.4	<0.001	6.7	4.1 to 10.9	<0.001§¶	High risk

*Adjusted by mother's age (continuous), ethnicity and parity.
†One timepoint positive group (including fasting, 1 hour and 2 hours positive groups) was set as the reference group.
‡Considering the small number cases in the group of fasting+2 hours, the groups fasting+1 hour and fasting+2 hours were combined (n=78), and the RR of postpartum dysglycaemia was determined to be 11.7 (95% CI 1.5 to 93.0).
§Compared with reference group, p<0.01.
¶Compared with two timepoint positive group, p<0.01.
GDM, gestational diabetes mellitus.

were observed to be independent predictors in women developing diabetes within 5 years postpartum. HbA1c and 2hPG levels, rather than FPG levels, were found to be associated with the development of diabetes postpartum in another study from Japan.[23] Evidence from large-scale population studies has consistently shown

Table 6 Comparison of the risk factors of postnatal dysglycaemia in women with GDM by groups

	Low-risk group		Intermediate-risk group		High-risk group			
	N	**Mean±SD or %**	**N**	**Mean±SD or %**	**N**	**Mean±SD or %**	**Statistics***	**P value**
Age (years)	532	32.6±4.9	298	32.9±4.6	112	32.6±4.4	0.44	0.801
Ethnicity								
Chinese	251	48.5	129	44.8	37	33.0	16.02	0.014
Indian	60	11.6	44	15.3	27	24.1		
Malay	109	21.0	62	21.5	28	25.0		
Others	98	18.9	53	18.4	20	17.9		
BMI at first visit (kg/m^2)	384	26.9±5.3	234	27.2±5.6	83	30.5±5.7†	29.12	<0.001
Parity								
1	226	43.6	137	47.6	56	50.0	4.54	0.338
2	188	36.3	87	30.2	32	28.6		
≥3	104	20.1	64	22.2	24	21.4		
Antenatal OGTT (mmol/L)								
FPG	532	4.5±0.5	298	4.7±0.6†	112	6.1±1.1†‡	286.56	<0.001
1hPG	532	9.9±1.1	298	11.1±1.1†	112	12.9±2.1†‡	332.76	<0.001
2hPG	532	7.7±1.2	298	9.0±1.2†	112	10.9±2.0†‡	347.29	<0.001

*While Analysis of Variance (ANOVA) was employed for comparing continuous variables, the χ^2 test was used to compare categorical variables. The Kruskal-Wallis test was performed to analyse non-normally distributed data.
†Compared with low-risk group, p<0.001.
‡Compared with intermediate-risk group, p<0.001.
BMI, body mass index; FPG, fasting plasma glucose; GDM, gestational diabetes mellitus; 1hPG, 1-hour plasma glucose; 2hPG, 2-hour plasma glucose; OGTT, oral glucose tolerance test.

that the 1hPG≥155 mg/dL (8.6 mmol/L) during the OGTT may detect incident T2DM and associated complications better than FPG or 2hPG levels.[24] These heterogeneous results may be caused by the overlap between group-specific distributions of the multiple blood glucose values. Hence, the notion that compared with single predictors, combined predictors are better for risk assessment and patient selection has become a consensus recently.[35 36] Although there are no clear advantages of one glucose measurement timepoint over the other, due to the frequent rate of discordance between measurements, simultaneous readings may prevent unspecific treatments and adverse outcomes.[37] In this study, the categories were determined by FPG and 1-hour and 2-hour post-load PG thresholds simultaneously based on IADPSG criteria, which can reduce potential misclassification caused by overlapping distributions for single predictors.

Defects in fasting and postprandial glucose metabolism are precipitated by different mechanisms.[38] In a recent review, it was concluded that hepatic insulin resistance is a dominant feature in isolated IFG and peripheral insulin resistance is a characteristic of those with isolated IGT.[39] Several interventional studies have furnished epidemiological evidence for these. For example, a fasting blood glucose abnormality was determined to be a positive predictor for insulin therapy,[40–42] whereas a 2-hour glucose derangement was significantly associated with diet therapy and reduced risk of insulin usage.[40] Furthermore, it has been shown in healthy Australian adults that physical activity was associated with reduced 2hPG but not FPG.[43] These findings highlight that personalised management for patients with antepartum GDM may be plausible. For the potentially tailored antepartum management of GDM, a current Canada study sought to evaluate glycaemia and incident prediabetes/diabetes in the first year postpartum in relation to GDM subtypes (GDM-sensitivity and GDM-secretion). However, these subtypes of GDM do not differ in their identification of future risk of diabetes.[25] It is known, after pregnancy, that chronic beta-cell dysfunction and the worsening thereof over time is the pathophysiologic basis for the development of prediabetes and diabetes in women with previous GDM.[44 45] The mutually exclusive categories in this study, formed by various positive OGTT timepoint combinations, may represent different stages of defective glucose metabolism in patients with antenatal GDM. Such stages have been demonstrated to be associated with different levels of insulin sensitivity and beta-cell dysfunction, leading to various outcomes in terms of T2DM.[36 46] This relationship between the mutually exclusive categorisation of patients with GDM in our study and different stages of beta-cell dysfunction could possibly form the basis for personalised management for preventing T2DM postpartum. Although the mechanisms and impact of each category in the clinic were not clear, the specific intervention methods for targeted categories, which have been proven to be effective and economical, would be valuable and helpful for the health promotion of mothers with GDM.

The value of this study lies in the layout of a new possible risk-stratification method for women with GDM based on a large cohort size, which avoided the overlapping of diagnosed indicators and selection bias. Nonetheless, there were several limitations to this study. The categorisation method was only suitable for diagnosing patients with GDM using IADPSG criteria and may not extend to other populations. Despite the large total sample cohort, the size of the reference group (FPG group) was relatively small, resulting in large 95% Cls of RR for the other OGTT timepoint groups. However, this did not affect the interpretation of our results since the ranks of RRs for postpartum dysglycaemia in other categories were not altered. In addition, data missing rate of BMI at first visit was over 20% due to data insufficiency. Although there were more women of Malay ethnicity in the women with BMI data than those without BMI data, no difference was observed in ethnicity distribution between postnatal dysglycaemia group and postnatal normoglycaemia group in the women with/without BMI data. As such, its impact on the results of this study was limited. On the other hand, because of the retrospective study design, we did not have information on certain risk factors for postnatal dysglycaemia such as income, education, family history of diabetes and clinical factors (eg, weight gain). Therefore, although we attempted to control for several important confounding variables, residual confounding could not be ruled out.

CONCLUSION

In conclusion, mutually exclusive categories based on the antenatal OGTT could be advantageous for risk stratification and personalised management of patients with antenatal GDM. Such a risk stratification strategy is feasible, likely more cost-effective and easily translatable into clinical practice, making it especially suitable for low-income and medical resource-poor areas.

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