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Impact of Time since Last Meal on the False Positive Result of 50 grams Glucose Challenge Test in the Pregnancy with Gestational Diabetes Mellitus Risk: A prospective cohort study

Suphawan Pattamathamakul, M.D.*,
Srisuda Songthamwat, M.D.*,
Ueamporn Summart, Ph.D.*,
Angkana Hansri, B.Sc.(M.T.)**,
Metha Songthamwat, M.D.*

** Department of Obstetrics and Gynecology, Udonthani Hospital, Udonthani, Thailand.*
*** Department of Medical Technology, Udonthani Hospital, Udonthani, Thailand.*

ABSTRACT

Objectives: To study the impact of time since last meal to the rate of false positive 50 grams glucose challenge test (GCT) during pregnancy with gestational diabetes mellitus (GDM) risk.

Materials and Methods: This prospective observational study was conducted in a tertiary care from December 2019 to August 2020. The participants were the singleton who had risks of GDM. The screening test was done using 50 grams GCT and then 100 grams oral glucose tolerance test (OGTT) used for diagnosis of GDM if GCT was ≥ 140 mg/dL. The participants' information, time and type of last meal, time of 50 grams glucose intake and blood drawing, result of GCT and OGTT were recorded. The time since last meal was categorized to < 1, < 2 and < 3 hours. Bivariate and multivariable regression analysis were applied to evaluate the effect of time since last meal to GCT.

Results: There were 426 pregnant women completed study: 30.75% had positive GCT and 19% of these were diagnosis for GDM. The time since last meal < 1, < 2, and < 3 hours group had 36.0, 29.8, and 25.8 % false-positive CGT compared with 20.8, 18.2, 20.3% of ≥ 1, ≥ 2, and ≥ 3 hours group. The adjusted risk ratio (95% confidence interval) were 1.60 (1.14-2.24), 1.53 (1.06-2.22) and 1.23 (0.75-2.04) and p value were 0.006, 0.023, and 0.397, respectively.

Conclusion: The interval between the last meal and GCT less than 2 hours significantly increased a false positive rate of the test.

Keywords: false-positive, glucose challenge test, gestational diabetes mellitus, last meal intake.

Correspondence to: *Suphawan Pattamathamakul, M.D., Department of Obstetrics and Gynecology, Udonthani Hospital, Udonthani 41000, Thailand. E-mail: garino66@gmail.com*

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ผลกระทบของระยะเวลาหลังอาหารมื้อสุดท้ายกับการเกิดผลบวกลวงจากการตรวจคัดกรองเบาหวานระหว่างตั้งครรภ์

ศุภวรรณ ปัทมธรรมกุล, ศรีสุดา ทรงธรรมวัฒน์, เอื้อมพร สุ่มมาตย์, อังคณา หารศรี, เมธา ทรงธรรมวัฒน์

บทคัดย่อ

วัตถุประสงค์: *เพื่อศึกษาผลกระทบของระยะเวลาหลังอาหารมื้อสุดท้ายก่อนตรวจคัดกรองเบาหวาน 50 กรัม glucose challenge testในสตรีตั้งครรภ์ที่มีความเสี่ยงเบาหวานต่อการเกิดผลบวกลวง*

วัสดุและวิธีการ: *งานวิจัยแบบศึกษาไปข้างหน้าในสถานพยาบาลตติยภูมิตั้งแต่ธันวาคม 2562 ถึง สิงหาคม 2563 โดยทำการศึกษาในสตรีตั้งครรภ์เดี่ยวที่มีความเสี่ยงในการเกิดภาวะเบาหวานระหว่างตั้งครรภ์ที่มาฝากครรภ์และได้รับการตรวจด้วยการคัดกรองด้วยวิธี 50 g GCT หากผลตรวจคัดกรองผิดปกติ (≥ 140 mg%) จะได้รับการตรวจวินิจฉัยภาวะเบาหวานด้วยวิธี 100g oral glucose tolerance test (OGTT) โดยการซักประวัติมารดาที่เข้าร่วมงานวิจัยเกี่ยวกับข้อมูลทั่วไป เวลาที่รับประทานมื้อสุดท้าย ชนิดและปริมาณของอาหารที่รับประทาน เวลาที่ได้รับการกลืนน้ำตาลและเวลาที่ได้รับการเจาะเลือด โดยระยะเวลาหลังอาหารมื้อสุดท้ายจะแบ่งเป็น < 1, < 2 และ < 3 ชั่วโมง ผลลัพธ์ของการตรวจจะถูกบันทึกและนำมาวิเคราะห์เพื่อหาผลกระทบและความสัมพันธ์ของระยะเวลาหลังอาหารมื้อสุดท้ายต่อระดับน้ำตาลและผลบวกลวงโดยใช้การคำนวณทางสถิติ bivariate and multivariable regression*

ผลการศึกษา: *สตรีตั้งครรภ์ที่เข้าร่วมงานวิจัยทั้งหมด 426 คน มีร้อยละ 30.75 ที่ตรวจคัดกรองได้ผลผิดปกติ ในกลุ่มนี้พบว่าร้อยละ 19 ได้รับวินิจฉัยภาวะเบาหวาน และเมื่อเปรียบเทียบความสัมพันธ์ของระยะเวลาจากอาหารมื้อสุดท้ายก่อนได้รับการตรวจคัดกรองเบาหวานพบว่าที่เวลา < 1,< 2 และ < 3 ชั่วโมง มีผลบวกลวงจากการตรวจร้อยละ 36.0, 29.8 และ 25.8 เทียบกับที่เวลา ≥ 1, ≥ 2 และ ≥ 3 ชั่วโมงที่มีผลบวกลวงร้อยละ 20.8, 18.2 และ 20.3 ตามลำดับ จากการวิเคราะห์แบบ multivariable regression analysis พบว่ามีค่า adjusted risk ratio 1.60 (1.14-2.24), 1.53 (1.06-2.22) และ 1.23 (0.75-2.04), มีค่า p value เท่ากับ 0.006, 0.023, and 0.397 ตามลำดับ*

สรุป: *ช่วงเวลาหลังอาหารมื้อสุดท้ายมีผลต่อตรวจต่อการคัดกรองเบาหวาน GCT พบว่าที่เวลาน้อยกว่าสองชั่วโมงเป็นต้นไปทำให้เพิ่มผลบวกลวงของการตรวจคัดกรองเบาหวานอย่างมีนัยสำคัญทางสถิติ*

คำสำคัญ: *ผลบวกลวง, การคัดกรองเบาหวาน, ภาวะเบาหวานขณะตั้งครรภ์, มื้ออาหาร*

Introduction

Gestational diabetes mellitus (GDM) is a common problem that effects both maternal and fetal health during pregnancy. The effects include increased risk of fetal macrosomia, fetal anomaly, shoulder dystocia, cesarean delivery rate, fetal death and further overt DM in both the mother and the newborn[1, 2]. In Thailand, the prevalence rate of GDM is reported as between 1.5-9.3%[3-7] compared with a prevalence rate in the United State of 9.2%[8].

There is no consensus on a standard GDM diagnostic tools and this has had an effect to the variation in diagnosis criteria, screening and management by different medical centers[9-12]. Two-step approach for diagnosis of GDM, consists of a 1 hour 50 grams glucose challenge test (GCT) followed by a 100 grams oral glucose tolerance test (OGTT). This method is recommended by the American College of Obstricians and Gynecologists (ACOG)[1] and has been widely used in many medical centers in Thailand.

A false-positve GCT is definded as the patient has a positive GCT but a negative OGTT. The false-positive GCT result is inconvenient for the patients, increases cost of screening, which can cause additional unnecessary diagnostic test, treatment and increased maternal concern about their health condition[13]. The significance of this false-positive group is questionable, there are some studies that considered the false-positive GCT as an early form of glucose intolerance[14-16] and effect to perinatal outcomes[17-20].

Recently, there have been some studies on the impact of meal timing and calories and their influence on glucose levels in adults[21-24]. There are a few studies that investigated the effect of timing, fasting duration and calories on glucose levels following GCT screening in pregnant woman which might effect the false-positive screening GCT[25-28]. There was neither a practical cut-off point since last meal nor calories were tested for application on the GCT. Thus, the primary objective of this study was to investigate the influence of last meal timing on GDM screening result. The secondary objective was to evaluate the effect of calories of last meal on the GCT result. The aim was to create practical patient advise for at risk patients who were undergoing GCT screening.

Materials and Methods

This prospective cohort study was conducted at the antenatal care (ANC) clinic, Udonthani Hospital, Udonthani, Thailand, from December 2019 to August 2020. The study protocol was approved by Human Research Ethical Committee of Udonthani Hospital (No.62/2562). All participants were counselled and gave their consent before participating in this study.

The inclusion criteria were all singleton pregnant women, who had risk for GDM according to the hospital's protocol including: maternal age ≥ 35 years at expected date of delivery, pre-pregnancy weight ≥ 70 kg or BMI > 30 kg/m^2, family member with DM, previous GDM, previous fetal macrosomia (> 4,000 g), previous unknown cause of intrauterine fetal death, previous child with shoulder dystocia, history of impaired blood glucose and glucosuria > 2$^+$ at least 2 times. This inclusion criteria were the Udonthani Hospital's protocol which applied from Royal Thai College of Obstetricians and Gynecologists and Srinagarind Hospital GDM guideline practice[29, 30]. The exclusion criteria were (1) known case of overt DM, (2) pregnant woman who had positive GCT, but did not receive 100 g OGTT confirmation, (3) unwilling to participate with this study. The screening test was conducted at first time ANC and repeat at 24-28 gestational age if negative result for first time screening.

All participants were asked for their: characteristics, risk of GDM factors as inclusion criteria protocols, time, and type of last meal intake. The time of glucose ingestion and blood drawing for glucose test were collected by nurses who were counselled the method to collect data at the ANC clinic. The time, since last meal until glucose intake, was divided into two groups: group 1 (less than 2 hours) and group 2 (equal to or more than 2 hours)[25, 26]. The calories were evaluated by calories table of Thai public health department and type of meal was divided into light (< 300 calories) and heavy meal (≥ 300 calories)[31]. Blood glucose at 1 hour after 50 grams glucose intake was measured.

Two step approach was applied to test in pregnant woman who had risks for GDM were performed a 50 grams GCT without starvation and venous plasma

glucose was measured at 1 hour after ingestion. All The positive GCT test was the blood glucose at 1 hour after 50 grams glucose intake ≥ 140 mg/dl. The confirmatory test by 100 grams OGTT was done within one week. The positive OGTT test was defined as at least 2 values of blood glucose levels at fasting, 1, 2, and 3 hours after 100 grams glucose intake were ≥ 105, 190, 165, 145 mg/dl, respectively according to the National Diabetes Data Group (NDDG) criteria[1]. The false positive GCT test was defined as the positive result of GCT (GCT ≥ 140 mg/dl) with negative result of 100 grams OGTT by NDDG criteria. The blood glucose was tested by hexokinase technique (Achitech 46000 machine, Abbott Laboratories Company).

Statistical analysis

The sample size was calculated by Stata statistical program using formula for Chi-squared test comparing two independent proportions. The proportion of false positive GCT in time since last meal equal to or more than 2 hours group (control) and less than 2 hours group from pilot study in our center were 0.15 and 0.30. The 0.01 significance level was used. The calculated sample size was 180 per group. The estimated prevalence of potential risk for GDM in our center was 30%. Therefore, the estimated time for collection of cases at ANC clinic was nine months, all cases, which compatible with the inclusion criteria between the study period, were collected.

The participants' characteristics were presented in term of number, percentage, mean and standard deviation. The comparison of factors between two groups was calculated by Pearson's chi square, Fisher exact or student t test depending on the characteristic of variables. The crude and adjusted risk ratio with 95% confidence interval were calculated by bivariable and multivariable regression analysis. The p value < 0.2 was used for selecting variable to multivariable analysis and p value < 0.05 was used for statistically significance. All analyses were performed using Stata Release 13 statistical software (Stata Corp, College Station, TX).

Results

There were 443 participants who meet the inclusion criteria for GDM screening from December 2019 to August 2020. There were 17 participants who were excluded: 2 were overt DM, 2 were unwilling to participate in this study and 13 were unobtainable to confirm diagnostic test (Fig. 1). The total number of participants was 426 which were divided into 2 group by timing from last meal to ingesting 50 grams glucose. These two groups were: group 1 (last meal intake time less than 2 hours) and group 2 (last meal intake equal to or more than 2 hours). The number of participants were 245 and 181 respectively. Mean age ± standard deviation (SD) of all participants was 27.5 ± 6.6 years and the mean BMI ± SD was 24.5 ± 5.8. Mean gestational age was 21.4 weeks and other data are presented in Table 1. There were no significant different of epidemiological characteristics in both groups.

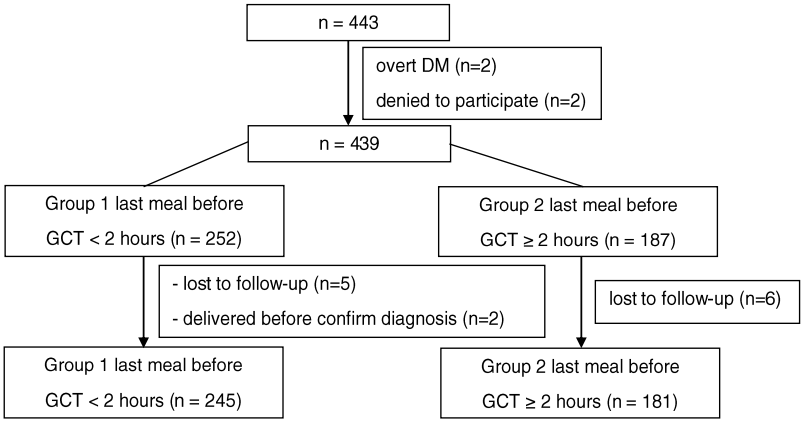

Fig. 1. Flow diagram of identification process for this study.

Table 1. Comparison of epidemiological characteristics between group 1(time since last meal less than 2 hours) and group 2 (time since last meal equal to or more than 2 hours).

Characteristics	Total (n = 426)	Group 1 (n = 245)	Group 2 (n = 181)	p value
Age (years)	27.5 ± 6.6	27.8 ± 6.8	27.1 ± 6.3	0.31
Primigravida, n (%)	158 (37.1%)	87 (35.5%)	68 (37.6%)	0.676
Gestational age (weeks)	21.4 ± 9.7	21.6 ± 9.5	21.2 ± 9.9	0.694
Weight (kgs)	61.8 ± 14.6	61.9 ± 14.1	61.6 ± 15.3	0.813
BMI (kgs/m^2)	24.5 ± 5.8	24.5 ± 5.5	24.5 ± 6.1	0.741
Category (n, %)				0.408
< 18.5	43 (10.1%)	20 (8.1%)	23 (12.7%)	
18.5 to < 25	221 (51.8%)	131 (53.5%)	90 (49.7%)	
25 to < 30	100 (23.5%)	59 (24.1%)	41 (22.6%)	
30 to < 40	56 (13.2%)	33 (13.5%)	23 (12.7%)	
≥ 40	6 (1.4%)	2 (0.8%)	4 (2.2%)	
Underlying disease				0.31
Hypertension	8 (1.9%)	2 (0.8%)	6 (3.3%)	
Hyperthyroid	4 (0.9%)	3 (1.2%)	1 (0.6%)	
SLE	3 (0.7%)	1 (0.4%)	2 (1.1%)	
Occupation				0.723
Housewife	212 (49.7%)	126 (51.4%)	86 (47.5%)	
Employee	130 (30.5%)	70 (28.5%)	60 (33.2%)	
Marchant	44 (10.3%)	26 (10.7%)	18 (9.9%)	
Government worker	37 (8.9%)	22 (8.9%)	15 (8.3%)	
Other	3 (0.7%)	1 (0.4%)	2 (1.1%)	
Relatives				0.6
First degree relatives	105 (24.6%)	65 (26.5%)	40 (22.1%)	
Second degree relatives	159 (37.3%)	96 (39.1%)	63 (34.8%)	
Previous pregnancy				0.597
Fetal macrosomia	5 (1.2%)	1 (0.4%)	4 (2.2%)	
Fetal anomalies	5 (1.2%)	3 (1.2%)	2 (1.1%)	
Previous GDM	4 (0.9%)	2 (0.8%)	2 (1.1%)	
Preeclampsia	3 (0.7%)	2 (0.8%)	1 (0.6%)	

Data are presented as mean ± standard deviation unless specified otherwise.
BMI: Body Mass Index, SLE: Systemic Lupus Erythematosus, GDM: Gestational Diabetes Mellitus

Fig. 2 and Table 2 demonstrate the primary outcome of this study. The mean of 50 g GCT of all participants was 127.4 mg/dl and 131 participants (30.8%) were GCT positive when used the cut-off point at 140 mg/dl (41.3% when used the cut-off at 130 mg/dl). There was 19.0% form this group had positive for diagnostic test by using NDDG criteria (26.7% using Carpenter's criteria), meanwhile prevalence of GDM in at risk group from this study was 5.8% (8.2% using Carpenter's criteria).

The positive OGTT (GDM) prevalence was higher in group 2 (time since last meal equal to or more than

2 hours). The GCT false positive was 106 participants from the total GCT screening (24.9%) which was higher in group 1 (time since last meal less than 2 hours) with statistical significance. The power of study calculated by number of participants and proportion of false positive cases was 0.83 with the alpha error at 0.05.

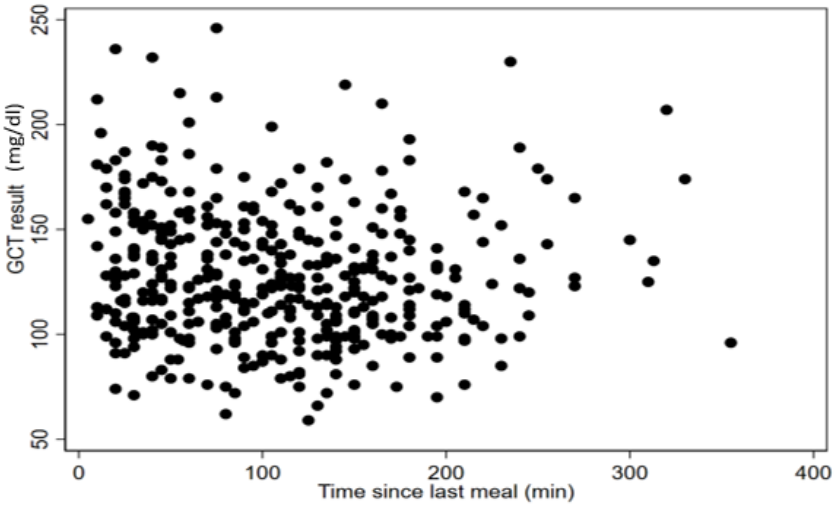

Fig. 2. Distribution of time since last meal (minutes) and 50 grams glucose challenge test (GCT) result (mg/dl).

Table 2. Result of GCT and OGTT between group 1 (time since last meal less than 2 hours) and group 2 (time since last meal equal to or more than 2 hours).

Results	Total (n = 426)	Group 1 (n = 245)	Group 2 (n = 181)	p value
50 grams GCT, mean ± SD (95%CI)	127.4 ± 31.7 mg/dl (124.4-130.4)	130.2 ± 31.9 mg/dl (126.1-134.2)	123.6 ± 31.1 mg/dl (119.1-128.2)	0.033
Positive GCT, n (%)	131 (30.8%)	85 (34.7%)	46 (25.4%)	0.040
Positive OGTT (GDM), n (%)	25/131 (19.1%)	12/85 (14.1%)	13/46 (28.3%)	0.049
False positive GCT/total GCT	106/426 (24.9%)	73/245 (29.8%)	33/181 (18.2%)	0.006

GCT: glucose challenge test, OGTT: oral glucose tolerance test, SD: standard deviation, CI: confidence interval, GDM: Gestational Diabetes Mellitus

The comparison of false positive GCT to various time since last meal and calories were presented in Table 3. The time since last meal of less than 1 and 2 hours had an effect to a false positive GCT with a risk ratio (RR) 1.72 (1.42-2.86) and 1.63 (1.13-2.35), respectively while 3 hours since last meal had no significant difference for false positive GCT with RR 1.27 (0.77-2.09). The mean calories of last meal intake were 389.8 kcal and the amount of last meal calories had no significant affect to the false positive GCT (p = 0.64). The blood collection time distribution is shown in Fig. 3. The only associated factor with the false positive GCT, which had a p value of less than 0.2, was the period of test (morning or afternoon). The multivariable analysis was done and there was no significant effect with the false positive GCT rate when it was adjusted with the time since last meal (Table 3).

Table 3. Comparison of false-positive result of 50 grams GCT between various time since last meal and calories of meal.

Group and type of meal	Total GCT (n)	False positive GCT (%)	Risk ratio (95%CI)	Adjusted risk ratio (95%CI)	p value
Time since last meal					
< 1 hour	114	41 (36.0%)	1.72 (1.42-2.86)	1.60 (1.14-2.24)[a]	0.006
≥ 1 hour	312	65 (20.8%)			
< 2 hours	245	73 (29.8%)	1.63 (1.13-2.35)	1.53 (1.06-2.22)[a]	0.023
≥ 2 hours	181	33 (18.2%)			
< 3 hours	357	92 (25.8%)	1.27 (0.77-2.09)	1.23 (0.75-2.04)[a]	0.397
≥ 3 hours	69	14 (20.3%)			
Calories of last meal					
Mean ± SD	389.8 ± 188.6	380.3 ± 188.9	1.00 (0.99-1.00)	NA	0.546
Light meal	150	37 (24.7%)	1.01 (0.71-1.43)	NA	0.939
Heavy meal	276	69 (25%)			
Light meal within 2 hours	80	24 (30%)	0.98 (0.66-1.49)	NA	0.961
Heavy meal within 2 hours	165	49 (29.7%)			
Time of GCT (blood collecting time)					
8.00 am to 12.00 pm	296	64 (21.6%)	1.49 (1.07-2.07)	1.36 (0.98-1.91)[b]	0.07
12.01 pm to 16.00 pm	130	42 (32.3%)			

[a] adjusted with time of GCT

[b] adjusted with time since last meal ≥ 2 hours

GCT: glucose challenge test, CI: confidence interval, SD: standard deviation

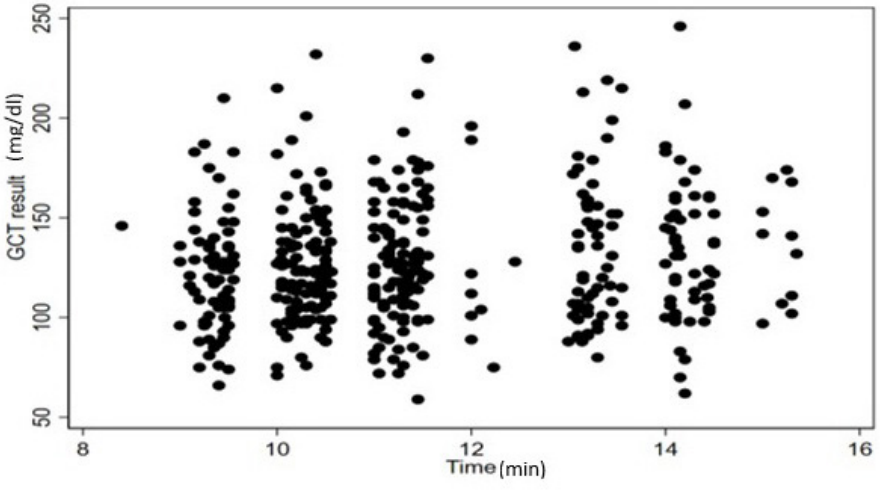

Fig. 3. Distribution between time of blood collection and result of 50 grams glucose challenge test (mg/dl).

Discussion

Gestational diabetes is the most common endocrine problem in pregnancy which has an impact as to pregnancy outcomes. There is still not a satisfactory detection method for this disease[1-10]. At present, there is no consensus regarding diagnostic tools between the one and two step methods, although the one step approch has greater proportion of women diagnosed with GDM but outcome of feto-maternal complications such as fetal macrosomia, cesarean section rate, birth trauma, etc. still no significant in both one and two step diagnostic methods[9-12]. A two-step approach method was applied in various countries for GDM diagnosis with different cut-off times for the 3 hour OGTT by NDDG and Carpenter and Coustan. The Carpenter and Coustan threshold could include a greater amount of pregnant women with GDM implied to a greater detection of feto-maternal complications[32, 33] but absence of clear comparative trials. Due to unclear benefit between Carpenter and NDDG cut-off, so our hospital decided to use NDDG cut-off in clinical practice. The two steps approach method could be applied to non-fasting pregnant woman that is more facilitative to use in various countries including Thailand[1, 34].

This study showed: first, GDM prevalence was 5.8% which was compatible with the previous studies which reported prevalence between 1.5-9.3%[3-7]. Second, false positive GCT prevalence was 24.9% which was similar to a previous report of between 8.8%-37.4%[19, 20, 35]. The prevalence increased if the Carpenter's criteria was used for diagnosis. The wide range for GDM prevalence and false positive GCT prevalence from previous studies were also due to the different diagnostic methods and GCT cut-off points, GDM detection and diagnosis[9, 10, 34, 36, 37].

The results from this study found that the time since last meal had an impact on the blood glucose level after a 50g GCT and a false positive GCT test (positive GCT but negative 100 g OGTT) especially when a last meal within 1 hour and 2 hours with RR 1.72 (1.42-2.86) and 1.63 (1.13-2.35), respectively. The results were comparable with previous studies by Sermer et al[25] and Cetin et al[26] who had reported the impact of time since last meal had an effect on mean plasma glucose. These former prior studies suggested the new cut-off level of 50 grams GCT if the time since last meal was < 2 hours in order to increase the results positive predictive value and specificity.

There were some previous studies about the effects of the period of the day, especially in the afternoon and at night, could decrease blood glucose GCT due to maternal metabolism and β-cell function[27, 28]. In contrast, Wong et al[37] and McElduff et al[38] reported that the afternoon GCT had higher positive rate but lower rate of GDM diagnosis due to cortisol metabolism. Data from this study found that the afternoon GCT (12.00 pm -16.00 pm) after the adjusted effect of time since last meal had no effect on the false positive GCT result. The calories of meal in this study had also less effect to glucose level of GCT which was compatible with a study that found a diet with low, medium, or high glycemic index had no effect on the GCT result[39].

The strength of this study were: first, a prospective observational cohort study which had the strength of potential relationship between exposure and outcome. Second, although the step approach to GDM diagnosis is one of the methods widely used, there are few studies about the factors for false positive in this test. This study found the factor of food and time since last meal to affect the false positive GCT result. Third, from the previous studies review this topic was the first study, which focused on the time and type of meal to false positive effect of GCT and last, the result of this study is easy to advice and apply for practical use.

There had some limitations with this study: first, recall bias, because even this study was a prospective cohort study, the information from participants about the previous meal and time intake might not be precise information. Second, the definition of light and heavy meals was applied from other countries (due to a lack of a Thai classification), thus the difference in food type might have some misclassification. Third, the risk approach screening GCT was used in this study because it is the routine practice of our center and many other centers in Thailand. A higher rate of GDM is assumed if routine GCT screening is performed.

Finally, there were lack of information of the effect of false positive GCT to the pregnancy outcome in this study. The long-term study is needed to access this effect.

Conclusion

Time since last meal had an impact to the false positive GCT result. A Time interval of more than 2 hours before the 50 grams GCT is suggested to avoid the unnecessary investigation for GDM screening.

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Potential conflicts of interest

The authors declare no conflicts of interest.

References

1. American College of Obstetricians and Gynecologists. Committee on Practice Bulletin No. 190: Gestational Diabetes Mellitus. Obstet Gynecol 2018;131:e49-e64.
2. Cunningham FG, Leveno KJ, Bloom SL, Dashe JS, Hoffman BL, Casey BM, et al. Williams Obstetrics. 25th ed. McGraw-Hill education, New York 2018:1097-1114.
3. Serirat S, Deerochanawong C, Sunthornthepvarakul T, Jinayon P. Gestational diabetes mellitus. Thai J Obstet Gynaecol 1992;75:315-9.
4. Boriboonhirunsarn D, Sunsaneevithayakul P, Nuchangrid M. Incidence of gestational diabetes mellitus diagnosed before 20 weeks of gestation. Thai J Obstet Gynaecol 2004;87:1017-21.
5. Chanprapaph P, Sutjarit C. Prevalence of gestational diabetes mellitus (GDM) in women screened by glucose challenge test (GCT) at Maharaj Nakorn Chiang Mai Hospital. J Med Assoc Thai 2004;87:1141-6.
6. Sunsaneevithayakul P, Boriboohirunsarn D, Sutanthavibul A, Ruangvutilert P, Kanokpongsakdi S, Singkiratana D, et al. Risk factor-based selective screening program for gestational diabetes mellitus in Siriraj Hospital: result from clinical practice guideline. Thai J Obstet Gynaecol 2003;86:708-14.
7. Arora D, Arora R, Sangthong S, Leelaporn W, Sangratanathongchai J. Universal screening of gestational diabetes mellitus: prevalence and diagnostic value of clinical risk factors. J Med Assoc Thai 2013;96:266-71.
8. DeSisto CL, Kim SY, Sharma AJ. Prevalence estimates of gestational diabetes mellitus in the United States, Pregnancy Risk Assessment Monitoring System (PRAMS), 2007-2010. Prev Chronic Dis 2014;11:E104.
9. Saccone G, Khalifeh A, Al-Kouatly HB, Sendek K, Berghella V. Screening for gestational diabetes mellitus: one step versus two step approach. A meta-analysis of randomized trials. J Matern Fetal Neonatal Med 2020;33:1616-24.
10. Li-zhen L, Yun X, Xiao-Dong Z, Shu-bin H, Zi-lian W, Adrian Sandra D, et al. Evaluation of guidelines on the screening and diagnosis of gestational diabetes mellitus: systematic review. BMJ Open 2019;9:e023014.
11. Farrar D, Duley L, Dowswell T, Lawlor DA. Different strategies for diagnosing gestational diabetes to improve maternal and infant health. Cochrane Database Syst Rev 2017;8:Cd007122.
12. Palatnik A, Swanson K, Churchill T, Bilski A, Grobman WA, Miller ES. Association between type of screening for gestational diabetes mellitus and cesarean delivery. Thai J Obstet Gynaecol 2017;130:539.
13. Grotegut CA, Tatineni H, Dandolu V, Whiteman VE, Katari S, Geifman-Holtzman O. Obstetric outcomes with a false-positive one-hour glucose challenge test by the Carpenter-Coustan criteria. J Matern Fetal Neonatal Med 2008;21:315-20.
14. Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes: a systematic review. Diabetes Care 2002;25:1862-8.
15. England LJ, Dietz PM, Njoroge T, Callaghan WM, Bruce C, Buus RM, et al. Preventing type 2 diabetes: public health implications for women with a history of gestational diabetes mellitus. Am J Obstet Gynecol 2009;200:365.e1-.e8.
16. Sivaraman SC, Vinnamala S, Jenkins D. Gestational diabetes and future risk of diabetes. J Clin Med Res 2013;5:92.
17. Figueroa D, Landon MB, Mele L, Spong CY, Ramin SM, Casey B, et al. Relationship between 1-hour glucose challenge test results and perinatal outcomes. Obstet Gynecol 2013;121:1241-7.
18. Kemal Akpak Y, Gün I, Kaya N, Atay V. A comparison of pregnant subgroups with positive 50-gram glucose challenge test results to those with negative results in terms of obstetric and perinatal outcomes. Med Glas (Zenica) 2012;9:262-7.
19. Stamilio DM, Olsen T, Ratcliffe S, Sehdev HM, Macones GA. False-positive 1-hour glucose challenge test and adverse perinatal outcomes. Obstet Gynecol

2004;103:148-56.
20. Thananyai A, Panchalee T, Borriboonhiransan D. Prevalence of false positive 50-g glucose challenge test in risk-based ccreening before 20 weeks of gestation and relationship with adverse pregnancy outcomes. Thai J Obstet Gynaecol 2020;28:34-43.
21. Moebus S, Göres L, Lösch C, Jöckel K-H. Impact of time since last caloric intake on blood glucose levels. Eur J Epidemiol 2011;26:719-28.
22. Poirier P, Tremblay A, Catellier C, Tancrède G, Garneau C, Nadeau A. Impact of time interval from the last meal on glucose response to exercise in subjects with type 2 diabetes. J Clin Endocrinol Metab 2000;85:2860-4.
23. Reynolds AN, Venn BJ. The timing of activity after eating affects the glycaemic response of healthy adults: A randomised controlled trial. Nutrients 2018;10:1743.
24. Meng H, Matthan NR, Ausman LM, Lichtenstein AH. Effect of prior meal macronutrient composition on postprandial glycemic responses and glycemic index and glycemic load value determinations. Am J Clin Nutr 2017;106:1246-56.
25. Sermer M, Naylor CD, Gare DJ, Kenshole AB, Ritchie J, Farine D, et al. Impact of time since last meal on the gestational glucose challenge test: the Toronto Tri-Hospital Gestational Diabetes Project. Am J Obstet Gynecol 1994;171:607-16.
26. Cetin M, Cetin A. Time-dependent gestational diabetes screening values. Int J Gynaecol Obstet 1997;56:257-61.
27. Goldberg RJ, Ye C, Sermer M, Connelly PW, Hanley AJ, Zinman B, et al. Circadian variation in the response to the glucose challenge test in pregnancy: implications for screening for gestational diabetes mellitus. Diabetes Care 2012;35:1578-84.
28. Wang P, Lu M-C, Yu C-W, Yan Y-H. Influence of the time of day and fasting duration on glucose level following a 1-hour, 50-gram glucose challenge test in pregnant women. PloS one 2014;9:e112526.
29. The Royal Thai College of Obstetricians and Gynaecologists. Diabetes mellitus screening in pregnancy. In: Clinical Practice Guidelines. RTCOG 2017;1.170-84.
30. Medical complications in elderly gravida. Srinagarind Med J 2007;22:39-42.
31. Kimberley E. How many calories are in a low calorie meal? In: The spruce eats; 2019.
32. Ferrara A, Hedderson MM, Quesenberry CP, Selby JV. Prevalence of gestational diabetes mellitus detected by the national diabetes data group or the carpenter and coustan plasma glucose thresholds. Diabetes Care 2002;25:1625-30.
33. Cheng YW, Block-Kurbisch I, Caughey AB. Carpenter-Coustan criteria compared with the national diabetes data group thresholds for gestational diabetes mellitus. Obstet Gynecol 2009;114:326-32.
34. Behboudi-Gandevani S, Amiri M, Yarandi RB, Tehrani FR. The impact of diagnostic criteria for gestational diabetes on its prevalence: a systematic review and meta-analysis. Diabetol Metab Syndr 2019;11:11.
35. Gumus II, Turhan NO. Are patients with positive screening but negative diagnostic test for gestational diabetes under risk for adverse pregnancy outcome? J Obstet Gynaecol Res 2008;34:359-63.
36. Lu M-C, Huang S-S, Yan Y-H, Wang P. Use of the National Diabetes Data Group and the Carpenter-Coustan criteria for assessing gestational diabetes mellitus and risk of adverse pregnancy outcome. BMC Pregnancy Childbirth 2016;16:231.
37. Wong VW, Garden F, Jalaludin B. Hyperglycaemia following glucose challenge test during pregnancy: When can a screening test become diagnostic? Diabetes Res Clin Pract 2009;83:394-6.
38. McElduff A, Hitchman R. Screening for gestational diabetes: the time of day is important. Med J Aust 2002;176:136.
39. Southgate KM. The effect of a low glycemic index diet on glucose challenge test results in women at risk for gestational diabetes mellitus. University of Toronto 2012:1-124.