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COMPARISON OF METHODS FOR IDENTIFYING SMALL-FOR-GESTATIONAL-AGE INFANTS AT RISK OF PERINATAL MORTALITY AMONG OBESE MOTHERS: A HOSPITAL BASED COHORT STUDY

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Abstract

Objective—Assess differences in small-for-gestational age (SGA) classifications for the detection of neonates with increased perinatal mortality risk among obese women and subsequently assess the association between prepregnancy body mass index (BMI) status and SGA.

Design—Hospital-based cohort.

Setting—12 U.S. clinical centers (2002–2008)

Population—114,626 singleton, non-anomalous pregnancies.

Methods—Data were collected using electronic medical record abstraction. Relative risks (RR) with 95% confidence intervals (CI) were estimated.

Main outcome measures—SGA trends (birthweight <10th percentile) classified using population-based (SGA_{POP}), intrauterine (SGA_{IU}) and customized (SGA_{CUST}) references were

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assessed. The SGA associated perinatal mortality risk was estimated among obese women. Using the SGA method most associated with perinatal mortality, the association between prepregnancy BMI and SGA was estimated.

Results—The overall perinatal mortality prevalence was 0.55% and this increased significantly with increasing BMI ($P<0.01$). Among obese women, SGA_{IU} detected the highest proportion of perinatal mortality cases (2.49%). Perinatal mortality was 5.32 times (95% CI 3.72–7.60) more likely among SGA_{IU} neonates than non-SGA_{IU} neonates. This is in comparison with the 3.71- (2.49–5.53) and 4.81 (3.41–6.80)-fold increased risk observed when SGA_{POP} and SGA_{CUST} were used, respectively. Compared to normal weight women, overweight [RR=0.82 (0.78–0.86)] and obese [RR=0.80 (0.75–0.83)] women had a lower risk for delivering an SGA_{IU} neonate.

Conclusion—Among obese women, the intrauterine reference best identified neonates at risk of perinatal mortality. Based on SGA_{IU}, SGA is less common among obese women but these SGA babies are at a high risk of death and remain an important group for surveillance.

TWEETABLE ABSTRACT

SGA is less common among obese women but these SGA babies are at a high risk of death.

Keywords

Fetal growth; Small-for-gestational-age; obesity; birthweight

INTRODUCTION

Prepregnancy obesity is associated with metabolic dysfunction (e.g. excessive insulin resistance), systematic inflammation, and overnutrition, which can contribute to fetal overgrowth and adiposity.¹² However, fetuses of women with obesity may also be at increased risk for growth restriction due to increased maternal hypertensive diseases.³ While studies consistently report an increased risk for macrosomia or large-for-gestational-age,⁴ there is conflicting evidence on whether obesity decreases the risk for fetal growth restriction or small-for-gestational-age (SGA) birthweight, a condition of greater immediate health concern due to stronger associations with neonatal morbidity and mortality.⁵ This conflict may be due to differences in definitions of growth restriction and SGA.⁶

The simplest SGA definition uses a population-based reference to classify infants based on cutpoints.⁷ A similar approach uses intrauterine estimated fetal weight reference curves, which better accounts for infants delivered earlier being growth restricted compared to their counterparts who remain in utero.⁶ Customized percentiles account for the influence of physiologic and pathologic characteristics on fetal growth.

The objective of this study was to determine the relationship between prepregnancy obesity and SGA. First, we described the SGA pattern across prepregnancy BMI using various SGA definitions. Second, we assessed which SGA method best captured neonates at risk for perinatal mortality specifically among obese women. Lastly, we report the unadjusted and adjusted association between maternal prepregnancy BMI and SGA using the method selected for best detecting neonates at risk for perinatal mortality.

METHODS

The Consortium on Safe Labor (CSL) was a retrospective cohort study conducted by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development.⁸ Detailed information on 228,438 deliveries 23 weeks gestation from 208,695 women at 12 U.S. clinical centers (2002–2008) was extracted from maternal and infant electronic medical records and supplemented with International Classification of Diseases, ninth revision (ICD9) discharge codes. All study procedures were reviewed and approved by each participating site's Institutional Review Board.

The current analysis was limited to a woman's first singleton delivery 40 weeks without congenital anomalies (n=176,741). Deliveries >40 weeks gestation were not included as the intrauterine reference⁹ does not provide percentiles >40 weeks. Records were excluded if relevant data were missing or implausible (maternal age [n_{missing}=242; 0.1%]; height [n_{missing}=28,642; 16.2%]; prepregnancy weight [n_{missing}=49,680; 28.1%]; race/ethnicity [n_{missing}=7,572; 4.3%]; parity [n_{implausible}=1; 0.0%]; sex [n_{missing}=325; 0.2%]; birthweight [n_{missing}=1701, n_{implausible}=189; 1.1%]), resulting in 114,626 deliveries. The magnitude of differences between included and excluded records tended to be small, but significant due to the large sample (P<0.001). For example, excluded records were less likely to be from non-Hispanic white women (42.2% vs 54.3%), but more likely to be from unmarried (47.3% vs 37.3%), nulliparous women (42.4% vs 41.4%) with private insurance (62.8% vs 52.3%), or smokers (93.6% vs 93.2%).

Maternal age at delivery, race-ethnicity, parity, marital status, insurance status, smoking, height, and prepregnancy weight were obtained from the electronic medical record. Prepregnancy body mass index (BMI; kg/m²) was categorized as underweight (<18.5), normal weight (18.5–24.9), overweight (25.0–29.9), and obese (≥30.0). Maternal pregnancy complications and medical history of diabetes and hypertension diseases were obtained from the medical record and supplemented with *ICD9* codes.

Infant gestational age at delivery, according to the best obstetrical estimate (weeks), birthweight (grams), sex and perinatal mortality (antepartum, intrapartum or other unspecified stillbirth and/or neonatal death) were obtained from the electronic medical record. Neonates with a birthweight 10th percentile based on intrauterine⁹ and population-based⁷ references were classified as SGA_{IU} and SGA_{POP}, respectively. Neonates with a birthweight 10th customized percentile defined using customization coefficients derived using the CSL data based on the method of Gardosi and colleagues¹⁰ were classified as SGA_{CUST}. Briefly, an individualized expected term optimal birthweight was estimated using coefficients for physiologic parameters affecting birthweight (maternal age, race/ethnicity, parity, height and weight; and infant sex), accounting for pathologic parameters (smoking, diabetes, hypertension, underweight/obesity), and utilized intrauterine proportionality curves.⁹ The overlap in the three SGA classification methods was compared.

Differences across prepregnancy BMI groups were assessed using the Mantel-Haenszel chi-square. The prevalence of each SGA classification and perinatal mortality was plotted across the range of BMI using non-parametric generalized additive models. For each classification,

sensitivity and specificity, and positive and negative predictive values were estimated for the detection of perinatal mortality. Relative risks (RR) with 95% confidence intervals (CI) were estimated for perinatal mortality using log-binomial regression. To understand how comorbid conditions impact perinatal mortality risk, sensitivity analyses focused only on women without chronic or pregnancy-related hypertension or diabetes. Lastly, the adjusted RR of SGA was assessed by prepregnancy BMI category using the SGA classification determined to best identify neonates at risk for perinatal mortality. SAS version 9.4 (Cary, NC) and R version 3.1.2 (Vienna, Austria) were used, with P-values <0.05 considered significant.

RESULTS

In this U.S. cohort, 53.8% of the women were normal weight at the start of their pregnancy with 5.5% underweight, 22.2% overweight and 18.5% obese. Characteristics of the sample differed by prepregnancy BMI status (Table 1). Mean birthweight tended to increase with increasing BMI, although there was no significant difference between overweight or obese mothers ($P=0.11$). The overall perinatal mortality prevalence was 0.55% and this increased significantly with increasing BMI ($P<0.01$). Overall 8.6% ($n=9,848$), 9.4% ($n=10,796$), and 8.8% ($n=10,131$) of neonates were classified as SGA_{POP}, SGA_{IU} and SGA_{CUST}. There was considerable overlap across classifications with 6.2% ($n=7,158$) of neonates classified as SGA according to all three methods.

Figure 1 describes the varying pattern in the unadjusted SGA prevalence across prepregnancy BMI. SGA_{POP} and SGA_{IU} curves were substantially overlapping. There was a higher SGA proportion among underweight women with all classifications, but the magnitude was different, specifically SGA was as high as approximately 25% with SGA_{POP} and SGA_{IU}, but only about 13% with SGA_{CUST}. All classifications tended to reach a lower SGA proportion within the normal weight range (approximately 20–25 kg/m²), but rather than leveling off, as with SGA_{POP} and SGA_{IU}, SGA_{CUST} increased slightly with increasing BMI.

Table 2 shows that among obese women SGA_{IU} detected the highest proportion of perinatal mortality cases and was most strongly associated with perinatal mortality. SGA_{IU} neonates had an approximate 5-fold increased risk of death compared the 3- and 4-fold increased risk when SGA_{POP} and SGA_{CUST} were used, respectively.

Because women with obesity have a high risk for comorbid conditions that may influence perinatal mortality risk, we excluded women with chronic or pregnancy related diabetes or hypertensive diseases. Similar findings were observed as with the full sample although the difference between SGA_{IU} and SGA_{CUST} ability to detect at risk neonates was smaller (data not shown).

Table 3 presents the unadjusted and adjusted SGA relative-risk by prepregnancy BMI status. Compared to normal weight women, underweight women had an increased relative risk for delivering an SGA_{IU} neonate, while the relative risk was lower among overweight and obese

women. Specifically, the risk for SGA was 20% lower among obese women than normal weight women.

DISCUSSION

Main findings

In this large hospital-based U.S. cohort we sought to examine the relation between maternal obesity and SGA. Compared to women of a healthy weight, the intrauterine reference indicated that women with obesity had a lower risk for delivering an SGA neonate. Among the three different SGA classifications explored, we observed the intrauterine SGA reference best identified neonates at risk of mortality in obese women. Importantly, SGA neonates of obese women had a five-fold increased risk for mortality, highlighting the clinical importance of monitoring for SGA among obese women. We also provide evidence simultaneously comparing how utilization of these three different SGA classifications can lead to clinically meaningful different conclusions regarding the risk of SGA among obese women.

Strengths and Limitations

SGA was defined according to birthweight as estimated fetal weights based on ultrasound were not abstracted from the medical record. Therefore, corroboration of these findings using estimated fetal weight and antenatal testing to identify intrauterine growth restriction is critical as the ultimate goal is prediction of at risk fetuses prior to delivery. Additional studies focused on assessing intrauterine growth restriction in obese mothers using estimated fetal weight will likely be more definitive, but the message of the current study remains that it is important to critically evaluate SGA classifications across the spectrum of BMI. Also, while some were better than others, all SGA methods based on birthweight were only moderately associated with perinatal mortality. The goal of the current study was not to predict perinatal mortality per se, but to use it to evaluate the methods for classifying SGA given that perinatal mortality may be considered the most important clinical neonatal outcome. This point is evidenced by the relatively low sensitivity and positive predictive values with all of the methods. However, in reality none of these methods would be used in isolation of other important clinical predictors and SGA is only one screening method for detecting at-risk neonates. Lastly, a large proportion of women were excluded from this analysis due to missing prepregnancy height and/or weight; however, maternal BMI or birth outcome should not be related to the reason these variables were not abstracted from the electronic medical record.

The large, diverse population is a strength of this study. In this modern cohort of U.S. women, obesity was more prevalent (18%) than in a previous study of customized SGA and perinatal mortality focused on obesity¹¹ (obesity rate <7%) which allowed for thorough examination of the SGA-perinatal mortality relationship across the spectrum of BMI. Also, given the size of the cohort, the quality of the data is particularly notable. Validation studies have found high agreement between the electronic medical record data and chart review in this cohort.⁸

Interpretation

This study highlights the importance of choosing an SGA classification system that detects neonates at an increased perinatal mortality risk across the entire spectrum of maternal BMI. It was expected that more infants of obese mothers would be classified as SGA by the customized classification as it takes maternal size into account. We sought to identify whether customization improves detection of at risk infants over the intrauterine and population-based references particularly among obese women. We assessed perinatal mortality to evaluate if the SGA cases identified with each classification method were clinically meaningful. As has been previously described,¹² the population-based reference did not perform as well as other methods in regard to the detection of perinatal mortality and researchers should consider other methods for classifying SGA. Among obese women, the intrauterine reference best identified at-risk SGA cases, although the improvement over the customized reference was small. This similarity may be due to the fact that, like the intrauterine reference, the customization method also accounts for preterm deliveries being more likely to be growth restricted through the proportionally adjustment.⁶¹³ Also it is important to note that the customization method is substantially more complicated to implement and subject to additional modeling assumptions,¹⁴ which may impact its validity and thus we utilized this method for assessing the overall association between maternal weight status and SGA risk.

Differences in the methodological underpinnings of determining SGA have implications for reviewing and interpreting the literature on SGA because studies draw conclusions about SGA-related exposures and outcomes using different classifications that might impact their findings. For example, a prior study reported decreased second trimester plasma ascorbic acid concentrations associated with increased customized SGA among obese women;¹⁵ however, it is unclear if these findings would have persisted if an intrauterine reference was used in place of the customization method. It was previously reported that customized SGA increases with increasing BMI in a trend that parallels perinatal mortality,¹¹ and thus is better at identifying at risk neonates. However, the latter assertion was not corroborated in our study likely because the population based reference not the intrauterine reference was used as the comparison method in the prior study.

Most importantly, while much attention has been given to excess fetal growth associated with maternal obesity, less attention has been paid to growth restriction and its consequences among neonates born to mothers with obesity.¹⁶ Our findings suggest that when using the intrauterine reference, SGA risk is slightly lower among overweight and obese women compared to normal weight women. However, some obese women still delivered an SGA neonate and these neonates had a high SGA-related perinatal mortality risk. Thus given the competing factors associated with growth promotion, further research is needed to understand the SGA mechanism among women with obesity. Even after the exclusion of women with diabetes and hypertensive diseases, 7–8% of obese women delivered an SGA neonate (intrauterine reference) with a substantially higher perinatal mortality risk than non-SGA neonates, suggesting that the pathway for SGA was not solely through comorbidities. Indeed previous studies of uncomplicated pregnancies have shown that maternal obesity is

associated with increased placental oxidative stress which may contribute to placental dysfunction and growth restriction.^{17–19}

Conclusion

Choosing a meaningful definition for SGA is critical for making correct inferences about risk factors and exposures in the large body of work examining SGA as both an exposure and outcome. The intrauterine reference requires fewer steps and assumptions than the customized SGA definition and best detected at risk neonates among obese women in our study and thus our inferences regarding the relationship between maternal obesity and SGA are based on using the intrauterine reference. As such, the SGA risk, was lower among women with obesity than lean women. While less frequent, SGA babies among women with obesity are at a high risk of death and remain an important group for surveillance.

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ABBREVIATIONS

BMI	body mass index
CI	confidence interval
LAG	Large-for-gestational-age
RR	relative risk
SGA	small-for-gestational-age
SGA_{POP}	population-based reference small-for-gestational-age
SGA_{IU}	intrauterine reference small-for-gestational-age
SGA_{CUST}	customized small-for-gestational-age reference

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Figure 1. Small-for-gestational-age birthweight prevalence according to the population-based reference, intrauterine reference and customization methods across the spectrum of prepregnancy body mass index, Consortium on Safe Labor, United States.

Table 1

Sample characteristics by maternal prepregnancy body mass index status, Consortium on Safe Labor, United States (n=114,626).

Maternal characteristics	Underweight (n=6,336) %	Normal weight (n=61,617) %	Overweight (n=25,457) %	Obese (n=21,216) %
Age ^a , years	26.1 (6.1)	27.5 (6.2)	27.9 (6.1)	28.2 (5.9)
Race-ethnicity				
Non-Hispanic white	58.7	59.3	48.8	45.2
Non-Hispanic black	15.2	15.7	23.1	31.3
Hispanic	15.7	18.2	23.1	19.6
Asian/pacific islander	7.9	4.6	2.3	1.6
Other/unknown race	2.6	2.3	2.7	2.3
Private Insurance	48.6	55.3	51.0	48.9
Married	59.6	66.5	60.7	54.8
Nuliparous	52.2	45.7	36.8	31.2
Smoked	9.1	6.0	7.0	8.5
Diabetes				
Preexisting diabetes	0.4	0.8	1.6	4.1
Gestational diabetes	1.9	3.0	6.2	10.9
Hypertensive diseases				
Gestational hypertension	1.6	2.0	3.5	5.2
Preeclampsia/ Eclampsia	2.7	3.4	5.0	7.3
Superimposed preeclampsia	0.2	0.4	1.1	2.4
Chronic hypertension	0.4	0.8	2.1	5.5
Neonatal characteristics				
Preterm, <37 weeks	11.9	9.6	10.9	13.0
Birthweight ^a , grams	3081 (523)	3238 (522)	3291 (569)	3301 (612)
SGA _{POP} ^b	15.2	8.8	7.4	7.4
SGA _{IU} ^c	16.1	9.6	8.2	8.3
SGA _{CUST} ^d	9.6	7.9	9.0	11.2
Perinatal mortality	0.35	0.52	0.60	0.64

^aData presented as mean (standard deviation)

^bSGA_{POP}, small-for-gestational-age defined using a population-based birthweight reference.

^cSGA_{IU}, small-for-gestational-age defined by applying birthweight to an intrauterine reference using estimated fetal weight.

^dSGA_{CUST}, small-for-gestational-age defined using the customization approach with the following parameters: fetal sex, gestational age, race-ethnicity, parity, maternal height, prepregnancy weight, (smoking), (diabetes), (hypertension) and (underweight/obesity). Pathologic variables shown in parentheses were included in model for beta coefficients but not in calculating individual expected term optimal birthweight.

^eAll differences across prepregnancy body mass index status significant at P<0.001, except for perinatal mortality where P=0.02.

Table 2

Perinatal mortality associated with small-for-gestational-age among obese women only, Consortium on Safe Labor, United States (n= 21,216).

	% Perinatal Mortality	Sensitivity	Specificity	PPV	NPV	RR (95% CI)
SGA _{Pop} ^a	1.97	23.0	92.7	2.0	99.5	3.71 (2.49, 5.53)
SGA _{IU} ^b	2.49	32.6	91.8	2.5	99.5	5.32 (3.72, 7.60)
SGA _{CUST} ^c	2.15	37.8	89.0	2.1	99.6	4.81 (3.41, 6.80)

Abbreviations: CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value; RR, relative risk; SGA, small-for-gestational-age.

^aSGAPOP, small-for-gestational-age defined using a population-based birthweight reference.

^bSGAIU, small-for-gestational-age defined by applying birthweight to an intrauterine reference using estimated fetal weight.

^cSGACUST, small-for-gestational-age defined using the customization approach with the following parameters: fetal sex, gestational age, race-ethnicity, parity, maternal height, prepregnancy weight, (smoking), (diabetes), (hypertension) and (underweight/obesity). Pathologic variables shown in parentheses were included in model for beta coefficients, but not in calculating individual expected term birthweight.

Table 3

Small for gestational age birthweight^a risk by maternal prepregnancy body mass index status, Consortium on Safe Labor, United States (n=114,626).

	Unadjusted RR (95% CI)	Adjusted RR (95% CI)
Underweight	1.67 (1.57, 1.78)	1.55 (1.46, 1.65)
Normal weight	1.00 (Reference)	1.00 (Reference)
Overweight	0.85 (0.81, 0.89)	0.82 (0.78, 0.86)
Obese	0.87 (0.82, 0.91)	0.80 (0.75, 0.83)

Abbreviations: CI, confidence interval; RR, relative risk.

^b Small-for-gestational-age defined by applying birthweight to an intrauterine reference using estimated fetal weight.

^d Estimates adjusted for maternal age, race-ethnicity, parity, marital status, insurance and smoking status, chronic diabetes, chronic hypertension and study site.