

Bariatric Surgery in Women of Childbearing Age, Timing Between an Operation and Birth, and Associated Perinatal Complications

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IMPORTANCE Metabolic changes after maternal bariatric surgery may affect subsequent fetal development. Many relevant perinatal outcomes have not been studied in this postoperative population, and the risks associated with short operation-to-birth (OTB) intervals have not been well examined.

OBJECTIVE To examine the risk for perinatal complications in women with a history of bariatric surgery (postoperative mothers [POMs]) by comparing them with mothers without operations (nonoperative mothers [NOMs]) and examining the association of the OTB interval with perinatal outcomes.

DESIGN, SETTING, AND PARTICIPANTS This investigation was a population-based retrospective cohort study (January 1, 1980, to May 30, 2013) at hospitals in Washington State. Data were collected from birth certificates and maternally linked hospital discharge data. Participants were all POMs and their infants (n = 1859) and a population-based random sample of NOMs and their infants frequency matched by delivery year (n = 8437).

EXPOSURES Bariatric operation before birth or categories of OTB intervals.

MAIN OUTCOMES AND MEASURES The primary outcomes were prematurity, neonatal intensive care unit (NICU) admission, congenital malformation, small for gestational age (SGA), birth injury, low Apgar score (≤ 8), and neonatal mortality. Poisson regression was used to compute relative risks (RRs) and 95% CIs, with adjustments for maternal body mass index, delivery year, socioeconomic status, age, parity, and comorbid conditions.

RESULTS A total of 10 296 individuals were included in the analyses for this study. In the overall cohort, the median age was 29 years (interquartile range, 24-33 years). Compared with infants from NOMs, infants from POMs had a higher risk for prematurity (14.0% vs 8.6%; RR, 1.57; 95% CI, 1.33-1.85), NICU admission (15.2% vs 11.3%; RR, 1.25; 95% CI, 1.08-1.44), SGA status (13.0% vs 8.9%; RR, 1.93; 95% CI, 1.65-2.26), and low Apgar score (17.5% vs 14.8%; RR, 1.21; 95% CI, 1.06-1.37). Compared with infants from mothers with greater than a 4-year OTB interval, infants from mothers with less than a 2-year interval had higher risks for prematurity (11.8% vs 17.2%; RR, 1.48; 95% CI, 1.00-2.19), NICU admission (12.1% vs 17.7%; RR, 1.54; 95% CI, 1.05-2.25), and SGA status (9.2% vs 12.7%; RR, 1.51; 95% CI, 0.94-2.42).

CONCLUSIONS AND RELEVANCE Infants of mothers with a previous bariatric operation had a greater likelihood of perinatal complications compared with infants of NOMs. Operation-to-birth intervals of less than 2 years were associated with higher risks for prematurity, NICU admission, and SGA status compared with longer intervals. These findings are relevant to women with a history of bariatric surgery and could inform decisions regarding the optimal timing between an operation and conception.

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Bariatric operations may be considered for individuals with a body mass index (BMI [calculated as weight in kilograms divided by height in meters squared]) of 40 or higher or a BMI of 35 or higher with obesity-related comorbidities.^{1,2} These surgical procedures result in restriction of stomach size (banded gastroplasty, adjustable gastric banding, and sleeve gastrectomy) or restriction of stomach size with altered absorption of nutrients (Roux-en-Y gastric bypass).¹ After an operation, patients experience a mean postoperative weight loss of approximately 30% and often have resolution of obesity-related comorbidities, with reported long-term effectiveness lasting 10 years and beyond.^{1,3,4}

In the United States, approximately one-fifth of women are obese at the time of conception.³ Obesity during pregnancy is associated with significant morbidity, including fetal macrosomia, hypertensive disorders, and gestational diabetes.^{3,4} Several observational studies^{3,5,6} have shown that bariatric operations before pregnancy are associated with a reduced prevalence of macrosomic infants, maternal diabetes, and hypertension relative to the prevalence found among obese women who did not undergo a bariatric operation. However, to our knowledge, several other relevant indicators of perinatal health in this population have not been fully explored in the published literature. In particular, because bariatric operations can result in nutritional deficiencies in the mother,⁷ there has been some concern that surgery may adversely influence fetal development and infant outcomes.^{5,6,8} Outcomes, such as neonatal intensive care unit (NICU) admissions, Apgar scores,⁹ and congenital malformations, are likely to be affected by maternal metabolic and nutritional derangements.³ Although some preliminary studies¹⁰⁻¹⁴ have investigated these outcomes, conclusions are conflicting and limited by small sample sizes.

In addition, a “safe” interval between bariatric surgery and childbirth remains undefined. The year after a bariatric operation is characterized by rapid weight loss and a higher risk for nutritional deficiencies, which may be a poor environment for fetal development.¹⁵ The American College of Gynecologists recommends avoiding pregnancy for a minimum of 2 years after a bariatric operation, but this recommendation is based largely on expert opinion rather than on robust evidence.^{3,16,17} Further studies are needed to determine the safest operation-to-birth (OTB) interval and to assess the influence this interval has on perinatal outcomes.

In this retrospective cohort study, our overall objective was to inform women with a history of bariatric surgery about their altered likelihood of perinatal complications. Herein, we describe the association of bariatric surgery with subsequent perinatal outcomes and examine the association of the OTB interval with perinatal risks.

Methods

Study Design, Participants, Setting, and Data Collection

Data from Washington State birth certificates (January 1, 1980, to May 30, 2013) were linked to longitudinal maternal discharge data on prior hospitalizations using the Comprehen-

Key Points

Question In women of childbearing age, is a prior bariatric operation associated with risks for perinatal complications, and does the time between an operation and birth alter these risks?

Findings In this cohort study, mothers with prior bariatric surgery had infants with significantly higher risks for prematurity, small-for-gestational-age status, and intensive care unit admission. Operation-to-birth intervals of less than 2 years were associated with the highest risks for prematurity and intensive care unit admission.

Meaning Bariatric operations in women of childbearing age are associated with elevated risks for subsequent perinatal complications, but some of these risks may decrease after postoperative year 2.

sive Hospital Abstract Reporting System (CHARS), as described in previous work.¹⁸ All data related to key exposure variables, outcomes, and covariates were collected from these sources. Most variables were recorded independently in both birth certificate data sets and the CHARS data set, which enabled cross-checking and verification.

All mothers with a delivery year from January 1, 1980, through May 30, 2013, in Washington State were screened for potential inclusion in this retrospective cohort study (Figure 1). All mothers with a history of a bariatric operation at any time before conception were included. This group is referred to herein as postoperative mothers (POMs). In addition, a population-based random sample of Washington State mothers and their infants was included for purposes of comparison and was frequency matched by infant delivery year in an approximately 4:1 ratio. The comparison group, referred to herein as nonoperative mothers (NOMs), did not have a prior bariatric operation.

The conduct of this study was approved by the Washington State Department of Health Institutional Review Board. It was determined to be exempt from informed consent because of the deidentified nature of the data.

Exposures and Outcomes

The primary exposure of interest was a history of a bariatric operation at any time before conception; this aggregate categorical exposure included banded gastroplasty, adjustable gastric banding, sleeve gastrectomy, or Roux-en-Y gastric bypass, as defined by *International Classification of Diseases, Ninth Revision (ICD-9)* codes V45.86 and 649.2. These codes were assigned during prior hospitalizations (CHARS-linked data) or were assigned at the time of birth (birth certificate data). Exposure definition using ICD-9 codes for bariatric surgery has been used in previous cohort studies.^{19,20} The secondary exposure of interest among POMs was the OTB interval (<2 years, 2-4 years or >4 years), with the shortest time defined by expert guidelines as the minimum safe interval.¹⁷

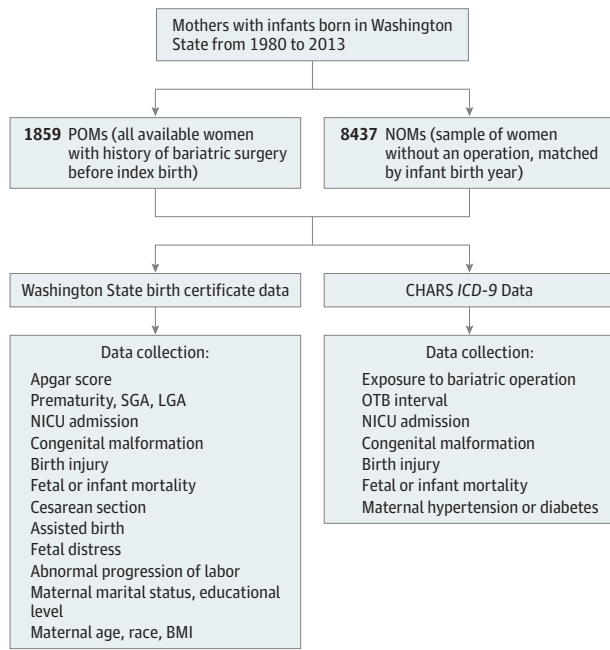
Primary outcomes were related to neonatal complications. These variables included the following: (1) prematurity, defined by a “late preterm” category (gestational age, <37 weeks) and an “early preterm” category (gestational age, <32 weeks); (2) NICU admission, defined as any infant admission

to the NICU at any point during the birth hospitalization; (3) congenital malformation, defined as any malformation diagnosis coded on the birth certificate or any infant with discharge diagnosis ICD-9 codes from 740 to 756 (predominantly heritable or chromosomal abnormalities [eg, Down syndrome and other abnormal karyotypes] were excluded from the malformation definition because their etiology is thought to be independent of the maternal metabolic and

nutritional environment); (4) small for gestational age (SGA) or large for gestational age (LGA), defined as the lowest 10% and highest 10% of birth weights, based on Washington State population data from 1989 to 2002, as previously described²¹; (5) Apgar scores, which constitute a combined measure of neonatal activity and vital signs and are determined by the obstetrician 5 minutes after birth⁹; (6) birth injury, defined as any injury occurring during labor and delivery with ICD-9 code 767, including shoulder dystocia, intraventricular hemorrhage, nerve palsy, scalp hematoma, and skeletal trauma; and (7) fetal or infant mortality, defined as any stillbirth or infant death during the birth hospitalization.

Secondary outcomes were related to labor and delivery complications. These variables included the following: (1) cesarean section, defined as any abdominal operation (planned or unplanned) that results in the delivery of the infant; (2) fetal distress in labor, defined by an obstetrician's interpretation of fetal heart rate monitoring, as has been previously described²²; (3) operative vaginal delivery, defined as any vaginal delivery requiring forceps or vacuum assist; and (4) precipitous or prolonged labor, defined as less than 3 hours or more than 20 hours for primigravid women and more than 14 hours for multiparous women, respectively.²³

Figure 1. Retrospective Cohort Study of Washington State Mothers With Bariatric Operations and Their Infants



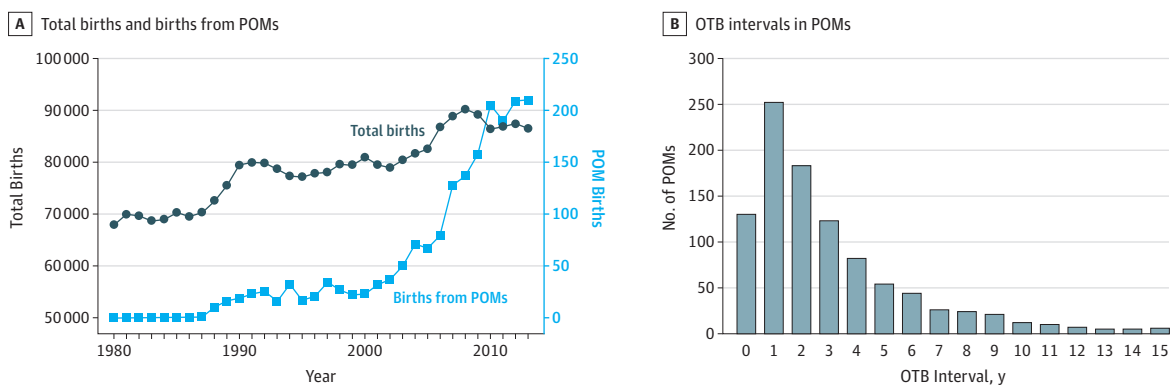
BMI indicates body mass index; CHARS, Comprehensive Hospital Abstract Reporting System; ICD-9, *International Classification of Diseases, Ninth Revision*; LGA, large for gestational age; NICU, neonatal intensive care unit; NOMs, nonoperative mothers; OTB, operation-to-birth; POMs, postoperative mothers with a history of a bariatric surgery prior to conception; and SGA, small for gestational age.

Statistical Analysis and Data Presentation

Categorical data are presented as counts with percentages. Continuous data are presented as medians with interquartile ranges (IQRs).

Poisson regression with robust SEs was used to calculate the relative risk (RR) for each outcome listed above. The independent variable for all models was exposure to bariatric surgery before the index birth. Categorical variables for the mother's age, race/ethnicity, educational level, parity, and annual household income were included in these models as potential confounders because these factors are known to be associated with the exposure of interest (bariatric surgery)²⁴ and with neonatal outcomes.^{25,26} The matching variable (infant delivery year) was also included in all models.

Figure 2. Data From 1980 to 2013 in Washington State



Data were obtained from Washington State birth certificates, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System. OTB indicates operation-to-birth; POMs, postoperative mothers with a history of a bariatric surgery prior to conception.

Maternal prepregnancy BMI, hypertension, and diabetes are factors that were potentially affected by bariatric surgery and may be associated with the outcomes of interest (in the causal pathway).³⁻⁵ Additional Poisson regression models included all previously listed covariates and were also adjusted for maternal BMI, hypertension, and diabetes to assess the effect of surgery apart from its influence on these factors.

For individuals with available OTB interval data, additional Poisson regression models were constructed to examine the association of this interval with each of the aforementioned outcomes. The independent categorical variable for all models was the OTB interval (defined as <2 years, 2-4 years, or >4 years).¹⁷ Covariates included in these models were all those previously listed except for maternal hypertension and diabetes.

Body mass index data were missing in 24.9% of NOMs and 24.7% of POMs. Therefore, multiple imputation with chained equations was used. All other variables analyzed had less than 5% missing data.

Given an a level of .05, a power of 80%, and this sample size, the minimum detectable RRs for the main outcomes were calculated to be 1.21 for prematurity, 1.20 for NICU admission, and 1.69 for congenital malformation. All analyses were performed using Stata (version 12.1; StataCorp LP), the R software environment (version 3.2.3; The R Foundation), and GraphPad Prism (version 6.0; GraphPad Software, Inc).

Results

In Washington State from 1980 to 2013, there were 2 679 082 births, 1859 of which were from mothers who had a history of a bariatric operation (POMs). The annual proportion of births from POMs in Washington State has increased substantially since 2000 (Figure 2A).

A total of 10 296 individuals were included in the analyses for this study. All 1859 POMs and their infants were enrolled, along with a random population-based sample of 8437 NOMs and their infants. In the overall cohort, the median age was 29 years (IQR, 24-33 years) and the median BMI was 26 (IQR, 22-31). Among POMs, the median OTB interval was 30 months (IQR, 17-52 months) (Figure 2B). Compared with NOMs, POMs were generally older, had a higher annual household income, and were more likely to be of white race. The median BMI among NOMs was 24.7 (IQR, 21.8-28.9), and the median BMI among POMs was 31.2 (IQR, 27.0-37.0) (Table 1).

Higher Risks for Complications in Infants From Mothers Who Underwent Bariatric Surgery

Relative to NOMs, POMs of similar age, BMI, parity, socioeconomic status, and comorbid conditions had generally worse perinatal outcomes. More specifically, 8.6% of infants from NOMs were premature (gestational age, <37 weeks) compared with 14% of infants from POMs (RR, 1.57; 95% CI, 1.33-1.85). Early preterm births (gestational age, <32 weeks) occurred in 1.5% of NOMs and 3.0% of POMs (RR, 1.71; 95% CI, 1.16-2.01). Eleven percent of infants from NOMs required NICU admission compared with 15.2% of infants from POMs (RR, 1.25; 95% CI, 1.08-1.44). Relative to infants from NOMs, in-

Table 1. Characteristics of Mothers Who Had a Bariatric Operation Before Conception^a

Characteristic	NOMs (n = 8437)	POMs (n = 1859)
Age, median (IQR), y	28 (24-32)	32 (28-36)
BMI, median (IQR) ^b	24.7 (21.8-28.9)	31.2 (27.0-37.0)
Race/ethnicity, No. (%)		
White	6025 (71.4)	1594 (85.7)
Nonwhite	2236 (26.5)	247 (13.3)
Educational level, No. (%)		
High school or less	1150 (13.6)	74 (4.0)
High school graduate or some college	4388 (52.0)	1114 (59.9)
College graduate or advanced degree	2623 (31.1)	594 (32.0)
Parity, No./total No. (%)		
No prior birth	3454/8310 (41.6)	641/1835 (34.9)
1 Prior birth	2657/8310 (32.0)	631/1835 (34.4)
≥2 Prior births	2199/8310 (26.5)	563/1835 (30.7)
History of prior preterm birth, No. (%)	201 (2.4)	91 (4.9)
Married, No. (%)	5824 (69.0)	1367 (73.5)
Annual household income, median (IQR), \$ ^c	44 000 (35 000-55 000)	46 000 (37 000-57 000)
Hypertension, No. (%)	1363 (16.2)	336 (18.1)
Diabetes, No. (%) ^d	499 (5.9)	186 (10.0)
Malnutrition, No. (%) ^e	73 (0.9)	57 (3.1)
OTB interval, median (IQR), mo ^b	1 [Reference]	30.3 (17.3-52.3)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); IQR, interquartile range; NOMs, nonoperative mothers; OTB, operation to birth; POMs, postoperative mothers with a history of a bariatric surgery prior to conception.

^a Percentages may not sum to 100 because of missing values. Data were obtained from Washington State birth certificates from January 1, 1980, to May 30, 2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System.

^b Variables with greater than 5% missingness were BMI (24.8%) and OTB interval (49.2%).

^c Amount was based on census tract median annual household income.

^d Mothers had established or gestational diabetes.

^e Malnutrition was defined by *International Classification of Diseases, Ninth Revision*, codes for malnourishment, iron-deficient anemia, vitamin B₁₂ deficiency, vitamin D deficiency, or other vitamin or mineral deficiency not otherwise specified.

fantoms from POMs were also at higher risk for SGA status (13.0% vs 8.9%; RR, 1.93; 95% CI, 1.65-2.26) and low Apgar score of 8 or less (17.5% vs 14.8%; RR, 1.21; 95% CI, 1.06-1.37). Infants from POMs had trended toward higher risks for congenital malformations and mortality but had lower risk for LGA status (8.7% vs 6.6%; RR, 0.53; 95% CI, 0.44-0.65). Moreover, 40.7% of POMs underwent cesarean section compared with 25.4% of NOMs (RR, 1.21; 95% CI, 1.12-1.31) (Table 2 and Figure 3A and B). Alternative analyses without adjustments for maternal BMI, hypertension, and diabetes (Table 2) resulted in risk estimates that were not meaningfully different.

Higher Risks for Complications in Infants From Mothers With Short OTB Intervals

Risks for perinatal complications were associated with OTB intervals. Compared with infants from mothers with greater than

Table 2. Outcomes for Mothers Who Had a Bariatric Operation Before Conception Compared With Mothers Who Did Not Have an Operation^a

Outcome	No. (%)		Value (95% CI)		
	NOMs (n = 8437)	POMs (n = 1859)	RR	Adjusted RR ^b	Adjusted RR ^c
Neonatal					
Prematurity	723 (8.6)	261 (14.0)	1.64 (1.43-1.87)	1.60 (1.38-1.86)	1.57 (1.33-1.85)
NICU admission	956 (11.3)	282 (15.2)	1.34 (1.18-1.51)	1.32 (1.15-1.52)	1.25 (1.08-1.44)
Congenital malformation ^d	1359 (16.1)	403 (21.7)	1.35 (1.22-1.49)	1.26 (1.13-1.41)	1.12 (0.99-1.26)
SGA	754 (8.9)	242 (13.0)	1.48 (1.29-1.70)	1.80 (1.55-2.08)	1.93 (1.65-2.26)
LGA	736 (8.7)	122 (6.6)	0.77 (0.64-0.92)	0.63 (0.52-0.77)	0.53 (0.44-0.65)
Apgar score ≤8	1246 (14.8)	326 (17.5)	1.19 (1.06-1.33)	1.23 (1.09-1.39)	1.21 (1.06-1.37)
Birth injury	223 (2.6)	50 (2.7)	1.02 (0.76-1.40)	1.11 (0.81-1.51)	1.11 (0.79-1.56)
Fetal or infant mortality	81 (1.0)	27 (1.5)	1.51 (0.98-2.33)	1.55 (1.01-2.45)	1.54 (0.91-2.61)
Labor					
Cesarean section	2139 (25.4)	757 (40.7)	1.61 (1.50-1.72)	1.49 (1.38-1.60)	1.21 (1.12-1.31)
Fetal distress	349 (4.1)	97 (5.2)	1.27 (1.02-1.58)	1.25 (0.98-1.58)	1.11 (0.86-1.42)
Assisted birth ^e	495 (5.9)	71 (3.8)	0.65 (0.51-0.83)	0.66 (0.51-0.86)	0.78 (0.60-1.02)
Precipitous labor	249 (3.0)	47 (2.5)	0.86 (0.63-1.17)	0.89 (0.65-1.23)	0.99 (0.71-1.39)
Prolonged labor	180 (2.1)	23 (1.2)	0.58 (0.38-0.89)	0.60 (0.37-0.97)	0.59 (0.37-0.96)

Abbreviations: LGA, large for gestational age; NICU, neonatal intensive care unit; NOMs, nonoperative mothers [reference]; OTB, operation to birth; POMs, postoperative mothers with a history of a bariatric surgery prior to conception; RR, relative risk; SGA, small for gestational age.

^a Data were obtained from Washington State birth certificates from January 1, 1980, to May 30, 2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System.

^b Adjusted RRs and 95% CIs are presented using Poisson regression with model structure as follows: (1) exposure was operation, (2) outcomes are listed in the far left column, and (3) maternal covariates were categorical variables for

race/ethnicity, educational level, parity, hypertension, diabetes, birth year, and linear spline variables for age, body mass index, and annual household income.

^c Adjusted RRs and 95% CIs are presented using the same Poisson regression model above in footnote b but with additional categorical maternal covariates for prepregnancy body mass index, hypertension, and diabetes. Missing body mass index values were imputed.

^d Congenital malformation was defined by *International Classification of Diseases, Ninth Revision*, codes 740 through 756.

^e Assisted birth was defined as vacuum or forceps use to assist vaginal delivery.

a 4-year OTB interval, infants from mothers with less than a 2-year interval had higher risks for prematurity (11.8% vs 17.2%; RR, 1.48; 95% CI, 1.00-2.19), NICU admission (12.1% vs 17.7%; RR, 1.54; 95% CI, 1.05-2.25), and SGA status (9.2% vs 12.7%; RR, 1.51; 95% CI, 0.94-2.42) (eTable 1 in the Supplement and Figure 3C). Infants of mothers with less than 2-year and 2- to 4-year OTB intervals had similar risks for SGA status relative to infants of mothers with greater than a 4-year interval (RR, 1.51; 95% CI, 0.94-2.42 and RR, 1.67; 95% CI, 1.04-2.68, respectively). Infants of POMs with a 2- to 4-year OTB interval had prevalences of prematurity and NICU admission that were not meaningfully different from the population-based random sample of other infants. Moreover, infants of POMs with greater than a 4-year OTB interval had a prevalence of SGA status that was not meaningfully different from the population-based sample of infants.

No other outcomes showed an association of appreciable magnitude with the OTB interval. These results are summarized in eTable 2 in the Supplement.

Discussion

Compared with a large population-based random sample of infants from Washington State, infants from mothers with prior bariatric operations (POMs) were at a higher risk for prematurity, NICU admission, SGA status, and low Apgar score. Moreover, relative to infants from NOMs, infants from POMs tended to have

more congenital malformations. Infants of mothers who had an OTB interval of less than 2 years demonstrated higher risks for complications compared with those who had longer intervals. Taken together, these results indicate that neonatal risks are generally higher for POMs relative to mothers of similar age, prepregnancy BMI, parity, socioeconomic status, and comorbidity. These findings could inform postoperative counseling, preconception advice, and perinatal risk assessment for POMs.

Prior analyses of perinatal outcomes in mothers with a history of bariatric surgery have often failed to account for BMI and comorbidities.³ It is well established that bariatric operations reduce BMI and the prevalence of hypertension and diabetes, and several studies^{3,5,6} indicate that maternal operations likely reduce the risk for some birth complications and neonatal complications. However, our analyses included multiple other outcomes and adjusted for BMI. The findings herein likely reflect relevant metabolic and nutritional consequences of an operation that may compromise fetal development, factors that are separate from mediators of biological pathways for maternal obesity, hypertension, and diabetes. Based on our analysis of these data, POMs should be counseled that their risks for perinatal complications are elevated compared with women of similar prepregnancy BMI and comorbid health conditions.

Undoubtedly, bariatric operations result in many health benefits for morbidly obese women of childbearing age⁴ and reduce obesity-related obstetrical complications.^{17,27} Findings from this study should not deter bariatric surgeons from offering such therapy to this population. Although we found

evidence for some increased perinatal complications among POMs, our results indicate that these risks attenuate over time and approach the baseline population risk within 2 to 3 years. In other words, after 2 to 3 years, mothers appear to reap the benefits of a weight loss operation without increasing fetal risk.

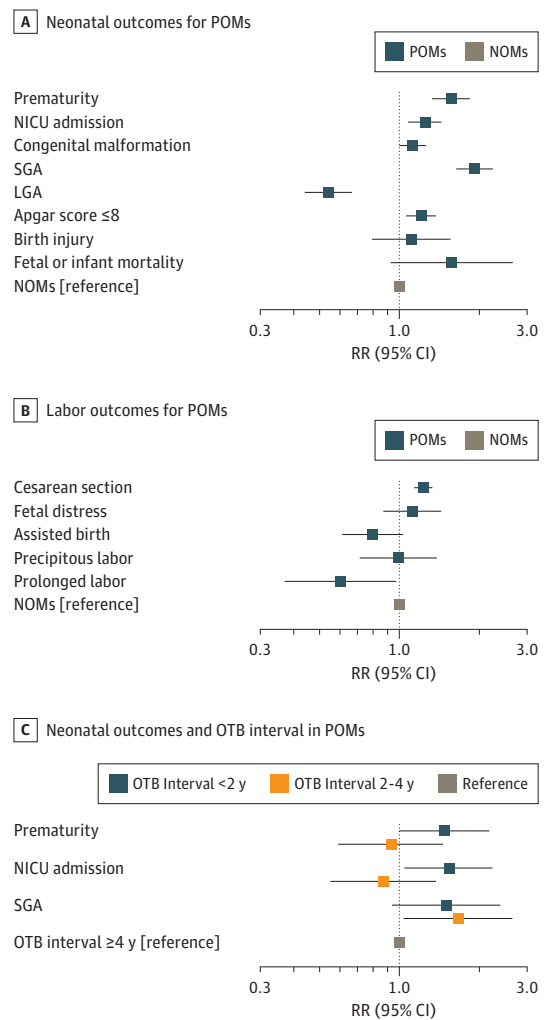
Expert consensus from the American College of Obstetricians and Gynecologists¹⁷ has previously recommended avoiding pregnancy for a minimum of 2 years after a bariatric operation. The first 12 to 16 months after surgery are a time of rapid weight loss and metabolic changes that can potentially result in nutritional deficiencies.^{3,7} Conception during this period may expose a fetus to suboptimal conditions for development. Placental development, fetal well-being, and long-term infant outcomes have been linked with the metabolic and nutritional status of the mother.^{28,29} Therefore, it is biologically plausible that underlying maternal nutritional deficits after a bariatric operation create a poor environment for a developing fetus and could adversely affect neonatal outcomes. Data from this study indicate that these adverse effects may persist up to 3 years after a bariatric operation and suggest that the minimum recommended safe interval should perhaps be extended to 3 years after surgery.

Some prior studies^{15,30} have evaluated OTB intervals and found no significant differences in perinatal risks. However, many investigations are limited by small sample sizes and fail to evaluate several relevant outcomes. To our knowledge, only 1 other adequately powered population-based cohort study²⁷ has evaluated the timing of surgery in relation to birth. In that study, Roos et al²⁷ enrolled 2562 POMs from 1980 to 2009 in Sweden. As part of a subanalysis, the authors evaluated OTB intervals and found increased risks for prematurity and SGA status for all intervals up to 5 years. However, their use of logistic regression for common outcomes likely led to overstated risk estimates,³¹ and only 2 outcomes were evaluated. Our study evaluated a more comprehensive list of relevant outcomes and used Poisson regression with robust SEs, which is more suitable to directly estimate RR in the context of common outcomes.

Bariatric operations may be associated with fewer labor and delivery complications, presumably due to weight loss, less anatomic constraints, and reduced fetal macrosomia.^{5,8} Our study found that POMs have lower risks for macrosomic infants and prolonged labor compared with NOMs. Taken together, these findings suggest that bariatric operations confer some advantages during labor and delivery. However, this conclusion is tentative at best because there were more cesarean sections in POMs compared with NOMs.

Several limitations are important to consider when interpreting our results. First, our database did not contain details on subtypes of bariatric operations, and all were combined into an aggregate exposure to bariatric surgery. Undoubtedly, these operations create widely different effects on physiology, metabolism, nutrition, and hormonal balance.⁴ It is likely that differences in neonatal outcomes will depend, in part, on which type of bariatric operation the mother had.³² Nevertheless, previous studies^{3,10,13,14} have used a similar aggregate approach, and valuable information can still be gleaned from this type of analysis. Second, the results of this study may have limited generalizability to contemporary patients because enrollment spanned more than 30 years. Surgical and obstetrical approaches have improved

Figure 3. Neonatal and Labor Outcomes



Data were obtained from Washington State birth certificates from January 1, 1980, to May 30, 2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System. Adjusted relative risks (RR) and 95% CIs are presented using Poisson regression with model structure as follows: (1) exposure was operation, (2) outcomes are listed in the far left column, and (3) maternal covariates were categorical variables for race/ethnicity, educational level, parity, hypertension, diabetes, birth year, and linear spline variables for age, body mass index, and annual household income. Congenital malformation was defined by *International Classification of Diseases, Ninth Revision*, codes 740 through 756. Missing body mass index values were imputed. LGA indicates large for gestational age; NICU, neonatal intensive care unit; NOMs, nonoperative mothers; OTB, operation-to-birth; POMs, postoperative mothers with a history of a bariatric surgery prior to conception; and SGA, small for gestational age.

over time,¹ metabolic follow-up has become more standardized,² and associated risks have likely changed as well. However, only 14.3% of births from POMs occurred before 2000, and 52.0% occurred after 2008, making this study group a fairly contemporary cohort. Third, one could posit that adjustment for BMI “adjusts away” some of the anticipated benefits of a bariatric operation for mothers and their infants. However, unadjusted analyses still showed risk estimates of similar direction and magnitude, indicating that these risks are likely independent of biological

mediators for obesity. Fourth, this study does not inform the decision process for an obese woman contemplating a bariatric operation before pregnancy. Addressing this issue would have required matching POMs to NOMs on the basis of preoperative BMI. Unfortunately, only prepregnancy BMI (not preoperative BMI) was available in the data set. Therefore, the analyses and results of this study are mainly relevant to women who have already had a bariatric operation, and our conclusions inform these women about their altered likelihood of perinatal complications.

Conclusions

Infants of mothers with a prior bariatric operation had higher risks for multiple perinatal complications compared with infants of

NOMs of similar age, BMI, parity, socioeconomic status, comorbidity, and delivery year. Infants of mothers who had a short OTB interval demonstrated higher risks for complications compared with those who had longer intervals. In particular, infants of mothers who had less than a 2-year OTB interval demonstrated higher risks for prematurity and NICU admission compared with those who had longer intervals. Moreover, an elevated risk for SGA status may persist up to 3 years after a bariatric operation. This study underscores the higher risk status of this population and may indicate that a recently postoperative mother with underlying nutritional, metabolic, and physiological changes is at an elevated risk for perinatal complications. These findings could help inform health care professionals and postoperative women of childbearing age about the optimal timing between bariatric surgery and conception.

ARTICLE INFORMATION

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Study concept and design: Parent, Martopullo, Khandelwal, Fay, Rowhani-Rahbar.

Acquisition, analysis, or interpretation of data:

Parent, Martopullo, Weiss, Rowhani-Rahbar.

Drafting of the manuscript: Parent, Martopullo, Fay.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Parent, Martopullo, Rowhani-Rahbar.

Administrative, technical, or material support: Parent, Fay.

Study supervision: Weiss.

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Additional Contributions: Bill Obrien, BS (Department of Epidemiology, University of Washington School of Public Health) compiled the database that made this study possible. Kristjana Asbjornsdottir, MPH, PhD, Brianna Mills, MA, Alyson Littman, PhD, and Stephen Hawes, PhD (Department of Epidemiology, University of Washington School of Public Health) assisted in the conception of this project. We thank the Washington State Department of Health for data access. No direct compensation was given for any of the above contributions.

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Invited Commentary

Corrected vs Uncorrected Obesity in Childbearing Women—What Really Drives Fetal Risks?

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Bariatric surgery has helped to improve the health and quality of life of thousands of morbidly obese Americans. Yet, despite a notable short-term safety profile, several questions have recently been raised about its long-term physiological and psychosocial effects. Suicide, for example, may be more common after bariatric surgery than before, in spite of apparent improvements in patients' underlying



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depression.¹ In this issue of *JAMA Surgery*, Parent and colleagues² add to this debate

by suggesting that women who undergo bariatric surgery may be at higher risk for certain perinatal complications, especially if they get pregnant within 2 years of their operation. While these findings are compelling, additional questions must be answered before they can be used to guide patient care.

First, is this link a causal one? Multiple pathways can be drawn between bariatric surgery and delivering a neonate who is preterm, small for gestational age, or in need of intensive care. Surgically induced nutritional deficits—the primary mechanism suggested by the authors—is plausible: bariatric surgery has been linked to iron deficiency anemia,³ a known risk factor for low birth weight, abnormal fetal oxygenation, and perinatal mortality.⁴ However, other potential mechanisms must be explored. For example, patients who are obese are more likely to require preterm delivery for maternal or fetal indications,⁵ a fact that must be accounted for when comparing raw (ie, not gestational age adjusted) birth weights. A stron-

ger argument for nutritional causes could have been made if Parent and colleagues² had stratified postoperative mothers by the type of procedure they received. If malnutrition is, in fact, responsible, then one would expect to see higher rates of perinatal complications among women who underwent gastric bypass (in part a malabsorptive procedure) than among those who underwent gastric banding (primarily a restrictive one). In addition, measuring actual nutritional parameters (eg, vitamin B₁₂ levels) or rates of maternal anemia would have been informative.

Second, and perhaps most important, are we making the right comparison? Even if obese women who undergo bariatric surgery are at higher risk for perinatal complications than a random sample of mostly white, educated, and normal-weight Washingtonians, are they at lower or higher risk than they would have been without the operation? Obesity—along with its associated comorbid health conditions—has itself been repeatedly linked to multiple perinatal complications, including preeclampsia, placental abruption, congenital anomalies, miscarriage, and stillbirth.³

Although many of these risks may decline as patients lose their excess weight, others may endure. Therefore, it is difficult to know if the apparent increase in perinatal complications that Parent and colleagues² found is due to the persistent effects of obesity or to the operation meant to correct them, especially considering that the majority of postoperative mothers in the current study remained obese.

ARTICLE INFORMATION

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