Bariatric surgery in women of child-bearing age, timing between an operation and birth, and associated perinatal complications

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Abstract

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Importance: Metabolic changes after maternal bariatric surgery may impact 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: 1) To assess perinatal complications in postoperative mothers ('POMs') compared to mothers without operations (non-operative mothers, 'NOMs'). 2) To examine the association of the OTB interval with perinatal outcomes.

Design: Population-based retrospective cohort study from 1980-2013. Data were collected from birth certificates and maternally-linked hospital discharge data.

Setting: Hospitals in Washington State

Participants: a) All POMs and their infants (n=1,859); b) a population-based random sample of NOMs and their infants, frequency-matched by delivery year (n=8,437).

Exposures: a) Bariatric operation prior to birth or b) categories of OTB intervals.

Main Outcomes and Measures: 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 (RR) and confidence intervals (CI), with adjustments for maternal body mass index, delivery year, socioeconomic status, age, parity, and co-morbid conditions.

Results: Compared to infants from NOMS, infants from POMs had a higher risk for prematurity (14% vs. 9%, RR 1.6, 95% CI 1.3-1.9), NICU admission (15% vs. 11%, RR 1.3, 95% CI 1.1-1.4), SGA status (13% vs. 9%, RR 1.9, 95% CI 1.7-2.3), and low APGAR scores (18% vs. 15%, RR 1.2, 95% CI 1.1-1.4). Compared to infants from mothers with a ≥4 year OTB interval, infants from mothers with a ≤2 year interval had higher risks for prematurity (RR 1.5, 95% CI 1.0-2.2), NICU admission (RR 1.5, 95% CI 1.1-2.3), and SGA status (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 to infants of non-operative mothers. Operation-to-birth intervals <2 years were associated with higher risks for prematurity, SGA status, and NICU admission, compared to longer intervals. These findings are relevant to bariatric surgeons, obstetricians, and their patients, and could inform decisions regarding the optimal timing between an operation and conception.

Supplementary material included:

Figure 1, 2 and 3: Flow diagram, epidemiologic birth trends, and forest plot of risk estimates

Supplemental Tables 1 and 2: risks associated with operation-to-birth intervals

Introduction:

Bariatric operations may be considered for individuals with a body mass index (BMI) ≥ 40 or a BMI ≥ 35 with obesity-related co-morbidities.[1,2] These surgeries 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 about 30% and often have resolution of obesity-related co-morbidities, 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 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 in obese women who did not undergo a bariatric operation.[3,5,6] However, there are several other relevant indicators of perinatal health in this population that have not been fully explored in the published literature. In particular, since bariatric operations can result in nutritional deficiencies in the mother,[7] there has been some concern that surgery may adversely impact 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 studies have investigated these outcomes, conclusions are conflicting and limited by small sample sizes.[10-14]

In addition, a “safe” interval between an operation and childbirth remains undefined. The year following 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 on perinatal outcomes.

We conducted a population-based retrospective cohort study to investigate the association of bariatric surgery with subsequent perinatal outcomes. We also aimed to assess the influence of OTB interval on perinatal risks.

Methods:

Study design, subjects, setting and data collection

Data from Washington State birth certificates (1980-2013) were linked to longitudinal maternal discharge data on prior hospitalizations, using the Comprehensive 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. The majority of variables were recorded independently in both birth certificate datasets and the CHARS dataset. This enabled cross-checking and verification.

All mothers with a delivery year from 1980 to 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 prior to conception were included. This group is referred to here 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 here as ‘non-operative 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 and determined to be ‘exempt’ due to the de-identified nature of the data.

Exposures and outcomes

The primary exposure of interest was a history of a bariatric operation at any time prior to 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 Disease (ICD9) codes V45.86 and 649.2. These codes indicate the postoperative status of the mother, and were assigned during prior hospitalizations (CHARS-linked data), or were assigned at the time of birth (birth certificate data). Exposure definition using ICD9 codes for bariatric surgery has been utilized in previous cohort studies.[19,20] The secondary exposure of interest among POMs was operation-to-birth (OTB) interval (≤2 years, 2-4 years or ≥4 years), with the shortest time-interval defined by expert guidelines as the minimum safe interval.[17]

Primary outcomes were related to neonatal complications. These included: a) *prematurity*, defined by a 'late preterm' category (gestational age <37 weeks) and an 'early preterm' category (gestational age <32 weeks); b) *NICU admission*, defined as any infant admission to the ICU, at any point during the birth hospitalization; c) *congenital malformation*, defined as any malformation diagnosis coded on the birth certificate, and/or any infant discharge diagnosis ICD-9 codes from 740-756;[i] d) *small/large for gestational age* (*SGA or LGA)*, defined as the lowest 10% and highest 10% of birth weights, based upon Washington State population data from 1989-2002, as previously described;[21] e) *APGAR scores,* which constitute a combined measure of neonatal activity and vital signs, and are determined by the obstetrician 5 minutes after birth;[9] f) *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; g)*fetal/infant mortality*, defined as any 'still-birth' or infant death during the birth hospitalization.

Secondary outcomes were related to labor and delivery complications. These included: a) *cesarean-section (C-section)*, defined as any abdominal operation (planned or unplanned) which results in the delivery of the infant; b) *fetal distress* in labor, defined by an obstetrician's interpretation of fetal heart-rate monitoring, as has been previously described;[22] c) *operative vaginal delivery*, defined as any vaginal delivery requiring forceps, or vacuum-assist; d) *precipitous or prolonged labor*, defined as <3 hours or >20 hours for primigravid women and > 14 hours for multiparous women, respectively.[23]

Statistical analysis and data presentation

Categorical data are presented as counts with percentages, and continuous data are presented as medians with inter-quartile range (IQR).

[i] Predominantly heritable or chromosomal abnormalities (e.g. Down's Syndrome, other abnormal karyotypes) were excluded from the malformation definition because their etiology is thought to be relatively independent of the maternal metabolic and nutritional environment.

Poisson regression with robust standard errors was used to calculate the relative risk for each outcome listed above. The independent variable for all models was exposure to bariatric surgery prior to the index birth. Categorical variables for the mother's race, age, education, income, and parity were all included in these models as potential confounders, because these are factors which have been shown previously to be associated with both the exposure of interest (bariatric surgery)[24] and with neonatal outcomes.[25,26] Of note, the matching variable (infant delivery year) was also included in all models.

Maternal pre-pregnancy BMI, diabetes and hypertension are factors that were potentially affected by the operation and are potentially associated with 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, diabetes and hypertension, in order to assess the impact 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 OTB interval (defined as ≤ 2 years, 2-4 years, or ≥4years).[17] Covariates included in these models were all those previously listed, except for maternal diabetes and hypertension.

BMI data were missing in 25% of both NOMs and POMs. Therefore, multiple imputation with chained-equations (MICE) was used. All other variables analyzed had <5% missing data.

Given an alpha level of 0.05, a power of 80%, and this sample size, the minimum detectable relative risks for main outcomes were calculated to be: 1.21 for prematurity, 1.69 for congenital malformation, and 1.20 for NICU admission. All analyses were performed using Stata 12.1 (StataCorp, College Station, TX), the R software environment (version 3.2.3), and GraphPad Prism (version 6.0).

Results:

In Washington State from 1980-2013, there were a total of 2,679,082 births. Of these, 1,859 births were from mothers who had a history of a bariatric operation (postoperative mothers, POMs). The annual proportion of births from POMs in Washington State increased substantially since the year 2000 (Figure 2a).

A total of 10,296 subjects were included in the analyses for this study. All 1,859 POMs and their infants were enrolled, along with a random population-based sample of 8,437 non-operative mothers (NOMs) and their infants. In the overall cohort, the median age was 29 years (IQR 24-33) and the median BMI was 26 kg/m^2 (IQR 22-31). Among POMs, the median OTB interval was 30 months (IQR 17-52 months) (Figure 2b). Compared to NOMs, POMs were generally older, had a higher income, and were more likely to be Caucasian. 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).

Infants from mothers who underwent bariatric surgery had higher risks for complications

Relative to NOMs, POMs of similar BMI, socioeconomic status, age, parity, and co-morbidity had generally worse perinatal outcomes. More specifically, 9% of infants from NOMs were premature (gestational age <37 weeks), compared to 14% of infants from POMs (RR 1.6, 95% CI 1.3-1.9). '*Early* preterm' births (gestational age <32 weeks) occurred in 1.5% of NOMs and 3% of POMs (RR 1.7, 95% CI 1.1-2.6). 11% of infants from NOMs required NICU admission, compared to 15% of infants from POMs (RR 1.3, 95% CI 1.1-1.4). Relative to infants from NOMs, infants from POMs were also at relatively higher risks for small-for-gestational-age status (RR 1.9, 95% CI 1.6-2.3), and low APGAR score (RR 1.2, 95% CI 1.1-1.4). Infants from POMS had trends toward higher risks for malformations and mortality, but had lower risk for large-for-gestational-age status (RR 0.53, 95% CI 0.44-0.65). Moreover, 41% of POMs underwent C-section, compared to 25% of NOMs (RR 1.21, 95% CI 1.12-1.31) (Table 2, Figure 3a,b). Alternative analyses without adjustments for maternal BMI, diabetes and hypertension (Table 2) resulted in risk estimates that were not meaningfully different.

Infants from mothers with short operation-to-birth intervals had higher risks for complications

The risks for perinatal complications were associated with OTB intervals. Compared to infants of mothers with a ≥4 year OTB interval, infants of mothers with a ≤2 year interval had higher risks of prematurity (12% vs. 17%, RR 1.5, 95% CI 1.0-2.2), NICU admission (12% vs. 18%, RR 1.5, 95% CI 1.1-

2.3), and SGA status (9% vs. 13%, RR 1.51, 95% CI 0.94-2.42) (Supplemental Table 1 , Figure 3c). Infants of mothers with <2 year and 2-4 year OTB intervals had similar risks for SGA status, relative to infants of mothers with 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 2-4 year OTB interval had a prevalence of prematurity and NICU admission which were not meaningfully different from the population-based random sample of other infants. Moreover, infants of POMs with a ≥4 year interval had a prevalence of SGA status which was not meaningfully different from the population-based sample of infants.

No other outcomes showed an association of appreciable magnitude with OTB interval (Supplemental Table 2).

Discussion:

Compared to a large population-based random sample of infants from Washington State, infants from mothers with prior bariatric operations (POMs) were at a higher risk of prematurity, SGA status, NICU admissions, and low APGAR scores. Moreover, relative to infants from NOMs, infants from POMs tended to have more congenital malformations. Infants of mothers who had an operation-to-birth interval <2 years demonstrated higher risks of complications compared to those who had longer intervals. Taken together, these results indicate that neonatal risks are generally higher for mothers who had a prior bariatric operation, relative to mothers of similar age, pre-pregnancy BMI, socioeconomic status, parity, and co-morbidity.

Prior analyses of perinatal outcomes in mothers with a history of bariatric surgery have often failed to account for body mass index and co-morbidities.[3] It is well established that bariatric operations reduce BMI, and the prevalence of hypertension and diabetes, and multiple studies indicate that maternal operations likely reduce the risk for some birth complications and neonatal complications.[3,5,6] However, our analyses included multiple other outcomes, and adjusted for BMI. Our findings likely reflect relevant metabolic and nutritional consequences of an operation which may compromise fetal development– factors that are *apart from* mediators of biologic pathways for maternal obesity, diabetes and hypertension. Based on our analysis of these data, women who have had bariatric operations should be counseled that their risks of perinatal complications are elevated, compared to women of similar pre-pregnancy BMI and co-morbid health conditions.

Undoubtedly, bariatric operations result in many health benefits for morbidly-obese women of child-bearing age,[4] and reduce obesity-related obstetric complications.[17,27] Findings from this study should *not* deter bariatric surgeons from offering this therapy to this population. Although we found evidence for some increased perinatal complications among postoperative mothers, our findings indicate that these risks attenuate over time and approach the baseline population risk within 2-3 years. In other words, after 2-3 years, mothers appear to reap the benefits of a weight-loss operation without increasing fetal risk.

Expert consensus from the American College of Gynecologists has previously recommended avoiding pregnancy for a minimum of 2 years after a bariatric operation.[17] The first 12-16 months after a bariatric operation are a time of rapid weight loss and metabolic changes that can potentially result in nutritional deficiencies. [3,7] Conception during this time period may expose a fetus to sub-optimal conditions for growth and development. Placental development, fetal well-being, and long-term infant outcomes have all been linked with the metabolic and nutritional status of the mother.[28,29] It is therefore biologically plausible that underlying maternal nutritional deficits following a bariatric operation create a poor environment for a developing fetus, and could adversely impact neonatal outcomes. Data from this study indicate that these adverse effects may persist up to 3 years after an operation, and suggest that the minimum recommended safe interval should perhaps be extended to 3 years postoperatively.

Some prior studies have evaluated operation-to-birth interval, and have found no significant differences in perinatal risks.[15,30] However, almost all of these studies are limited by small sample sizes and fail to evaluate several relevant outcomes. To our knowledge, only one other adequately-powered population-based cohort study has evaluated timing of surgery in relation to birth.[27] In this study, Roos, et al. enrolled 2562 mothers with prior bariatric operations from 1980-2009 in Sweden. As part of a sub-analysis, the authors evaluated operation-to-birth intervals, and found increased risks for SGA status and prematurity for all intervals up to 5 years. However, their use of logistic regression for relatively common outcomes likely led to overstated risk estimates,[31] and only two outcomes were evaluated. Our study evaluated a more comprehensive list of relevant outcomes, and utilized Poisson regression with robust standard errors, which is more suitable to directly estimate relative risk in the context of common outcomes.

Bariatric operations may be associated with less labor and delivery complications, presumably due to weight loss, fewer anatomic constraints and reduced fetal macrosomia.[5,8] Our study found that POMs have lower risks for macrosomic infants and prolonged labor compared to NOMs. POMs also showed a trend toward lower delivery assistance requirements (use of vacuum or forceps in vaginal delivery). Taken together, these findings suggest that bariatric operations confer some advantages during labor and delivery. However, this conclusion is tentative, at best, since there were more C-sections in POMs compared to NOMs (for unclear reasons).

Several limitations are important to consider when interpreting our results. First, our database did not contain details on subtypes of bariatric operation, and all were combined into an aggregate exposure: '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. Mal-absorptive procedures, such as Roux-en-y gastric-bypass, are more likely to lead to nutritional deficiencies compared to purely restrictive procedures, such as gastric banding.[32] Nevertheless, previous studies have used a similar aggregate approach,[3,10,13,14] 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 since enrollment spanned over 30 years. Surgical and obstetrical approaches have improved over time,[1] metabolic follow-up has become more standardized,[2] and associated risks have likely changed as well. However, only 14% of births from POMs occurred before the year 2000, and 52% occurred after 2008, making this 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 biologic mediators for obesity.

Conclusions

Infants of mothers with a prior bariatric operation had higher risks for multiple perinatal complications, compared to infants of non-operative mothers with similar age, BMI, delivery-year, socioeconomic status, parity, and co-morbidity. Infants of mothers who had a short operation-to-birth interval demonstrated higher risks of complications compared to those who had longer intervals. In particular, infants of mothers who had a ≤2 year operation-to-birth interval demonstrated higher risks for prematurity and NICU admission compared to 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 physiologic changes, is at an elevated risk for perinatal complications. These findings could help to inform health-care providers and women of child-bearing age about the optimal timing between bariatric surgery and conception.

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Dr. Brodie Parent, from the University Of Washington Department Of Surgery, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Author contributions:

Dr. Brodie Parent: study conception and design, data acquisition, data analysis and interpretation, statistical analysis, manuscript drafting, and critical revision of manuscript.

Ira Martopullo: study conception and design, data acquisition, data analysis and interpretation, statistical analysis, and critical revision of manuscript.

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Figure legends:

Figure 1. Flow diagram for a retrospective cohort study of Washington State mothers with bariatric operations and their infants.

Footnote: BMI=body mass index, CHARS= Comprehensive Hospital Abstract Reporting System, LGA/SGA=large/small for gestational age, NICU=neonatal intensive-care unit, NOMs=non-operative mothers, POMs= postoperative mothers.

Figure 2. From 1980-2013 in Washington State: a) total births and births from mothers with a prior bariatric surgery, and b) operation-to-birth intervals in mothers with a prior bariatric surgery.[a]

Footnote: a: Data were obtained from Washington State Birth Certificates, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System.

POM='postoperative mothers' / mothers with a history of a bariatric surgery

Figure 3.a)Neonatal and b) labor outcomes for mothers with a prior bariatric surgery, compared to mothers who did not have an operation (non-operative mothers); c) neonatal outcomes and the operation-to-birth (OTB) interval in mothers with a prior bariatric surgery.[a]

Footnote:

a: Data were obtained from Washington State Birth Certificates from 1980-2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System (CHARS). Adjusted relative risks and 95% confidence intervals are presented, using Poisson regression with model structure as follows: 1) exposure: operation, 2) outcomes: as listed above, and 3) maternal covariates: categorical variables for birth year, race, education, parity, diabetes, hypertension, and linear spline variables for BMI, age and income. Missing body mass index values were imputed.

b: Neonatal Intensive Care Unit

c: Congenital malformation defined by ICD-9 codes 740-756

d: Small/Large for Gestational Age

e: "Appearance, Pulse, Grimace, Activity, Respiration" score, to quickly summarize newborn health, measured at 5 minutes after birth.

f: *cesarean* section

g: assisted labor defined as vacuum or forceps use to assist vaginal delivery

Table 1. Characteristics for mothers who had a bariatric operation before conception (postoperative mothers, 'POMs') and mothers who did not have an operation (non-operative mothers, 'NOMs')[a]

Maternal Characteristic	**NOMs (n=8,437)**	**POMs (n=1,859)**
Age (years)	28 (24-32)	32 (28-36)
Body-mass-index (kg/m^2)[b]	24.7 (21.8-28.9)	31.2 (27.0-37.0)
Race		
White	6025 (71)	1594 (86)
Non-white	2236 (27)	247 (13)
Education		
high school or less	1150 (14)	74 (4)
high school graduate or some college	4388 (52)	1114 (60)
college graduate or advanced degree	2623 (31)	594 (32)
Parity		
No prior birth	3454 (41)	641 (35)
One prior birth	2657 (32)	631 (34)
Two or more prior births	2199 (26)	563 (30)
History of prior preterm birth	201 (3)	91 (5)
Married	5824 (69)	1367 (74)
Annual household income (thousands of dollars)[c]	44 (35-55)	46 (37-57)
Hypertension	1363 (16)	336 (18)
Diabetes[d]	499 (6)	186 (10)
Malnutrition[e]	73 (1)	57 (3)
Operation-to-birth interval' (months)[b]	1.00	30.3 (17.3-52.3)

a: Categorical variables are presented as n(%) and continuous variables are presented as median (interquartile range). Percentages may not add to 100 due to missing values. Data obtained from Washington State Birth Certificates from 1980-2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System (CHARS).

b: Variables with >5% missingness: body-mass-index (25%) and 'operation-to-birth interval' (49%).

c: based upon census-tract median annual household income

d: established or gestational

e: defined by ICD9 codes for malnourishment, iron deficient anemia, B12 deficiency, vitamin D deficiency, or other vitamin/mineral deficiency not-otherwise specified.

Table 2. Outcomes for mothers who had a bariatric operation before conception (postoperative mothers, 'POMs') compared to mothers who did not have an operation (non-operative mothers, 'NOMs')[a]

Outcome category	Outcome	NOMs (n=8437, referent)	POMs (n=1859)	RR	95% CI	aRR[b]	95% CI[b]	aRR[c]	95% CI[c]
Neonatal	Prematurity	723 (9)	261 (14)	1.64	1.43-1.87	1.60	1.38-1.86	1.57	1.33-1.85
	NICU[d] admit	956 (11)	282 (15)	1.34	1.18-1.51	1.32	1.15-1.52	1.25	1.08-1.44
	Malformation[e]	1359 (16)	403 (22)	1.35	1.22-1.49	1.26	1.13-1.41	1.12	0.99-1.26
	SGA[f]	754 (9)	242 (13)	1.48	1.29-1.70	1.80	1.55-2.08	1.93	1.65-2.26
	LGA[f]	736 (9)	122 (7)	0.77	0.64-0.92	0.63	0.52-0.77	0.53	0.44-0.65
	APGAR[g] ≤8	1246 (15)	326 (18)	1.19	1.06-1.33	1.23	1.09-1.39	1.21	1.06-1.37
	Birth injury	223 (3)	50 (3)	1.02	0.76-1.40	1.11	0.81-1.51	1.11	0.79-1.56
	Mortality	81 (1)	27 (2)	1.51	0.98-2.33	1.55	1.01-2.45	1.54	0.91-2.61
Labor	C-section[h]	2139 (25)	757 (41)	1.61	1.50-1.72	1.49	1.38-1.60	1.21	1.12-1.31
	Fetal distress	349 (4)	97 (5)	1.27	1.02-1.58	1.25	0.98-1.58	1.11	0.86-1.42
	Vacuum/forceps[i]	495 (6)	71 (4)	0.65	0.51-0.83	0.66	0.51-0.86	0.78	0.60-1.02
	Precipitous	249 (3)	47 (3)	0.86	0.63-1.17	0.89	0.65-1.23	0.99	0.71-1.39
	Prolonged	180 (2)	23 (1)	0.58	0.38-0.89	0.60	0.37-0.97	0.59	0.37-0.96

a: Categorical variables are presented as n(%). Data obtained from Washington State Birth Certificates from 1980-2013, linked with maternal hospital discharge data from the Comprehensive Hospital Abstract Reporting System (CHARS).
b: Adjusted relative risk and 95% confidence interval, using Poisson regression with model structure 1) exposure: operation, 2) outcomes: as listed above, and 3) maternal categorical variables for birth year, race, education, parity and linear spline variables for age and income.
c: Adjusted relative risk and 95% confidence interval, using the same Poisson regression model above, but with additional categorical maternal covariates for pre-pregnancy body mass index, diabetes and hypertension. Missing body mass index values were imputed.

d: Neonatal Intensive Care Unit

e: Congenital malformation defined by ICD-9 codes 740-756

f: Small/Large for Gestational Age

g: "Appearance, Pulse, Grimace, Activity, Respiration" score, to quickly summarize newborn health, measured at 5 minutes after birth.
h: cesarean section
i: 'operative vaginal delivery'; defined as vacuum or forceps use to assist vaginal delivery