Optimal Plan for Delivery in Women with Obesity: A Large Population-based Retrospective Cohort Study Using the Better Outcomes Registry and Network (BORN) Database

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Running Title: Optimal Plan for Delivery in Women with Obesity

Abstract

Objective To discern the optimal plan for delivery in nulliparous women with obesity at term gestation.

Design Large population-based retrospective cohort study

Setting Maternity hospitals in Ontario, Canada

Population Nulliparous women with obesity (BMI>30) with live, singleton, uncomplicated term gestations (37+0 to 41+6 weeks) between April 1st, 2012 and March 31st, 2019

Methods Women were divided by plan for delivery (expectant management, induction of labour and no-labour caesarean section). The outcomes of interest were adverse delivery outcomes. Analyses were conducted using multivariable regression models. Analyses were stratified by each week of gestational age and by obesity class.

Main Outcome Measures The primary outcome was the Adverse Outcome Index (AOI), a binary composite of 10 maternal and neonatal adverse events. The Weighted Adverse Outcome Score (WAOS) was the secondary outcome. It provides a weighted score of each adverse event included in the AOI.

Results No-labour caesarean section reduced the risk of adverse delivery outcome by 41% (aRR 0.59, 95%CI [0.50, 0.70]) compared to expectant management at term gestation. There was no statistically significant difference in adverse birth outcomes when comparing induction of labour to expectant management (aRR 1.03, 95% CI [0.96, 1.10]). The greatest benefit to no-labour caesarean section was observed in the reduction of adverse neonatal events (aRR 0.70, 95% CI [0.57, 0.87]) particularly at 39 weeks of gestation.

Conclusion In women with obesity, no-labour caesarean section reduces adverse birth outcomes.

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Keywords Plan for delivery, Induction of Labour, Caesarean Section, Obesity

Tweetable Abstract In women with obesity, no-labour caesarean section reduces adverse birth outcomes.

Background

Obesity is a growing epidemic among women of reproductive age worldwide. In Canada in 2018, over 20% of women aged 18-34 years reported being obese[1–3]. This is consistent with rates seen in other high-income countries. In low-and-middle-income countries, obesity among reproductive-aged women is growing at a pace faster than in high-income countries. This increase seems to be most significant for women of lower socio-economic status and those living in rural and low-resource environments[4,5].

Three options exist for ongoing care of women at term pregnancy after 37 weeks of gestation: expectant management, induction of labour and no-labour caesarean section. The optimal plan for delivery in the population of women with obesity at term gestation remains equivocal and several challenges often arise.

Maternal obesity is associated with an increased risk of pre-conception type II diabetes, gestational diabetes, hypertensive disorders of pregnancy, large-for-gestational-age infants, and stillbirth[4,6–14]. The increased morbidity of these pregnancies leads to an increase in recommendations for induction of labour. However, in this population, the rate of failed induction of labour has been estimated to be two-fold that of its normal-weight counterparts[15].Moreover, the risk of caesarean section after a trial of labour in women with extreme obesity (Body Mass Index (BMI)>50) has been shown to increase the risk of both maternal and perinatal adverse outcomes four-fold[16]. Caesarean section in the obese parturient has been associated with increased rates of wound infection and thromboembolic disease[17]. It can be technically demanding and has been shown to be associated with longer time to delivery with implications for worse composite neonatal outcomes[18].

These factors have fueled the debate surrounding optimal mode of delivery for women with obesity. Given the growing proportion of women of increased BMI in the population and the suggestion that this proportion is increasing amongst already vulnerable populations of women, there is an urgent need to clarify which mode of delivery results in the most favourable outcomes for both mothers and their newborns.

This study examines the association between planned mode of delivery (expectant management, induction of labour and no-labour caesarean section) and adverse birth outcomes in nulliparous women with obesity. To our knowledge, it is the first of its kind to compare all planned modes of delivery in this population and is designed to help clinicians in their delivery planning for women with obesity at term gestation.

Methods

Study design and population

This was a large population-based retrospective cohort study of all nulliparous women with obesity, with an uncomplicated pregnancy, having a singleton term birth at an Ontario hospital between April 1st, 2012 and March 31st, 2019. Obesity was defined according to the WHO definition as a BMI of greater than 30 kg/m^2. Obesity classes were further categorised as class I (30-34.9 kg/m^2), class II (35-39.9 kg/m^2), class III (40-44.9 kg/m^2), class IV (45-49.9 kg/m^2) and class V (over 50 kg/m^2). An uncomplicated pregnancy was defined as a pregnancy without obstetrical indications for iatrogenic delivery such as pre-existing hypertension, pre-eclampsia, gestational or pre-existing diabetes, antepartum hemorrhage, placental abruption, or premature rupture of membranes. Additional exclusion criteria included pregnancies with fetuses with severe congenital anomalies, large for gestational age (birth weight greater than 90th percentile for gestational age) or small for gestational age (birth weight less than 10th percentile for gestational age). A term birth was defined as a delivery between 37+0 weeks of gestational age and 41+6 weeks of gestational age.

Data sources

The data for the study was derived from the Better Outcome Registry and Network (BORN) Ontario birth registry. The BORN registry has been assessed as a valid, reliable, and high quality, comprehensive perinatal database[19,20]. Pregnancy and birth records were linked to the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database (DAD) to improve the ascertainment of independent variables and outcomes. Neighbourhood-level education and income quintiles were derived via linkage with 2011 Canadian Census data.

Exposure

Planned mode of delivery was the exposure of interest. We defined plan for delivery as expectant management, induction of labour or no-labour caesarean section (NLCS). This is distinct from actual type of birth which can be either spontaneous vaginal delivery, operative vaginal delivery or caesarean section. Women entering labour after a plan for either expectant management, induction of labour or no-labour caesarean section may have had any type of birth.

Outcomes

The primary outcome was the Adverse Outcome Index (AOI). This is a composite binomial outcome where presence of any of the included components confers a value of 1. The AOI is an obstetrical quality measure which has been validated as a measure of obstetrical patient safety in previous studies[21]. The index includes 10 adverse outcomes divided into maternal and fetal components. The maternal components identified are maternal death, uterine rupture, maternal intensive care unit admission, unanticipated operative procedure, blood transfusion and 3rd or 4th degree perineal tear. The fetal components measured are intrapartum or in-hospital newborn death, birth trauma, neonatal intensive care unit admission for more than 2 days and APGAR score less then 7 at 5 minutes. Adverse birth events were analysed overall and by maternal and fetal components. Each individual component was assessed as a secondary outcome.

The Weighted Adverse Outcome Score (WAOS) was also examined as a secondary outcome. Each maternal and neonatal outcome included in the AOI is assigned a weight based on the severity of the adverse event. These weights are summed to calculate a continuous variable which describes the weighted adverse event score per delivery[22].

Statistical Analysis

Demographic and baseline characteristics for women with different plans for delivery (expectant management, induction of labour and no-labour caesarean section) were assessed and contrasted. Descriptive analyses of all plans for delivery were conducted.

Bivariate analyses were conducted to assess the association between plan for delivery and each of the study outcomes using either log-binomial or linear regression, according to the binary or continuous nature of the outcome. Multivariable log-binomial and linear regression models were built, for the AOI and WAOS scores respectively, with adjustment for potential confounders. Potential confounders included in adjusted models were identified a priori by literature review and theoretical importance. They included maternal age, neighbourhood education quintiles, obesity class, substance use in pregnancy, maternal pre-existing health conditions, maternal mental health issues, maternal hospital level of care and type of antenatal care provider. Because of missing data, five data sets were imputed by using fully conditional specification. To account for within-hospital clustering of the data, binary outcomes were estimated using generalized estimating equation models with robust error variance.

Analyses were stratified by gestational age at each completed week of gestation between 37 and 41 weeks as well as by obesity class. Figure 1 describes the analysis flowchart at each gestational age.

A sensitivity analysis was conducted to verify the robust nature of the results by comparing the imputed data set to a complete case analysis.

The R table one package was used to create the tables comparing characteristics of each plan for delivery[23] . All other statistical analyses were conducted using SAS v9.4 (SAS Institute, Cary, NC).

Results

In total, 27 472 deliveries meeting our inclusion criteria were recorded between April 1st 2012 and March 31st, 2019. Of these, 15 752 women were managed expectantly, 9 712 women had a plan for induction of labour and 2008 had a no-labour caesarean section (Table 1). A total of 14 487 women had a spontaneous vaginal delivery, 3 439 women had an operative vaginal delivery, and 9 546 women had a no-labour caesarean section (Table 1 and Figure 1). Clinical and demographic data are described in Table 1.

The mean age of women included in our cohort was 29 years. In our cohort, 17 032 (62.0%) women had class I obesity, 6 529 (23.8%) had class II obesity, 2 363 (8.6%) had class III obesity, 855 (3.1%) had class IV obesity and 693 (2.5%) had class V obesity. The overall rate of caesarean section in our study was 34.7%. Of women who were managed expectantly, 3 631 (23.1%) had a caesarean section. Of women who were induced, 3 907 (40.2%) had a caesarean section delivery.

Table 2 depicts the association between planned mode of delivery (expectant management, induction of labour and no-labour caesarean section) and adverse birth outcomes. Overall, no-labour caesarean section reduced the risk of adverse events by 41% (aRR 0.59, 95%CI [0.50, 0.70]). Similarly, the WAOS showed a trend towards improved outcomes with no-labour caesarean section compared to expectant management (beta -0.96, 95%CI [-1.87, -0.06]). There was no statistically significant increase in risk of adverse outcomes when comparing induction of labour to expectant management (aRR 1.03, 95% CI [0.96, 1.10]).

In our study population, there were a total of 29 intrapartum or in-hospital newborn deaths, 12 of which occurred in the expectant delivery group and 17 in the induction of labour group. None were recorded in the no-labour caesarean section group. There was a 30% reduction in risk of adverse neonatal outcomes with no-labour caesarean section compared to expectant management (aRR 0.70, 95% CI [0.57, 0.87]) and this risk reduction was observed for all BMI classes (Figure 2).

We observed a trend towards increased neonatal adverse events with induction of labour compared to expectant management, but this was not significant (aRR 1.10, 95% CI [0.99, 1.21]). The WAOS showed a statistically significant increase in neonatal adverse events with induction of labour compared to expectant management (beta 0.61, 95% CI [0.16, 1.06]). The increase in neonatal risk with induction of labour was most observed in women of obesity classes III, IV and V (Figure 2) suggesting a small linear trend between increasing BMI and increasing neonatal adverse outcomes with induction of labour.

The observed decrease in neonatal adverse events was dependent on gestational age (Figure 2). At 37 weeks of gestation, no-labour caesarean section and induction of labour were both strongly associated with an increase in adverse neonatal outcomes across all BMI categories. At 39 weeks, the relationship was inversed and both induction of labour and no-labour caesarean section resulted in decreased neonatal adverse events for women of BMI category I, II, IV and V when compared to expectant management.

There were no maternal deaths recorded within our cohort. Comparing induction of labour to expectant management, there was no statistically significant difference in the relative risk of uterine rupture, blood transfusion, unanticipated operative procedure, or maternal ICU admission. Induction of labour appeared to provide a protective effect against 3rd and 4th degree lacerations compared to expectant management (aRR 0.85, 95% CI [0.75, 0.97]). Overall, there was no statistically significant difference in adverse maternal outcomes when comparing induction of labour to expectant management (aRR 0.95, 95% CI [0.85, 1.05]). There was a statistically significant increase in the risk of unanticipated operative procedure when comparing no-labour caesarean section to expectant management (aRR 1.92, 95% CI [1.32, 2.77]), but overall, no-labour caesarean section appeared to protect against adverse maternal outcomes (aRR 0.46, 95% CI [0.35, 0.60]). Conversely, the WAOS score showed a trend towards increased maternal adverse events with no-labour caesarean section compared to expectant management, but this was not statistically significant (beta 0.24, 95%CI [-0.06, 0.54]).

Results and observed associations held true when the complete case analysis was compared to the analysis with multiple imputation (Table S1).

Discussion

This was a large population-based retrospective cohort study examining all possible plans for delivery in women with obesity. Maternal, neonatal, and overall adverse outcomes associated with each plan for delivery were compared. No-labour caesarean section was shown to decrease both maternal and neonatal adverse events compared to expectant management, particularly at 39 weeks of gestation. Higher BMI was associated with increasing adverse neonatal outcomes when comparing induction of labour to expectant management. This relationship was most significant at early term gestation. Induction of labour was comparable to expectant management with regards to adverse maternal events across all BMI classes.

Our study found that no-labour caesarean section reduced adverse neonatal outcomes by 30% compared to expectant management. By contrast, we showed a trend towards worse neonatal adverse events with induction of labour compared to expectant management which increased with increasing BMI. Rates of failed induction in the population of women with obesity are high and increase linearly with increasing BMI[15,24–26]. In our study, the rate of caesarean section after induction of labour was 40%. This is consistent with estimates in previous literature[8,11,13,27–30]. Further, in women with extremes of obesity (BMI>50), adverse delivery outcomes have been shown to increase 4-fold when caesarean sections are performed after a trial of labour[16]. This reflects the increased technical challenges associated with emergent caesarean delivery in women with obesity[5]. Pulman et al. estimated that the time to delivery increased by a median of 4.5 minutes in women with obesity compared to women with a BMI under 30[31]. Conner et al. found that increasing BMI at caesarean section led to lower neonatal APGAR scores, increased neonatal metabolic acidemia and NICU admission in a dose-dependent manner[18]. It was inferred that this was due to the linear increase in incision to delivery time with increasing BMI. In the setting of emergent or urgent caesarean delivery after a trial of labour, where a degree of fetal compromise has already occurred, this prolonged delivery interval is of crucial significance.

The association between risk of neonatal adverse events and plan for delivery was strongly influenced by gestational age. At 37 weeks, expectant management conferred protection against neonatal adverse events when comparing it to both induction of labour and caesarean section. Conversely, at 39 weeks of gestation, both induction of labour and planned caesarean section were protective against increased risk of poor neonatal outcomes compared to expectant management. This reflects findings in previous literature that increased adiposity is associated with an increased risk of stillbirth at later gestation[6,32,33]. Indeed, the risk of stillbirth is estimated to increase between 3 and 8-fold after 40 weeks of gestation in women with a BMI over 30 compared to those with a BMI under 30[34,35]. Our findings support that delivery timing in this population should not occur prior to later term in women with obesity and otherwise uncomplicated pregnancies but should be considered at 39 weeks of gestation.

In our study, the risk of composite maternal adverse events was reduced in women undergoing no-labour caesarean section compared to expectant management. This result differs from prior literature. Grasch et al. conducted a small retrospective cohort study of 54 women with BMI over 50 and found a reduction in composite maternal adverse outcomes in women experiencing labour compared to those undergoing planned caesarean section[16]. Subramaniam et al. found no difference in the risk of adverse maternal events for women with class III obesity or more undergoing planned caesarean section compared to induction of labour[36]. In both of these studies, the majority of women undergoing planned caesarean delivery had had a previous caesarean section, thus creating a potential bias for increased operative morbidity. In our study, the reduction in maternal adverse events at no-labour caesarean section is driven by the reduction in third- and fourth-degree lacerations. This outcome was not included in the composite outcomes of the papers mentioned above and may further explain the discrepancy in findings. The WAOS score in our study shows a statistically non-significant trend towards worse composite maternal outcomes with no-labour caesarean section compared to expectant management. This may reflect the impact of planned caesarean delivery on rare but severe maternal morbidity as the WAOS provides a weighted average of adverse delivery events thus giving more importance to outcomes of greater severity. The increased risk of operative morbidity at caesarean section in the population of women with obesity has been clearly documented, notably with regards to an increase in wound infection and surgical complication(37).

Our findings show that composite maternal adverse events in women undergoing induction of labour compared to expectant management were similar. This finding has been reproduced in previous literature[38–40]. However, induction of labour was found to prevent third- and fourth-degree tears. This is consistent with the idea that induction of labour decreases macrosomia in the population of women with obesity [41,42].

The main strengths of this study rest in its aim to answer a challenging clinical question of utmost importance for practicing obstetricians using a large population of women with obesity. The analysis was stratified by both gestational age and obesity classes and compared all three available plans for delivery in this population thus providing vital information in a previously understudied area. In addition, our analysis strategy used planned mode of delivery as our main exposure in lieu of type of birth, thus mirroring clinical decision-making at each week of term gestation. Indeed, as it impossible to predict which patient will enter labour spontaneously or have a spontaneous vaginal delivery, the use of expectant management as our comparison group is more reflective of clinical practice and avoids the bias of observing more favourable outcomes when using spontaneous vaginal delivery as the main comparison group. The main limitation of our study rests in its small numbers of women with obesity classes IV and V. As such, we were unable to power the study to use the WAOS as our primary outcome which might have provided a more nuanced discussion regarding severe maternal and neonatal outcomes for women in extremes of obesity. In addition, our study was not powered to investigate individual outcomes of the composite scores and thus, these results should be interpreted with caution.

Conclusion

Expectant management, induction of labour and no-labour caesarean section remain available options for delivery planning in women with obesity at term gestation. Delivery in women with an uncomplicated pregnancy and obesity should be planned at 39 to 40 weeks to reduce the risk of adverse neonatal events. Women with obesity should be informed of the benefit of no-labour caesarean section for the reduction in risk of neonatal adverse events. If induction of labour is planned, a detailed discussion with the patient should include the risk of failed induction of labour and possible increase in adverse neonatal outcomes, particularly in women with class III obesity and above. While our study found a reduction in maternal adverse events with no-labour caesarean section, the discrepancy between the AOI and WAOS suggest further research is needed to clarify the meaning of this association. Shared decision making between patient and practitioner regarding plan for delivery remains paramount in the provision of quality obstetrical care.

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Disclosure of interests

The authors have no conflicts of interest to declare.

Contribution of authorship

Geneviève Horwood conducted the literature review, helped plan the data analysis, contributed to the data interpretation, wrote the primary manuscript, produced, and edited the figures and tables, and contributed to editing the paper.

Erica Erwin helped plan the data analysis, conducted the main data analysis, contributed to the writing of the manuscript, produced the figures and tables, contributed to the data interpretation, and edited the manuscript.

Yanfang Guo helped plan the data analysis, conducted supplementary data analyses, contributed to the data interpretation, helped produce the figures and tables, contributed to the writing of the manuscript and edited the paper.

Laura Gaudet designed the study, contributed to the literature review, helped plan the data analysis, contributed to the data interpretation, and edited the paper.

Ethics approval

Ethical approval for this research was granted by the Research Ethics Boards (REB) of the Ottawa Health Science Network (reference number: # 20190467) and the Children's Hospital of Eastern Ontario (reference number: # 19/15PE). The ethics approval was granted on December 19th, 2019. The investigators conducted the research in accordance with the approved study protocol and followed all applicable local regulatory requirements and laws.

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Table 1. Characteristics of nulliparous women with obesity, an uncomplicated pregnancy resulting in a singleton term birth in Ontario, Canada, between April 1st, 2012 to March 31st, 2019, by mode of delivery

Characteristics	Expectant delivery (n=15752)	Induced delivery (n=9712)	No labour cesarean delivery (n=2008)	Total (n=27472)	SMD
Maternal age (years, mean±SD)	28.6 ± 4.8	29.2 ± 5.2	31.3 ± 5.6	29.0 ± 5.0	0.30
Obesity class, n (%)					
Class I Obesity (BMI 30.0-34.9 kg/m²)	10117 (64.2)	5687 (58.6)	1228 (61.2)	17032 (62.0)	0.11
Class II Obesity (BMI 35.0-39.9 kg/m²)	3611 (22.9)	2422 (24.9)	496 (24.7)	6529 (23.8)	
Class III Obesity (BMI 40.0-44.9 kg/m²)	1201 (7.6)	1005 (10.4)	157 (7.8)	2363 (8.6)	
Class IV Obesity (BMI 45.0-49.9 kg/m²)	420 (2.7)	361 (3.7)	74 (3.7)	855 (3.1)	
Class V Obesity (BMI >50.0 kg/m²)	403 (2.6)	237 (2.4)	53 (2.6)	693 (2.5)	
Neighbourhood education level quintile [a], n (%)					
Quintile 1 (lowest)	3767 (25.5)	2481 (27.1)	445 (23.5)	6693 (25.9)	0.09
Quintile 2	3777 (25.6)	2343 (25.6)	456 (24.1)	6576 (25.5)	
Quintile 3	3096 (21)	1780 (19.5)	395 (20.9)	5271 (20.4)	
Quintile 4	2600 (17.6)	1645 (18)	359 (19)	4604 (17.8)	
Quintile 5 (Highest)	1525 (10.3)	899 (9.8)	238 (12.6)	2662 (10.3)	
Missing	987 (6.3)	564 (5.8)	115 (5.7)	1666 (6.1)	
Substance use during pregnancy [b], n (%)	2175 (13.8)	1391 (14.3)	265 (13.2)	3831 (13.9)	0.02
Maternal smoking [c]	1737 (11.0)	1101 (11.3)	216 (10.8)	3054 (11.1)	0.01
Alcohol use (any alcoholic drink during pregnancy)	406 (2.6)	302 (3.1)	53 (2.6)	761 (2.8)	0.07
Drug use (any drug)	358 (2.3)	180 (1.9)	36 (1.8)	574 (2.1)	0.07
Pre-existing maternal health condition [d], n (%)	2002 (12.7)	1702 (17.5)	362 (18)	4066 (14.8)	0.10
Mental health condition [e], n (%)	3028 (19.2)	1996 (20.6)	380 (18.9)	5404 (19.7)	0.03
Maternal level of care [f], n (%)					
Maternal Level I	2233 (14.2)	1248 (12.9)	227 (11.4)	3708 (13.5)	0.14
Maternal Level IIa	1933 (12.3)	1256 (13.0)	193 (9.7)	3382 (12.4)	
Maternal Level IIb	4672 (29.8)	2563 (26.5)	547 (27.4)	7782 (28.4)	
Maternal Level IIc	4086 (26)	2499 (25.8)	557 (27.9)	7142 (26.1)	
Maternal Level III	2773 (17.7)	2114 (21.8)	472 (23.6)	5359 (19.6)	
Missing	55 (0.4)	32 (0.3)	12 (0.6)	99 (0.4)	

Obstetrician on antenatal care team, n (%)	10453 (66.4)	6933 (71.4)	1531 (76.3)	18917 (68.9)	0.25
Type of birth, n (%)					
Spontaneous vaginal delivery	9996 (63.5)	4491 (46.2)	0 (0.0)	14487 (52.7)	1.57
Operative vaginal delivery	2125 (13.5)	1314 (13.5)	0 (0.0)	3439 (12.5)	
Cesarean section delivery	3631 (23.1)	3907 (40.2)	2008 (100.0)	9546 (34.7)	

Note: BMI = body mass index, SD = standard deviation, SMD = standardized mean difference.

**Unless otherwise indicated. Column statistics are provided. Missing data is excluded in the calculation of percentages*

a. Percentage of college and university degrees among adults aged 25–64 years.

b. Substance use during pregnancy includes any of the following conditions: maternal smoking, alcohol use or drug use during pregnancy.

c. Captures any smoking at the first prenatal visit or at the time of labour or admission for delivery.

d. Pre-existing maternal health conditions includes any of the following: autoimmune disease, maternal heart disease, hypothyroidism, hyperthyroidism, renal disease, maternal pulmonary diseases, or thrombophilia

e. Mental health condition includes anxiety, depression, bipolar disorder or schizophrenia.

f. Maternal hospital level of care classification based on newborn and maternal needs, risk and illness as defined by The Provincial Council for Maternal and Child Health in Ontario.

Table 2: Adverse outcome index (AOI) and Weighted Adverse Outcome Score (WAOS) by plan for delivery

	Expectant delivery n=15 752		Induced delivery n=9712		No labour cesarean delivery n=2008		Induced delivery vs. Expectant management	No labour cesarean delivery vs. expectant management
AOI component	n	%	n	%	n	%	Adjusted RR (95% CI)	Adjusted RR (95% CI)
Maternal component								
Maternal death	0	0.0	0	0.0	0	0.0	--	--
Uterine rupture	<6	S	7	0.1	<6	S	DNC	DNC
Maternal intensive care unit admission	26	0.2	23	0.2	8	0.4	1.21 (0.67, 2.19)	1.67 (0.72, 3.88)
Unanticipated operative procedure	111	0.7	84	0.9	35	1.7	1.16 (0.86, 1.56)	1.92 (1.32, 2.77)
Blood transfusion	150	1.0	112	1.2	22	1.1	1.16 (0.91, 1.49)	1.08 (0.68, 1.69)
3rd or 4th degree perineal tear	690	4.4	359	3.7	0	0.0	0.85 (0.75, 0.97)	--
Any maternal component	929	5.9	552	5.7	58	2.9	0.95 (0.85, 1.05)	0.46 (0.35, 0.60)
Fetal or neonatal component								
Intrapartum or in-hospital newborn death with birth weight>=2500g, with no congenital anomalies	12	0.1	17	0.2	0	0.0	2.31 (1.10, 4.87)	--
Birth trauma >=2000g	139	0.9	108	1.1	<6	S	1.27 (0.98, 1.63)	0.18 (0.06, 0.56)
NICU admission >=2 days or transfer within 24 hours of birth to a facility with a NICU for an infant >=2500 g	717	4.6	456	4.7	67	3.3	1.01 (0.90, 1.14)	0.72 (0.56, 0.92)
5-minute Apgar score < 7	334	2.1	232	2.4	36	1.8	1.08 (0.91, 1.28)	0.89 (0.63, 1.25)
Any neonatal component	1,013	6.4	698	7.2	91	4.5	1.10 (0.999, 1.21)	0.70 (0.57, 0.87)
Any AOI component	1,871	11.9	1,208	12.4	145	7.2	1.03 (0.96, 1.10)	0.59 (0.50, 0.70)
WAOS	Mean	SD	Mean	SD	Mean	SD	Beta (95% CI)	Beta (95%CI)
Maternal WAOS	0.83	5.92	0.99	6.56	1.23	8.97	0.11 (-0.05, 0.27)	0.24 (-0.06, 0.54)
Neonatal WAOS	2.96	16.02	3.61	21.21	1.71	8.30	0.61 (0.16, 1.06)	-1.20 (-2.04, -0.36)
Overall WAOS	3.79	17.42	4.60	22.52	2.93	12.54	0.72 (0.23, 1.21)	-0.96 (-1.87, -0.06)

Data source: BIS-CIHI linked data 2012-2019

Covariates included in adjusted model were maternal age, neighbourhood education quintile, substance use composite (smoke, drug, alcohol), pre-existing maternal health conditions, mental health, maternal hospital level of care, Obstetrician (y/n), gestational age categories (early term= 37+0 to 38+6, term=39+0 to 41+6), obesity class

DNC=Did not converge

Imputed data were used the estimation of adjusted RR or and adjusted Beta Coefficients

Binary outcomes were estimated using generalized estimating equation models with a log-link function, Poisson distribution and robust error variances.

Continuous outcomes were estimated using a generalized linear model with a normal distribution and identity link function and maternal person as the repeated subject.