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Risk associated with planned mode of delivery in women with obesity: a large population-based retrospective cohort study

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BACKGROUND/OBJECTIVE: As the pregnancy progresses, a decision about planned mode of delivery must be made. There is no consensus on optimal mode of delivery among pregnant women with obesity. We aimed to assess the risks associated with planned mode of delivery in women with obesity.
METHODS: This large population-based retrospective cohort study included 27472 nulliparous women with obesity who had live, singleton, and uncomplicated term gestations between April 1st 2012 and March 31st 2019. Planned mode of delivery included waiting for spontaneous labor, a plan for induction of labor, and planned non-labor cesarean section (NLCS). NLCS was defined as an elective CS that would happen before the pregnant woman goes into labor. The most common reasons for NLCS include maternal request, fetal position, and repeated CS. Adverse Outcome Index (AOI) was the primary outcome, a binary composite of 10 maternal-neonatal outcomes. Overall, maternal-specific, and neonatal-specific AOI scores were analyzed. Analyses were conducted using multivariable regression models and were stratified by each week of gestational age and by obesity class.
RESULTS: Planned NLCS was associated with reduced risk of overall, maternal-specific, and neonatal-specific AOI by 41% (adjusted risk ratio [aRR]: 0.59, 95% confidence interval [CI]: 0.50–0.70), 54% (aRR: 0.46, 95% CI: 0.35–0.60), and 30% (aRR: 0.70, 95% CI: 0.57–0.87) respectively when compared to spontaneous labor at term gestation. There was no statistically significant difference in overall AOI when comparing planned induction of labor to spontaneous labor (aRR: 1.03, 95% CI: 0.96–1.10).
CONCLUSION: Among women with obesity, NLCS may be considered as an option for planned mode of delivery due to the decreased AOI risk. However, further research on the association between NLCS and severe outcomes is needed. Shared decision making between patient and practitioner regarding plan for delivery remains paramount in the provision of quality obstetrical care.

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INTRODUCTION

Obesity is a growing epidemic among women of reproductive age worldwide [1]. In 2021, over 20% of Canadian women aged 18-34 years reported living with obesity [2]. This is consistent with rates seen in other high-income countries [3]. In low- and middle-income countries, obesity among reproductive-aged women is increasing at a pace faster than in high-income countries [4–6]. This increase seems most significant for women of lower socio-economic status and those living in rural and low-resource environments [7, 8].

Once a woman reaches term pregnancy (i.e., 37 weeks of gestation), there are three options when planning for delivery and managing her ongoing care: wait for spontaneous labor, induce labor, or perform a cesarean section prior to the onset of labor [9]. Spontaneous labor involves waiting for vaginal delivery to happen on its own without requiring a medical intervention. Among the delivery options that require intervention, induction of labor is the process of artificially stimulating uterine contractions to accomplish a vaginal delivery, while non-labor cesarean section (NLCS) involves an elective cesarean section scheduled before the pregnant woman goes into labor. Common reasons for NLCS include maternal request, fetal position, multiple gestation, and previous cesarean section [10]. Women and healthcare providers may plan for delivery with one of these three options; however, the actual type of delivery – such as spontaneous vaginal or emergency cesarean section may differ from the original plan. The optimal plan for delivery in the population of women with obesity at term gestation remains equivocal and several challenges often arise [11–13].

Maternal obesity is associated with an increased risk of pregestational type II diabetes, gestational diabetes, hypertensive disorders of pregnancy, large-for-gestational-age infants, and stillbirth [7, 14–22]. The high complication rates of these pregnancies lead to an increase in recommendations for induction

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of labor [23, 24]. However, in this population, the rate of failed induction of labor has been estimated to be two-fold that of its normal-weight counterparts [25]. Moreover, cesarean section after a trial of labor in women with extreme obesity (body mass index [BMI] ≥50 kg/m^2) has been shown to increase maternal morbidity four-fold [26]. High rates of wound infection and thromboembolic disease have been reported among parturients with obesity undergoing a cesarean section [27]. This surgical procedure can be technically demanding and has been associated with a longer time from skin incision to infant delivery [28].

The increased risks related to pregnant women with obesity have fueled the debate surrounding the optimal planned mode of delivery in this population. Three options exist for ongoing care of women at term pregnancy after 37 weeks of gestation: wait for spontaneous labor, plan for induction of labor, and NLCS. This study compares the association between planned mode of delivery and adverse outcomes in nulliparous women with obesity. Multiparous women have been excluded from the analysis due to the potential influence of a previous mode of delivery in the decision for the subsequent delivery type. We hypothesize that plan for induction of labor or NLCS at term may decrease maternal-neonatal adverse outcomes compared to spontaneous labor among pregnant women with obesity. To our knowledge, this study 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 is 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 World Health Organization definition as a BMI ≥ 30 kg/m^2. Obesity classes were further categorized 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 (≥ 50 kg/m^2). Pre-pregnancy BMI was used. An uncomplicated pregnancy was defined as a pregnancy without obstetrical indications for urgent delivery such as pre-existing hypertension, pre-eclampsia, gestational or pregestational diabetes, antepartum hemorrhage, placental abruption, or premature rupture of membranes.

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

As per standard practice, women with uncomplicated term pregnancies had the option to wait for spontaneous labor, be induced, or have a NLCS. Women who had obstetrical indications for urgent delivery, however, were strongly advised to undergo an induction of labor or NLCS. Furthermore, any adverse outcomes experienced could be in relation to their pregnancy complications rather than their BMI and planned mode of delivery. Therefore, women who had obstetrical indications for urgent delivery were excluded. 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). These criteria were excluded as adverse outcomes could be derived from the congenital anomalies or small/large birth weights as opposed to maternal BMI or planned mode of delivery. Malpresentation of the fetus, such as breech, was not excluded, as it was not considered an obstetrical indication for urgent delivery. A term birth was defined as a delivery between 37 + 0 and 41 + 6 weeks of gestational age. Gestational age was indicated by patients' obstetricians using last menstrual period estimates and/or prenatal ultrasound dating estimates, as per standard of care.

Data sources

The data for the study was derived from the Better Outcome Registry and Network (BORN) Ontario. The BORN Ontario has been assessed as a valid, reliable, and high quality, comprehensive perinatal database [29, 30]. Perinatal and birth data were collected by healthcare providers and submitted to the BORN database throughout their patients' perinatal clinic visits and hospital encounters. 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. Neighborhood-level education quintiles were derived via linkage with 2011 Canadian Census data.

Exposure

Planned mode of delivery was the exposure of interest and was defined by the plan for labor and delivery at the time of admission to the birthing unit. At any given week of term gestation, women who were not yet admitted to a birthing unit for delivery were deemed to still be undergoing expectant management. Women who delivered were excluded from subsequent weeks of the stratified analyses.

We defined planned mode of delivery as spontaneous labor, induced labor, or NLCS. This is distinct from actual type of birth which can be either spontaneous vaginal delivery, operative vaginal delivery (i.e., forceps or vacuum assisted delivery), or cesarean section. Regardless of the planned mode of delivery – spontaneous, induced, or NLCS – the women 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 [31]. The index includes 10 adverse outcomes divided into maternal and neonatal 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. Unanticipated operative procedures include DRG 370-375 or MS DRG 765-768 and 774-775 with one of the following procedure codes in first or second procedure field: 75.92 (evacuation of other hematoma of vulva or vagina) or 69.02 (D&C following delivery), 54.61 (reclosure of postoperative disruption of abdominal wall), 38.86 (other surgical occlusion of abdominal vessels), 39.98 (control of hemorrhage), 69.52 (aspiration curettage following delivery). The neonatal components measured are intrapartum or in-hospital newborn death, birth trauma, neonatal intensive care unit (NICU) admission for more than 2 days and APGAR score less than 7 at 5 min. Adverse birth events were analyzed overall and by maternal and fetal components. Each individual component was assessed as a secondary outcome.

The Weighted Adverse Outcome Score (WAOS) was examined as a secondary outcome. The WAOS represents an adverse event score per delivery. Each maternal and neonatal outcome included in the AOI is assigned a weight based on the severity of the adverse event. These weights for every outcome are summed and then divided by the number of deliveries to calculate a continuous variable which describes the weighted adverse event score per delivery [32]. This study did not include postnatal adverse events such as wound infections, thromboembolic events, and longer hospital stays.

Statistical analysis

Demographic and baseline characteristics of women with different plans for delivery (spontaneous labor, induction of labor and NLCS) were examined. Descriptive analyses by planned mode of delivery were conducted.

Bivariate analyses were employed to assess the association between planned mode of delivery and various study outcomes. Depending on whether the outcomes were binary or continuous, we used log-binomial or linear regression, respectively. Multivariable log-binomial and linear regression models were built for the AOI and WAOS scores, respectively, with adjustment for potential confounders, which were selected based on a priori literature review and theoretical importance. Due to convergence issues with the log-binomial regression models, multivariable modified Poisson regression models, employing a Poisson distribution with robust error estimation, were used to approximate a binomial outcome [33]. These models were fit to estimate adjusted risk ratios (aRR) and 95% CI for the association between the planned mode of delivery and the risk of AOI components.

The covariates included maternal age, neighborhood education quintiles, obesity class, gestational age categories (i.e., early term defined

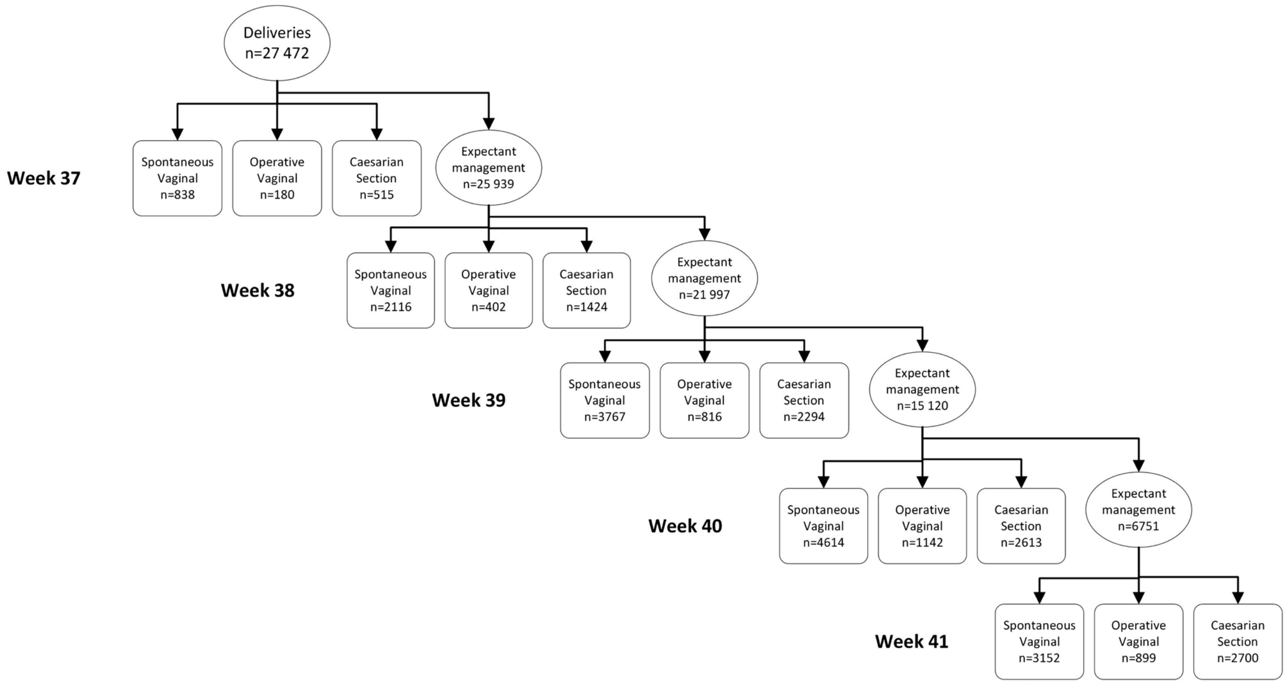

Fig. 1 Flowchart of the study design. Analyses were stratified by gestational week throughout term pregnancy (37–41 weeks). At each subsequent week of gestational age, women entering spontaneous labor were excluded.

as 37 + 0 to 38 + 6 weeks, and term defined as 39 + 0 to 41 + 6 weeks), substance use in pregnancy, maternal pre-existing health conditions (i.e., autoimmune disease, maternal heart disease, hypothyroidism, hyperthyroidism, renal disease, maternal pulmonary disease, or thrombophilia), maternal mental health issues (i.e., anxiety, depression, bipolar disorder, or schizophrenia), maternal hospital level of care, and type of antenatal care provider. In response to missing data, five datasets were imputed by using fully conditional specification method. To account for within-hospital clustering of the data, generalized estimating equation models with a log-link function and a Poisson distribution, using robust error variance, were used to assess the binary outcomes.

Analyses were stratified by obesity class and each completed week of gestational age. Figure 1 describes the analysis flowchart corresponding to each specific gestational age. To ensure the robustness of our findings, a sensitivity analysis was conducted involving a comparative assessment between the imputed dataset and a complete case analysis. To enhance statistical power, women in obesity classes IV and V were combined. The R table one package was used to create the tables comparing characteristics of each planned mode of delivery [34]. All remaining statistical analyses were conducted using SAS v9.4 (SAS Institute, Cary, NC).

RESULTS

In total, 27472 deliveries meeting our inclusion criteria were recorded between April 1st, 2012 and March 31st, 2019. Of these, 15752 (57.3%) women had planned spontaneous labor, 9712 (35.4%) had planned induction of labor, and 2008 (7.3%) had planned NLCS (Table 1). In terms of the actual mode of delivery, 14487 (52.7%) women had spontaneous vaginal deliveries, 3439 (12.5%) had operative vaginal deliveries (i.e., vacuum or forceps assisted delivery), and 9546 (34.7%) had cesarean section deliveries. Clinical and demographic data are described in Table 1.

The mean age of women included in this study was 29.0 ± 5 years. In our cohort, 17,032 (62.0%) women had class I obesity, 6529 (23.8%) had class II obesity, 2363 (8.6%) had class III obesity, 855 (3.1%) had class IV obesity and 693 (2.5%) had class V obesity. Of women who planned spontaneous labor, 9996 (63.5%) had a spontaneous vaginal delivery, 2125 (13.5%) had an operative vaginal delivery, and 3631 (23.1%) had a cesarean section. Of women who planned for induction, 4491 (46.2%) had a spontaneous vaginal delivery, 1314 (13.5%) had an operative vaginal delivery, and 3907 (40.2%) had a cesarean section. All women who planned NLCS ($n = 2008$) had a cesarean section.

Table 2 depicts the association between planned mode of delivery (spontaneous labor, induced labor, and NLCS) and maternal-neonatal AOI and WAOS. Planned NLCS reduced the risk of overall AOI by 41% (aRR: 0.59, 95% CI: 0.50, 0.70) when compared to planned spontaneous labor. Similarly, overall WAOS showed a trend towards improved outcomes with planned NLCS compared to spontaneous labor (beta: −0.96, 95% CI: −1.87, −0.06). There was no statistically significant increase in risk of overall AOI when comparing planned induced labor to spontaneous labor (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 planned spontaneous labor group and 17 in the planned induction of labor group. None were recorded in the planned NLCS group. When compared to planned spontaneous labor, planned induced labor had an increased risk of intrapartum or in-hospital newborn death with birth weight ≥2500 g and no congenital anomalies (aRR: 2.31, 95% CI: 1.10, 4.87). There was a 30% reduction in risk of neonatal AOI with planned NLCS compared to spontaneous labor (aRR: 0.70, 95% CI: 0.57, 0.87; Table 2). The WAOS showed a statistically significant increase in neonatal adverse events with planned induction of labor compared to spontaneous labor (beta: 0.61, 95% CI: 0.16, 1.06; Table 2).

There were no maternal deaths recorded within our cohort. Comparing planned induction of labor to spontaneous labor, there was no statistically significant difference in the relative risk of uterine rupture, blood transfusion, unanticipated operative procedure, or maternal ICU admission. Planned induction of labor appeared to provide a protective effect against 3rd and 4th degree lacerations compared to spontaneous labor (aRR: 0.85, 95% CI: 0.75, 0.97). There was no statistically significant difference in adverse maternal outcomes (i.e., any maternal AOI component) when comparing planned induction of labor to spontaneous labor (aRR: 0.95, 95% CI: 0.85, 1.05). There was a statistically significant

Table 1. Characteristics of nulliparous women with obesity, having an uncomplicated pregnancy resulting in a singleton term birth in Ontario, Canada, between April 1st, 2012 to March 31st, 2019, by planned mode of delivery ($n = 27,472$).

Characteristics	Spontaneous Labor ($n = 15,752$)	Induced labor ($n = 9712$)	No labor cesarean section ($n = 2008$)	Total ($n = 27,472$)	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/m^2)	10117 (64.2)	5687 (58.6)	1228 (61.2)	17032 (62.0)	0.11
Class II Obesity (BMI 35.0–39.9 kg/m^2)	3611 (22.9)	2422 (24.9)	496 (24.7)	6529 (23.8)	
Class III Obesity (BMI 40.0-44.9 kg/m^2)	1201 (7.6)	1005 (10.4)	157 (7.8)	2363 (8.6)	
Class IV Obesity (BMI 45.0–49.9 kg/m^2)	420 (2.7)	361 (3.7)	74 (3.7)	855 (3.1)	
Class V Obesity (BMI ≥ 50.0 kg/m^2)	403 (2.6)	237 (2.4)	53 (2.6)	693 (2.5)	
Neighborhood 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 II[a]	1933 (12.3)	1256 (13.0)	193 (9.7)	3382 (12.4)	
Maternal Level II[b]	4672 (29.8)	2563 (26.5)	547 (27.4)	7782 (28.4)	
Maternal Level II[c]	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)	

BMI body mass index, *SD* standard deviation, *SMD* standardized mean difference.
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 labor or admission for delivery.
[d]Pre-existing maternal health conditions include 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. Maternal-neonatal AOI components and WAOS by planned mode of delivery ($n = 27,472$).

		Spontaneous labor ($n = 15,752$)		Induced labor ($n = 9712$)		NLCS ($n = 2008$)		Induced vs. Spontaneous labor	NLCS vs. Spontaneous labor
		N	%	*N*	%	*N*	%	Adjusted RR (95% CI)	Adjusted RR (95% CI)
Maternal AOI	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)
Neonatal AOI	Intrapartum or in-hospital newborn death with birth weight ≥2500 g, 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-min 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	1013	6.4	698	7.2	91	4.5	1.10 (0.999, 1.21)	0.70 (0.57, 0.87)
Overall AOI		1871	11.9	1208	12.4	145	7.2	1.03 (0.96, 1.10)	0.59 (0.50, 0.70)
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**β (95%CI)**	**β (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. *RR* risk ratio, *CI* confidence interval, *SD* standard deviation, *NLCS* no-labor cesarean section, *AOI* Adverse Outcome Index, *WAOS* Weighted Adverse Outcome Score, *NICU* neonatal intensive care unit, *DNC* did not converge.

Covariates included in adjusted model were maternal age, neighborhood 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.

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.

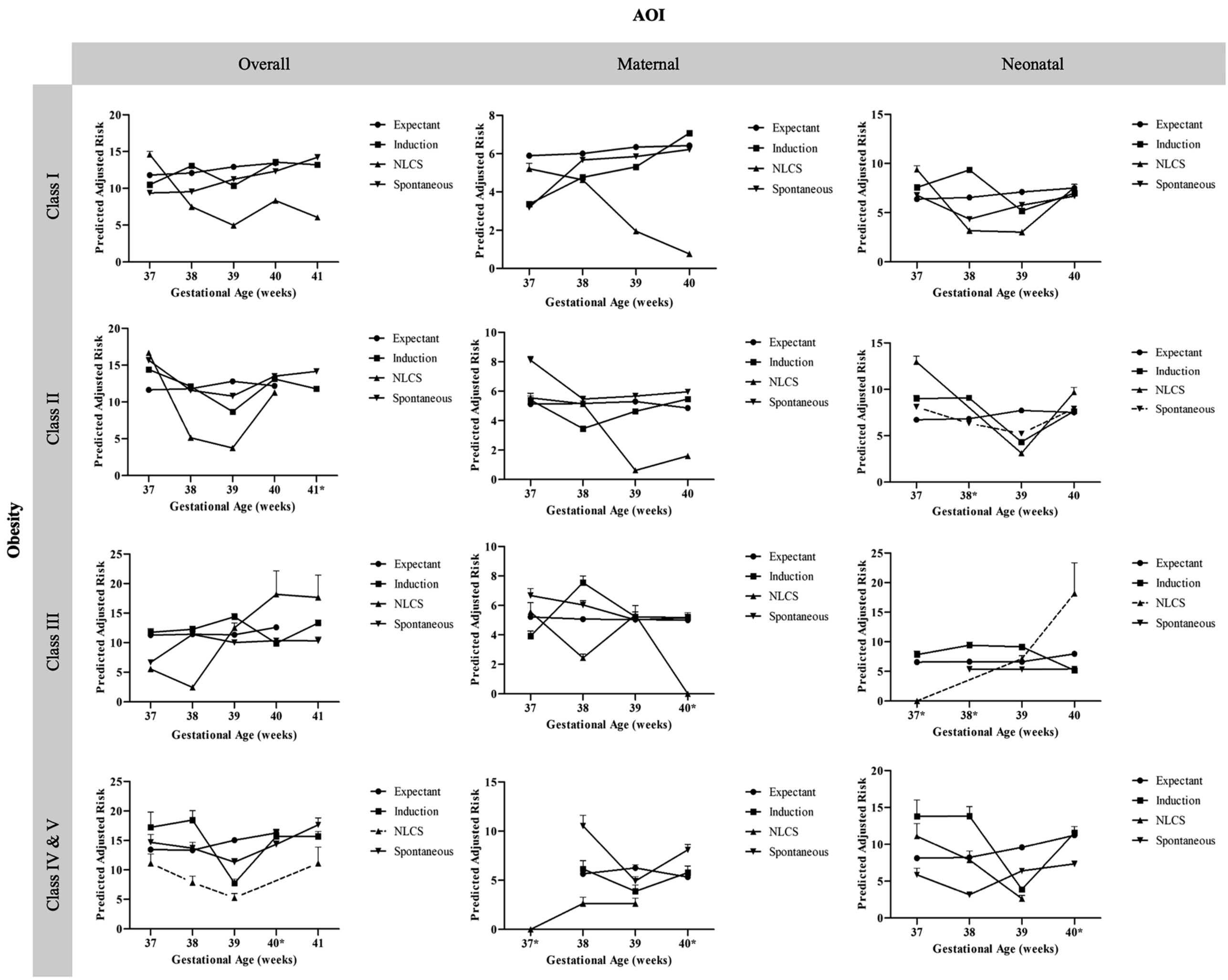

Fig. 2 Predicted adjusted risk of Adverse Outcome Index (AOI) by 100 deliveries by gestation age and obesity class. Obesity classes are defined as the following: Class I (BMI 30-34.9), Class II (35-39.9), Class III (40-44.9), Class IV & V (≥ 45). Women in obesity classes IV and V are grouped to improve power. *Fit of model questionable. --- line missing a time point.

increase in the risk of unanticipated operative procedures when comparing planned NLCS to spontaneous labor (aRR: 1.92, 95% CI: 1.32, 2.77), but planned NLCS appeared to protect against any maternal AOI component (aRR: 0.46, 95% CI: 0.35, 0.60). Conversely, the WAOS score showed a trend towards increased maternal adverse events with planned NLCS compared to spontaneous labor, but this was not statistically significant (beta: 0.24, 95% CI: −0.06, 0.54).

The predicted adjusted risk of AOI by 100 deliveries varied across different gestational age weeks and obesity classes (Fig. 2). Data for overall, maternal, and neonatal AOI were presented for women with obesity class I, II, III, and IV & V separately in Fig. 2. Expectant management represents the group of women who, at any given week of term gestation, were not yet admitted to a birthing unit for delivery. The AOI observed in the expectant management group, categorized by gestational age, serves as a valuable comparative cohort, as it was calculated based on the maternal and neonatal outcomes for all the subsequent weeks when delivery occurred. It is important to note that the fit model generated to calculate the predicted adjusted risk was questionable for some stratified analyses due to limited data availability.

Results and observed associations held true when the complete case analysis was compared to the analysis with multiple imputation (Supplementary Table 1).

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. Planned NLCS was shown to decrease overall, maternal, and neonatal AOI compared to spontaneous labor. On the other hand, the association between planned induced labor and AOI varied across maternal and neonatal components, when compared to spontaneous labor.

Our study found that planned NLCS reduced adverse neonatal outcomes by 30% (i.e., any neonatal AOI component; aRR: 0.70, 95% CI: 0.57, 0.87) compared to spontaneous labor. By contrast, we showed a non-significant trend (aRR: 1.10, 95% CI: 0.999, 1.21) towards worse neonatal adverse events with planned induction of labor compared to spontaneous labor. Rates of failed induction in the population of women with obesity are high and increase linearly with increasing BMI [25, 35–37]. In our study, the rate of cesarean section after planned induction of labor was 40%. This is consistent with estimates in previous literature [16, 19, 21, 38–41]. Moreover, for women in the highest obesity class (BMI ≥ 50 kg/m^2), adverse maternal outcomes have been shown to increase four-fold when cesarean sections are performed after a trial of labor [26]. This reflects the increased technical challenges associated with emergent cesarean delivery in women with obesity [8]. Pulman et al. estimated that the time to delivery increased by a median of 4.5 min in women with obesity compared to women with a BMI under 30 kg/m^2 [42]. Conner et al. found that increasing BMI at cesarean section led to lower neonatal APGAR scores, increased neonatal metabolic acidemia and NICU admission in a dose-dependent manner [28]. 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 cesarean delivery after a trial of labor, where a degree of fetal compromise may have already occurred, this prolonged delivery interval is of crucial significance.

Previous literature has shown that increased adiposity is associated with higher risk of stillbirth at later gestation [14, 43, 44]. Indeed, the risk of stillbirth is estimated to increase between three and eight-fold after 40 weeks of gestation in women with a BMI ≥ 30 kg/m^2 compared to those with a BMI < 30 kg/m^2 [45, 46]. When stratified by gestational age and obesity class, the predicted risk of AOI varied, showing that each BMI category should be individually analyzed when deciding on optimal mode of delivery. When considering NLCS, management between 38 and 40 gestational weeks may be beneficial to women with obesity class I and II. On the other hand, women with higher BMI (obesity class III +) may benefit from earlier management starting at 37 gestational weeks when considering NLCS.

In our study, the risk of composite maternal adverse events (i.e., any maternal AOI component) was reduced in women with planned NLCS compared to spontaneous labor. This result differs from prior literature looking at actual mode of delivery. Grasch et al. conducted a small retrospective cohort study of 54 women with BMI equal to or over 50 kg/m^2 and found a reduction in composite maternal adverse outcomes in women experiencing labor compared to those undergoing scheduled cesarean section [26]. Subramaniam et al. found no difference in the risk of adverse maternal events for women with class III obesity or more undergoing scheduled cesarean section compared to induction of labor [47]. In both studies, the majority of women undergoing scheduled cesarean delivery had a previous cesarean section, thus creating a potential bias for increased operative morbidity. The WAOS score in our study shows a non-significant trend towards worse composite maternal outcomes with planned NLCS compared to spontaneous labor. This may reflect the impact of planned cesarean 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 cesarean section in the population of women with obesity has been clearly documented, notably with regard to an increase in wound infection and surgical complications [48].

Our findings show that composite maternal adverse events in women undergoing planned induction of labor compared to spontaneous labor were not significantly different. However, planned induction of labor was found to prevent 3rd or 4th degree tears. Among the women planning induction of labor, the majority (46.2%) had a spontaneous vaginal delivery, followed by 40.2% of cesarean section deliveries, and 13.5% of operative vaginal deliveries. Current research among the population with obesity is limited to the actual type of delivery, not to their plan of delivery before term gestation, and the risks associated with induction of labor or scheduled cesarean section vary across studies [49–51]. Understanding the impact of planned mode of delivery continues to be important during antenatal counseling.

The main strengths of this study rest in its aim to answer a pragmatic and challenging clinical question of utmost importance for practicing maternity care providers and their patients 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 was impossible to predict which patient will enter labor 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 favorable outcomes when using spontaneous vaginal delivery as the main comparison group. Finally, as the study population was limited to people having their first delivery, the results are not generalizable to those who had a previous delivery.

Our study included several limitations. Our population included small numbers of women with class IV and V obesity. 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 with higher classes 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. Further, because our database did not include postnatal adverse events, we were unable to estimate the impact of NLCS on maternal adverse outcomes such as wound infections, thromboembolic events, and longer hospital stays. Our study also does not offer insight into the consequence of primary cesarean section on future pregnancies and the lack of socioeconomic data limits our sample characterization. Shared decision-making at the time of planning for delivery should include a discussion of the risks of repeat cesarean section including operative morbidity and placental implantation disorders.

CONCLUSION

Planned spontaneous labor, induction of labor and NLCS remain available options for delivery in women with obesity at term gestation. Women with obesity who are approaching their first delivery should be informed of the potential benefit of planned NLCS over spontaneous labor for the potential reduction in risk of maternal and neonatal adverse events. While our study found a decrease in maternal adverse events with planned NLCS, the discrepancy between the AOI and WAOS suggests 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.

STUDY IMPORTANCE

What is already known about this subject?

- Obesity in reproductive-aged women has been associated with several pregnancy complications that impact maternal and neonatal health. These complications lead to an increase in recommendations for induction of labor.
- Failed induction rates are doubled and cesarean sections after trial of labor have an even greater risk of maternal and neonatal adverse outcomes in women with obesity.
- Decisions on optimal delivery for women with obesity remain unclear.

What are the new findings in your manuscript?

- Planned spontaneous labor, induction of labor, and non-labor cesarean section (NLCS) remain options for delivery in women with obesity at term gestation. Women with obesity who are approaching their first delivery should be informed of the potential benefit of NLCS for the reduction in risk of adverse events.

- If induction of labor is planned, a detailed discussion with patients should include risk of failed induction of labor and possible increase in adverse neonatal outcomes.

How might your results change the direction of research or the focus of clinical practice?

- While our study found a reduction in maternal adverse events with planned NLCS, the discrepancy between the adverse outcome scores suggests 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.

DATA AVAILABILITY

The data analyzed during this study are held securely at the prescribed registry BORN Ontario. Data sharing regulations prevent these data from being made available publicly due to the personal health information in the datasets. The datasets generated during the current study are available upon reasonable request and may be directed to BORN Ontario (Science@BORNOntario.ca).

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AUTHOR CONTRIBUTIONS

GH, EE, YG and LMG contributed to the conception and design of this study. YG and EE contributed to the analysis of the data. All authors were involved in writing the paper and had final approval of the submitted versions.

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COMPETING INTERESTS

The authors declared no conflict of interest.

ADDITIONAL INFORMATION

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