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Maternal-Newborn Health System Changes and Outcomes in Ontario, Canada, During Wave 1 of the COVID-19 Pandemic—A Retrospective Study

N.F. Roberts

Nicole F. Roberts, MSc;[1] Ann E. Sprague, RN, PhD;[1,2] Monica Taljaard, PhD;[3,4] Deshayne B. Fell, PhD;[2,4] Joel G. Ray, MD, MSc;[5] Modupe Tunde-Byass, MD;[6,7] Anne Biringer, MD, CCFP;[8] Jon F.R. Barrett, MBBch, MD;[9] Faiza Khurshid, MBBS, MD;[10] Sanober Diaz, MSc;[11] Kara Bellai-Dussault, MSc;[1,2] Dana-Marie Radke, RN;[1] Lise M. Bisnaire, PhD;[1,2] Christine M. Armour, MD, MSc;[1,2,12] Ian C. Joiner, MPA;[1] Mark C. Walker, MD, MSc[1,3,13,14,15]

[1]Better Outcomes Registry & Network (BORN) Ontario, Ottawa, ON

[2]Children's Hospital of Eastern Ontario (CHEO) Research Institute, Ottawa, ON

[3]Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON

[4]School of Epidemiology and Public Health, University of Ottawa, Ottawa, ON

[5]Department of Obstetrics and Gynecology, St. Michael's Hospital, Toronto, ON

[6]Temerty Faculty of Medicine, University of Toronto, Toronto, ON

[7]Department of Obstetrics and Gynaecology, North York General Hospital, North York, ON

[8]Ray D. Wolfe Department of Family Medicine, Sinai Health System, University of Toronto, Toronto, ON

[9]Department of Obstetrics and Gynecology, McMaster University, Hamilton, ON

[10]Department of Pediatrics, School of Medicine, Queen's University, Kingston, ON

[11]Provincial Council for Maternal and Child Health, Toronto, ON

[12]Department of Pediatrics, University of Ottawa, Ottawa, ON

[13]International and Global Health, Faculty of Medicine, University of Ottawa, Ottawa, ON

[14]Champlain Maternal Newborn Regional Program, Ottawa, ON

[15]Department of Obstetrics, Gynecology & Newborn Care, The Ottawa Hospital, Ottawa, ON

ABSTRACT

Objective: To determine the population-level impact of COVID-19 pandemic–related obstetric practice changes on maternal and newborn outcomes.

Methods: Segmented regression analysis examined changes that occurred 240 weeks pre-pandemic through the first 32 weeks of the pandemic using data from Ontario's Better Outcomes Registry & Network. Outcomes included birth location, length of stay, labour analgesia, mode of delivery, preterm birth, and stillbirth. Immediate and gradual effects were modelled with terms representing changes in intercepts and slopes, corresponding to the start of the pandemic.

Results: There were 799 893 eligible pregnant individuals included in the analysis; 705 767 delivered in the pre-pandemic period and 94 126 during the pandemic wave 1 period. Significant immediate decreases were observed for hospital births (relative risk [RR] 0.99; 95% CI 0.98–0.99), length of stay (median change −3.29 h; 95% CI −3.81 to −2.77), use of nitrous oxide (RR 0.11; 95% CI 0.09–0.13) and general anesthesia (RR 0.69; 95% CI 0.58– 0.81), and trial of labour after cesarean (RR 0.89; 95% CI 0.83–0.96). Conversely, there were significant immediate increases in home births (RR 1.35; 95% CI 1.21–1.51), and use of epidural (RR 1.02; 95% CI 1.01–1.04) and regional anesthesia (RR 1.01; 95% CI 1.01–1.02). There were no significant immediate changes for any other outcomes, including preterm birth (RR 0.99; 95% CI 0.93–1.05) and stillbirth (RR 1.11; 95% CI 0.87–1.42).

Conclusion: Provincial health system changes implemented at the start of the pandemic resulted in immediate clinical practice changes but not insignificant increases in adverse outcomes.

Keywords: COVID-19 pandemic; pregnancy outcome; time series; maternal child; obstetrics; delivery of health care

Corresponding author: Nicole F. Roberts, niroberts@bornontario.ca

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RÉSUMÉ

Objectif : Déterminer les effets des changements dans la pratique de l'obstétrique apportés par la pandémie de COVID-19 sur les issues maternelles et néonatales dans la population obstétricale.

Méthodologie : Une analyse de régression segmentée a été effectuée pour connaître les changements qui ont eu lieu pendant les 240 semaines avant la pandémie jusqu'à 32 semaines après le début de la pandémie au moyen des données du Registre et réseau des bons résultats dès la naissance de l'Ontario. Les critères de jugement étaient le lieu de naissance, la durée du séjour, l'analgésie pendant le travail, le mode d'accouchement, l'accouchement prématuré et la mortinaissance. Les effets immédiats et graduels, correspondants au début de la pandémie, ont été modélisés au moyen de termes qui représentaient des changements dans les points d'intersection et les courbes.

Résultats : L'analyse s'appuie sur 799 893 personnes enceintes admissibles, desquelles 705 767 ont accouché avant la pandémie et 94 126, pendant la première vague de la pandémie. On remarque une diminution significative immédiate dans les naissances en milieu hospitalier (risque relatif [RR] : 0,99; IC à 95 % : 0,98-0,99), la durée du séjour (variation médiane : -3,29 h; IC à 95 % : -3,81 à -2,77), l'utilisation du protoxyde d'azote ([RR] : 0,11; IC à 95 % : 0,09-0,13) ainsi que dans l'anesthésie générale ([RR] : 0,69; IC à 95 % : 0,58-0,81) et l'épreuve de travail après une césarienne ([RR] : 0,89; IC à 95 % : 0,83-0,96). Inversement, on observe une augmentation significative immédiate dans les naissances à domicile ([RR] : 1,35; IC à 95 % : 1,21-1,51) ainsi que dans le recours à la péridurale ([RR] : 1,02; IC à 95 % : 1,01-1,04) et à l'anesthésie régionale ([RR] : 1,01; IC à 95 % : 1,01-1,02). Aucun changement significatif immédiat n'a été signalé pour les autres critères de jugement, y compris l'accouchement prématuré ([RR] : 0,99; IC à 95 % : 0,93-1,05) et la mortinaissance ([RR] : 1,11; IC à 95 % : 0,87-1,42).

Conclusion : Les modifications apportées au système de santé provincial en début de pandémie ont entraîné des changements immédiats dans la pratique clinique, mais aucune augmentation significative des issues défavorables.

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INTRODUCTION

During March and April of 2020, maternal-newborn care settings in Ontario (Canada's most populous province) quickly changed care routines to protect pregnant individuals, newborns, and care providers during the COVID-19 pandemic. For the antenatal period, this included rapidly pivoting to virtual care and limiting in-person prenatal, ultrasound, and laboratory testing visits. Because SARS-CoV-2 testing was not universally used in hospitals, preventive measures for care around birth included restriction of hospital visitors, changes to induction and emergency vaginal and cesarean delivery protocols, reduced options for trial of labour after cesarean (TOLAC), changes in anesthesia/analgesia, practice changes around breastfeeding and other newborn care, and reduction in time spent in hospital after birth. These changes were informed by the limited evidence available at that time: early case reports from China,[1,2] Italy,[3] and Spain[4]; previous experience with respiratory viral outbreaks such as H1N1 influenza[5] and severe acute respiratory syndrome (SARS)[6]; and early expert clinical opinions from the Society of Obstetricians and Gynaecologists of Canada (SOGC)[7] and other professional organizations. There was some evidence from international studies about possible increases in rates of cesarean birth, preterm birth, and potential fetal growth issues,[2,8] but robust evidence on which to guide practice was lacking. Although it was expected from the H1N1 and SARS pandemics that respiratory function could be compromised in pregnant individuals,[9] it was not until the fall of 2020 and into 2021 that stronger evidence emerged showing that pregnant people infected with SARS-CoV-2 were at higher risk of hospitalization and intensive care unit admission compared with non-pregnant infected individuals.[10]

While provincial and national-level guidance on practice changes for maternal-newborn care during the COVID-19 pandemic was being developed and finalized,[11,12] hospitals and regions immediately responded by implementing local guidelines, which varied across Canada. Contemporaneously, the media was reporting hesitancy of individuals to seek routine or urgent care,[13] which led to concerns about possible unintended consequences of these changes in care delivery. We carried out this study to examine the impact of the early COVID-19 pandemic time period on obstetric practices and pregnancy and birth outcomes at a provincial level in Ontario. We focused on clinical practices and maternal-newborn outcomes that we hypothesized could be most affected by the acute shock to the health system and care-seeking behaviour, and we evaluated corresponding rates of preterm birth and stillbirth.

METHODS

Study Design and Population

We conducted an interrupted time series (ITS) analysis using a province-wide birth registry to examine changes in outcomes from the pre-pandemic baseline period (March 1, 2015—February 29, 2020) through wave 1 of the COVID-19 pandemic (March 1, 2020—October 31, 2020; hereafter referred to as *COVID-19 wave 1*) in Ontario. ITS is a robust quasi-experimental approach that can be used to evaluate immediate and gradual impacts of interventions/exposures when random allocation is not possible.[14] Although the World Health Organization declared the pandemic on March 11, 2020, we chose March 1, 2020, as the start of the COVID-19 wave 1 period because clinical practice was already changing in care settings, and the SARS-CoV-2 virus was circulating in Ontario.[15] Because public health measures for the COVID-19 pandemic were implemented almost simultaneously across Ontario, ITS was an ideal approach for evaluating the impact of the pandemic at a population level, while accounting for any ongoing secular trends in obstetric care practices and maternal-newborn outcomes in the 5 years predating the pandemic.[14]

The study included records of all pregnancies in Ontario resulting in a live birth or stillbirth at ≥20 weeks gestation. Pregnant individuals choose their health care providers (family physicians, obstetricians, or midwives), and care is publicly funded by the provincial health insurance plan. Ontario has approximately 140 000 births per year, which represents around 40% of all births in Canada.[16]

Data Source

Since 2012, the Better Outcomes Registry & Network (BORN) Ontario has collected pregnancy, birth, and newborn information from all of Ontario's hospitals and midwifery practice groups for the purposes of facilitating and improving maternal-newborn care.[16] Data are collected in near real time by point-of-care manual data entry into a secure portal, direct feeds from hospital systems, or automated extraction and batch uploads from electronic health record systems. A robust linking and matching algorithm ensures data sources are appropriately aggregated to individual records. The routine data collected include sociodemographic information, health behaviours, prenatal screening, pregnancy interventions and complications, intrapartum events, peripartum outcomes, intensive care, and newborn screening information. Data quality assessments have concluded that these data are highly reliable.[17,18]

Outcomes

Detailed definitions of all study outcomes are provided in Table 1 (online Appendix). We examined system level, clinical practices, and birth outcomes that we anticipated might be affected by changes in maternal-newborn care delivery and for which we had reliable data.

Statistical Analysis

We described the study population using frequency distributions and computed cumulative incidence rates of all outcomes, stratified by 2 time periods: pre-pandemic and COVID-19 wave 1.

Robust statistical analysis of ITS data requires between 40 and 50 intervals, or a minimum of at least 12 pre- and post-intervention/exposure intervals. To avoid instability of interval estimates, denominator sizes of at least 50 to 100 per interval are preferred.[19] We used weekly intervals, providing 240 intervals in the pre-pandemic and 32 in COVID-19 wave 1 time periods. Data were aggregated to a provincial level. Binary outcomes were expressed as weekly percentages, and the continuous outcome (length of stay) was expressed as the median value for each week. We generated descriptive time-series plots of temporal patterns in study outcomes across the full time period to visually inspect the temporal trends.

The provincially aggregated numerator/denominator data were analyzed using segmented logistic regression. The model included terms for continuous time (week interval), a binary variable indicating whether the time interval was before or after the start of COVID-19 wave 1 on March 1, 2020, and continuous time after the onset of COVID-19 wave 1 (number of weeks after pandemic onset). In addition, because of regular seasonal fluctuations found in many perinatal outcomes, we included a categorical term for month.[20] The distribution was binomial, and log or identity link functions were used to produce estimates as relative risk (RR) or risk difference (RD). Each model was estimated using restricted pseudo-likelihood accounting for first-order autoregression. The findings were expressed as immediate and gradual effects (intercept and slope changes, respectively), together with 95% confidence intervals (CIs). Visual inspection of residual plots against time was used to assess goodness of fit. To improve the model fit for length of stay and nitrous oxide, the first 3 weekly intervals in the pandemic period were censored from the analysis. Because of the low rate of missing data, records with missing data on the outcome variables were excluded for the specified outcome.

All analyses were conducted using SAS Version 9.4 (Cary, NC), and the study was reported according to Strengthening the Reporting of Observational Studies in Epidemiology guidance.[21] We additionally followed guidance by Ramsay et al.[22] and Jandoc et al.[23] for the conduct and reporting of ITS studies. The Children's Hospital of Eastern Ontario Research Ethics Board approved the protocol (Number 20/20PE) on November 27, 2020.

Table 1. Descriptive characteristics of pregnant individuals in Ontario by time period

Characteristic	Period; no. (%)		Total, no. (%); n = 799 893
	Pre-pandemic[a]; n = 705 767	COVID-19 wave 1[b]; n = 94 126	
Maternal age, y			
<20	11 865 (1.7)	1141 (1.2)	13 006 (1.6)
20–24	68 602 (9.7)	7785 (8.3)	76 387 (9.6)
25–29	186 355 (26.4)	23 771 (25.3)	210 126 (26.3)
30–34	263 727 (37.4)	36 596 (38.9)	300 323 (37.6)
35–39	142 917 (20.3)	20 254 (21.5)	163 171 (20.4)
≥40	31 692 (4.5)	4569 (4.8)	36 261 (4.5)
Missing[c]	609 (0.1)	10 (0.01)	619 (0.1)
Neighbourhood household median income quintiles			
1 (lowest)	147 922 (23.1)	18 794 (22.8)	166 716 (23.0)
2	119 194 (18.6)	15 652 (19.0)	134 846 (18.6)
3	124 015 (19.3)	15 902 (19.3)	139 917 (19.3)
4	147 240 (22.9)	18 766 (22.8)	166 006 (22.9)
5 (highest)	103 433 (16.1)	13 178 (16.0)	116 611 (16.1)
Missing[c]	63 963 (9.1)	11 834 (12.6)	75 797 (9.5)
Neighbourhood education quintile[d]			
1 (lowest)	110 062 (17.0)	14 507 (17.5)	124 569 (17.1)
2	125 935 (19.5)	16 770 (20.2)	142 705 (19.5)
3	140 124 (21.6)	18 206 (22.0)	158 330 (21.7)
4	151 846 (23.5)	18 920 (22.8)	170 766 (23.4)
5 (highest)	119 209 (18.4)	14 546 (17.5)	133 755 (18.3)
Missing[c]	58 591 (8.3)	11 177 (11.9)	69 768 (8.7)
Parity			
Nulliparous	297 978 (42.5)	41 354 (44.1)	339 332 (42.7)
Multiparous	403 361 (57.5)	52 438 (55.9)	455 799 (57.3)
Missing[c]	4428 (0.6)	334 (0.4)	4762 (0.6)
Pre-pregnancy BMI category			
Underweight (<18.5 kg/m^2)	37 116 (5.8)	4446 (5.3)	41 562 (5.8)
Normal weight (18.5–24.9 kg/m^2)	324 129 (50.8)	41 046 (48.7)	365 175 (50.6)
Overweight (25.0–29.9 kg/m^2)	155 881 (24.5)	21 672 (25.7)	177 553 (24.6)
Obese (≥30 kg/m^2)	120 526 (18.9)	17 098 (20.3)	137 624 (19.1)
Missing[c]	68 115 (9.7)	9864 (10.5)	77 979 (9.7)
First prenatal visit in the first trimester			
Yes	596 449 (91.7)	81 558 (93.0)	678 007 (91.8)
No	54 361 (8.3)	6116 (7.0)	60 477 (8.2)
Missing[c]	54 957 (7.8)	6452 (6.8)	61 409 (7.7)
Preexisting diabetes			
Yes	7309 (1.0)	1069 (1.1)	8378 (1.0)
No	698 458 (99.0)	93 057 (98.9)	791 515 (99.0)
Gestational diabetes			
Yes	54 887 (7.8)	8582 (9.1)	63 469 (7.9)
No	650 880 (92.2)	85 544 (90.9)	736 424 (92.1)
Preexisting hypertension			
Yes	6428 (0.9)	1102 (1.2)	7530 (0.9)
No	699 339 (99.1)	93 024 (98.8)	792 363 (99.1)

(continued)

Table 1. *(Continued)*

Characteristic	Period; no. (%) Pre-pandemic[a]; n = 705 767	COVID-19 wave 1[b]; n = 94 126	Total, no. (%); n = 799 893
Gestational hypertension			
Yes	24 716 (3.5)	4107 (4.4)	28 823 (3.6)
No	681 051 (96.5)	90 019 (95.6)	771 070 (96.4)

[a]Pre-pandemic period includes births from March 1, 2015, to February 29, 2020.

[b]COVID-19 wave 1 period includes births from March 1, 2020, to October 31, 2020.

[c]Variables with missing data excluded from percentage calculations.

[d]Percentage of university degrees among patients aged 25–64 years.

BMI: body mass index.

RESULTS

Between April 1, 2015, and October 31, 2020, there were 799 893 eligible pregnant individuals, of whom 705 767 delivered in the pre-pandemic period and 94 126 in COVID-19 wave 1. The corresponding number of newborns was 811 700 (716 523 born in the pre-pandemic period and 95 177 in COVID-19 wave 1). Figure 1 in the online Appendix presents the study flow diagram. The distribution of population characteristics was similar during the pre-pandemic period and COVID-19 wave 1, although on average, pregnant individuals in the COVID-19 wave 1 period were slightly older and had a higher prevalence of overweight/obesity and comorbidities, and a higher percentage started prenatal care in the first trimester (Table 1).

The denominator sizes in each weekly interval varied by outcome, ranging from 58 records in the smallest week interval (vaginal birth after cesarean [VBAC]) to 3520 records in the largest week interval (preterm birth and stillbirth). The prevalence of missing data ranged from 0% to 6.4%, depending on the outcome.

The Figure presents descriptive time-series plots of the observed outcomes and fitted trends (excluding seasonal effects) for length of stay, nitrous oxide use, preterm birth, and stillbirth. For both length of stay and nitrous oxide use, there was an immediate drop at the pandemic onset, followed by a gradual increase towards baseline. Preterm birth and stillbirth showed no significant immediate or gradual changes after the onset of the pandemic. Figure 2 in the online Appendix depicts time-series plots for all other outcomes. Cumulative incidence rates and denominators for each outcome, stratified by the 2 time periods, are provided in Table 2, and corresponding RR and RD from segmented regression analyses are provided in Table 3 and Table 2 in the online Appendix.

Overall, statistically significant decreases (immediate effects) were observed for rates of hospital birth (RR 0.99; 95% CI 0.98–0.99), length of stay for mother-infant dyads discharged together (median difference −3.29 hours; 95% CI −3.81 to −2.77), nitrous oxide use (RR 0.11; 95% CI 0.09–0.13), general anesthesia (RR 0.69; 95% CI 0.58–0.81), and TOLAC (RR 0.89; 95% CI 0.83–0.96). Conversely, statistically significant immediate increases were found in rates of home birth (RR 1.35; 95% CI 1.21–1.51), epidural use (RR 1.02; 95% CI 1.01–1.04), and regional anesthesia (RR 1.01; 95% CI 1.01–1.02). There were no statistically significant immediate changes for any adverse perinatal outcomes, including neonatal intensive care unit (NICU) admission (RR 1.01; 95% CI 0.97–1.05), preterm birth (RR 0.99; 95% CI 0.93–1.05), stillbirth (RR 1.11; 95% CI 0.87–1.42), and 5-minute Apgar <4 or arterial cord blood pH <7.0 (RR 1.09; 95% CI 0.93–1.27). Risk differences showed similar patterns. There was virtually no change in the rate of general anesthesia use per week prior to the pandemic (RD 0.0002%; 95% CI −0.002 to 0.002); after the start of the pandemic, there was an absolute immediate decrease of 1.57% (95% CI −2.23 to −0.91), followed by a gradual return to baseline (0.022%; 95% CI −0.011 to 0.055) per week.

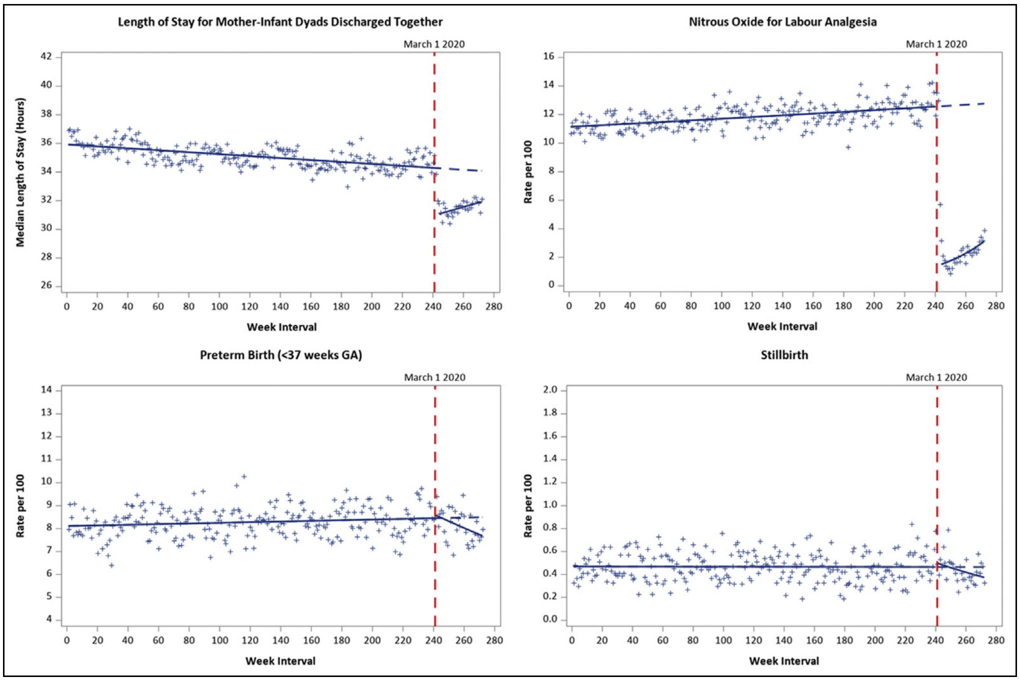
There were no statistically significant immediate or gradual effects of COVID-19 wave 1 on labour induction, opioid use for labour analgesia, VBAC, cesarean delivery, medically indicated preterm birth, or spontaneous preterm birth.

DISCUSSION

Main Findings

This study examined population-level effects of COVID-19 wave 1 on obstetric practices and outcomes in Ontario. The start of the pandemic resulted in an

Figure. Time series plots of length of stay, nitrous oxide use, preterm birth, and stillbirth.



Plots include terms for continuous time (week interval), a binary indicator for whether the time interval was before or after the start of the COVID-19 pandemic on March 1, 2020, and continuous time after the onset of COVID-19 wave 1 (number of week intervals after pandemic onset). The counterfactual line is what would have occurred in the absence of the pandemic (extrapolated preinterruption trend). +, observed; —, trends; - - -, counterfactual.GA: gestational age.

immediate decrease in hospital births, length of hospital stay, nitrous oxide use for labour analgesia, general anesthesia for cesarean delivery, and TOLAC. There were no statistically significant increases in adverse outcomes such as preterm birth and stillbirth. After the immediate effect of the pandemic, the majority of outcomes demonstrated a trend returning towards pre-pandemic levels.

Results in the Context of What Is Known

Two meta-analyses examining the effects of the pandemic time period on maternal and perinatal outcomes have been published.[24,25] Similar to our findings, Chmielewska et al.[24] found no significant differences between pandemic and pre-pandemic periods in pooled analyses of labour induction, cesarean delivery, NICU admission, or 5-minute Apgar score. Although these outcomes are important, our major concern was whether changes in clinical care were temporally associated with any changes in adverse perinatal outcomes, such as rates of preterm birth or stillbirth. Although Chmielewska et al.[24] did not observe any significant impact of the pandemic on preterm birth overall (odds ratio [OR] 0.94; 95% CI 0.87–1.02), when limited to studies from high-income countries, they documented a small, but significant, decrease in the odds of preterm birth during the early pandemic time period (OR 0.91; 95% CI 0.84–0.99). Yang et al.[25] also reported a significant decrease in the unadjusted pooled OR for preterm birth; however, this decrease was driven by results from single-centre studies and was not significant when limited to studies that provided adjusted ORs (OR 0.95; 95% CI 0.80–1.13). Although we found a slight decrease in the rate of preterm birth at the beginning of the pandemic, neither the immediate nor gradual changes were statistically significant. When differentiating type of preterm birth, both systematic reviews reported a significant decrease in spontaneous preterm birth (OR 0.81 [95% CI 0.67–0.97][24]; OR 0.89 [95% CI 0.82–0.98][25]) based on 192 and 767 spontaneous preterm birth events in the pandemic period, respectively. In comparison, our study had 2877 spontaneous preterm births in COVID-19 wave 1, and we found no significant difference from pre-pandemic rates.

Similar to our study, no significant change in stillbirths during the pandemic time period was observed in the Yang et al.[25] review, which included 21 studies (6029 stillbirths) in its pooled estimates. Although the Chmielewska et al.[24] review reported no significant impact on stillbirths in 8 studies originating from high-income country settings, the

Table 2. Cumulative incidence rates for each outcome, by time period

Outcome	Pre-pandemic[a] No. (%)[c]	Pre-pandemic[a] n[d]	COVID-19 wave 1[b] No. (%)[c]	COVID-19 wave 1[b] n[d]
System outcomes				
Location of birth				
Hospital	682 922 (96.8)	705 766	90 525 (96.2)	94 126
Home	18 343 (2.6)	705 766	2864 (3.0)	94 126
Length of stay, h, median (IQR)				
Overall	35.1 (21.5)	597 482	31.7 (17.2)	78 115
Vaginal birth	29.9 (11.4)	427 306	28.2 (9.7)	54 059
Cesarean delivery	50.4 (11.1)	170 176	46.4 (16.2)	24 056
Maternal outcomes				
Induction of labour	190 628 (27.9)	682 885	29 106 (32.2)	90 516
Nitrous oxide for labour analgesia	67 171 (11.9)	567 067	2233 (3.0)	74 638
Epidural use for labour analgesia	372 185 (65.6)	567 067	51 820 (69.4)	74 638
Opioid use for labour analgesia	54 656 (9.6)	567 067	6504 (8.7)	74 638
General anesthesia for cesarean delivery	9676 (4.9)	196 771	1060 (3.8)	28 259
Regional anesthesia for cesarean delivery	190 144 (96.6)	196 771	27 574 (97.6)	28 259
TOLAC	22 605 (36.2)	62 418	2957 (33.5)	8840
VBAC	16 561 (73.3)	22 605	2155 (72.9)	2957
Cesarean delivery	200 055 (29.3)	682 922	28 641 (31.6)	90 525
Newborn outcomes				
NICU admission	94 275 (13.2)	713 175	12 495 (13.2)	94 762
Term infants only	56 844 (8.7)	656 416	7719 (8.8)	87 322
Breastfeeding during hospital stay	531 908 (91.8)	579 553	70 650 (92.4)	76 493
Preterm birth (GA <37 wk)	59 323 (8.3)	716 523	7741 (8.1)	95 177
<24	2161 (0.3)	716 523	243 (0.3)	95 177
$24-27^6$	2809 (0.4)	716 523	345 (0.4)	95 177
$28-31^6$	5191 (0.7)	716 523	662 (0.7)	95 177
$32-33^6$	6533 (0.9)	716 523	806 (0.9)	95 177
$34-36^6$	42 629 (6.0)	716 523	5685 (6.0)	95 177
Medically indicated preterm birth	22 243 (38.5)	57 762	2981 (39.5)	7554
Spontaneous preterm birth	23 583 (40.8)	57 762	2877 (38.1)	7554
Stillbirth	3348 (0.5)	716 523	415 (0.4)	95 177
5-minute Apgar score <4 or arterial cord blood pH <7.0	7116 (1.0)	688 484	934 (1.0)	90 993
Term infants only	5185 (0.8)	632 709	700 (0.8)	83 685

[a]Pre-pandemic period includes births from March 1, 2015, to February 29, 2020.

[b]COVID-19 wave 1 period includes births from March 1, 2020, to October 31, 2020.

[c]Unless otherwise specified.

[d]Denominator for each specified outcome varies due to eligibility for that outcome and missing data.

GA: gestational age; IQR: interquartile range; NICU: neonatal intensive care unit; TOLAC: trial of labour after cesarean; VBAC: vaginal birth after cesarean.

overall pooled OR for stillbirth across 12 studies was 1.28 (95% CI 1.07−1.54), indicating a significant increase during the pandemic period. Differences in pooled estimates from these systematic reviews and our study may be due to differences in study time period, study populations, and the study design and analytical approaches used. A strength of our study was the use of an ITS analysis, which allowed us to account for baseline temporal patterns and seasonality when examining immediate and gradual effects over many time intervals; in contrast, the majority of studies published to date have used a before-and-after comparison.

For purposes of comparison, we were unable to find other studies examining the impact of the COVID-19 pandemic on the health system or clinical practice outcomes such as birth location, length of stay, labour analgesia, and anesthesia method for cesarean delivery or TOLAC.

Table 3. Results from segmented logistic regression analyses

Outcome	Relative risk (95% CI)[a]	*P* value	Risk difference (95% CI)[a]	*P* value
System outcomes				
Location of birth: hospital				
Preintervention trend (per week)	1.000 (1.000–1.000)	0.0139	0.001 (0.0002–0.002)	0.0140
Change in level	0.99 (0.98–0.99)	<0.0001[b]	−1.13 (−1.51 to −0.74)	<0.0001[b]
Change in slope	1.000 (1.000–1.000)	0.0146[b]	0.024 (0.005–0.043)	0.0151[b]
Location of birth: home				
Preintervention trend (per week)	1.000 (1.000–1.000)	<0.0001	−0.002 (−0.003 to −0.001)	<0.0001
Change in level	1.35 (1.21–1.51)	<0.0001[b]	0.90 (0.56–1.25)	<0.0001[b]
Change in slope	1.000 (1.000–1.000)	0.1573	−0.015 (−0.032 to 0.002)	0.0791
Length of stay: overall, h, median difference[c]				
Preintervention trend (per week)			−0.007 (−0.008 to −0.006)	<0.0001
Change in level			−3.29 (−3.81 to −2.77)	<0.0001[b]
Change in slope			0.046 (0.021–0.071)	0.0005[b]
Maternal outcomes				
Induction of labour				
Preintervention trend (per week)	1.001 (1.001–1.001)	<0.0001	0.028 (0.026–0.030)	<0.0001
Change in level	1.00 (0.97–1.02)	0.7731	0.094 (−0.74 to 0.93)	0.8254
Change in slope	1.001 (1.000–1.002)	0.1420	0.030 (−0.012 to 0.071)	0.1690
Nitrous oxide for labour analgesia[c]			N/A[d]	
Preintervention trend (per week)	1.001 (1.000–1.001)	<0.0001		
Change in level	0.11 (0.09–0.13)	<0.0001[b]		
Change in slope	1.03 (1.02–1.03)	<0.0001[b]		
Epidural use for labour analgesia			N/A[d]	
Preintervention trend (per week)	1.000 (1.000–1.000)	<0.0001		
Change in level	1.02 (1.01–1.04)	0.0021[b]		
Change in slope	1.000 (1.000–1.001)	0.5452		
Opioid use for labour analgesia				
Preintervention trend (per week)	1.000 (1.000–1.000)	<0.0001	−0.011 (−0.012 to −0.010)	<0.0001
Change in level	1.03 (0.97–1.09)	0.3586	0.25 (−0.30 to 0.80)	0.3725
Change in slope	1.002 (1.000–1.005)	0.2384	0.018 (−0.010 to 0.046)	0.2013
General anesthesia for cesarean delivery				
Preintervention trend (per week)	1.000 (1.000–1.000)	0.7814	0.0002 (−0.002 to 0.002)	0.8018
Change in level	0.69 (0.58–0.81)	<0.0001[b]	−1.57 (−2.23 to −0.91)	<0.0001[b]
Change in slope	1.006 (0.997–1.014)	0.1760	0.022 (−0.011 to 0.055)	0.1886
TOLAC				
Preintervention trend (per week)	1.000 (1.000–1.000)	0.0485	−0.006 (−0.012 to 0.0001)	0.0464
Change in level	0.89 (0.83–0.96)	0.0040[b]	−3.82 (−6.37 to −1.26)	0.0037[b]
Change in slope	1.003 (0.999–1.007)	0.1241	0.10 (−0.029 to 0.23)	0.1311
VBAC				
Preintervention trend (per week)	1.000 (1.000–1.000)	0.1767	−0.006 (−0.015 to 0.003)	0.1841
Change in level	0.99 (0.94–1.05)	0.7626	−0.62 (−4.65 to 3.40)	0.7618
Change in slope	1.001 (1.000–1.003)	0.6708	0.044 (−0.16 to 0.24)	0.6714
Cesarean delivery				
Preintervention trend (per week)	1.000 (1.000–1.000)	<0.0001	0.011 (0.010–0.013)	<0.0001
Change in level	1.01 (0.99–1.04)	0.3814	0.39 (−0.43 to 1.21)	0.3561
Change in slope	1.001 (1.000–1.002)	0.1415	0.032 (−0.009 to 0.073)	0.1322
Newborn outcomes				
NICU admission				
Preintervention trend (per week)	1.000 (1.000–1.000)	0.1213	0.001 (−0.0003 to 0.002)	0.1284

(continued)

Table 3. *(Continued)*

Outcome	Relative risk (95% CI)[a]	*P* value	Risk difference (95% CI)[a]	*P* value
Change in level	1.01 (0.97−1.05)	0.6200	0.15 (−0.41 to 0.71)	0.6026
Change in slope	0.999 (0.997−1.001)	0.4613	−0.011 (−0.039 to 0.017)	0.4487
Breastfeeding during hospital stay				
Preintervention trend (per week)	1.000 (1.000−1.000)	<0.0001	0.005 (0.004−0.007)	<0.0001
Change in level	1.007 (1.000−1.014)	0.0638	0.64 (−0.033 to 1.31)	0.0636
Change in slope	1.000 (1.000−1.000)	0.0116[b]	−0.044 (−0.078 to −0.010)	0.0115[b]
Preterm birth: GA <37 wk				
Preintervention trend (per week)	1.000 (1.000−1.000)	0.0098	0.001 (0.0003−0.003)	0.0110
Change in level	0.99 (0.93−1.05)	0.7308	−0.084 (−0.57 to 0.40)	0.7312
Change in slope	0.998 (0.996−1.001)	0.3461	−0.011 (−0.035 to 0.013)	0.3580
Stillbirth				
Preintervention trend (per week)	1.000 (1.000−1.001)	0.8593	−0.00002 (−0.0003 to 0.0002)	0.8771
Change in level	1.11 (0.87−1.42)	0.3833	0.05 (−0.06 to 0.16)	0.3932
Change in slope	0.99 (0.98−1.00)	0.0979	−0.005 (−0.01 to 0.001)	0.0988
5-minute Apgar score <4 or arterial cord blood pH <7.0				
Preintervention trend (per week)	1.000 (1.000−1.000)	0.7626	0.00005 (−0.0003 to 0.0004)	0.7809
Change in level	1.09 (0.93−1.27)	0.2836	0.095 (−0.092 to 0.26)	0.2670
Change in slope	0.993 (0.986−1.002)	0.1354	−0.007 (−0.015 to 0.001)	0.1123

Models included terms for continuous time (week interval), a binary indicator for whether the time interval was before or after the start of the COVID-19 pandemic on March 1, 2020, continuous time after the onset of COVID-19 wave 1, and seasonality (month). Intercept and seasonality parameter estimates not shown. All models accounted for first-order autocorrelation.

[a]Unless otherwise specified.

[b]*P* values <0.05 for immediate effects (change in level after onset of COVID-19 wave 1) and gradual effects (change in slope after onset of COVID-19 Wave 1).

[c]Models for length of stay and nitrous oxide have the first 3 time points in the pandemic period set to missing.

[d]Model did not converge.

GA: gestational age; NICU: neonatal intensive care unit; TOLAC: trial of labour after cesarean; VBAC: vaginal birth after cesarean.

Clinical and Research Implications

Most of the significant changes identified occurred immediately after the pandemic started when health care providers, clinical committees, and policymakers were rapidly deciding which practice changes were needed based on limited and constantly shifting evidence. Media reports about people avoiding hospitals, overwhelmed hospitals, and special COVID-19 units being set up within hospitals[13,26] were likely associated with our findings of an initial decrease in hospital births and increase in home births, as well as a decrease in length of hospital stay regardless of mode of delivery.

Some practice changes occurred quickly, in alignment with recommendations. Nitrous oxide use showed the most dramatic decrease; recommendations against the use of nitrous oxide were largely due to the potential for aerosolization of the SARS-CoV-2 virus and thus risk of infection for others in the room.[27] The same rationale applied to general anesthesia. It is not surprising that epidural use for labour analgesia and regional anesthesia for cesarean delivery increased in line with provincial and national guidelines.[11,12] TOLAC decreased dramatically after the pandemic onset because of the unpredictability of emergency cesarean delivery during a TOLAC. In September 2020, the SOGC issued a statement recommending that TOLAC continue to be offered during the pandemic versus routinely resorting to elective repeat cesarean delivery.[28] It is a sign of progress that we found TOLAC rising towards prepandemic levels since this statement, and indeed many of our study outcomes were trending towards prepandemic levels by the end of the study time period. It is apparent that the first few months led to the most upheaval as health care providers and hospitals were trying to adapt in accordance with emerging research and experience.

It is reassuring that we did not find significant increases in adverse outcomes (e.g., preterm birth, stillbirth, NICU admissions, low Apgar scores, and abnormal arterial cord blood pH) because these could have been unintended consequences of avoiding hospitals or ultrasounds when care was necessary or of time delays for cesarean delivery in labour because of the need to properly don personal protective equipment.

Additionally, there were 387 cases of SARS-CoV-2 reported in pregnant individuals in Ontario from the onset of the pandemic to the end of September 2020.[29] Given that our study included 94 126 pregnant individuals in the COVID-19 wave 1 period, it is extremely unlikely that the study outcomes were influenced by the virus itself instead of pandemic countermeasures.

Strengths and Limitations

We used a robust quasi-experimental design allowing an assessment of the impact of COVID-19 wave 1 across the entire obstetric population, while accounting for any pre-pandemic secular trends.[14,30] Additionally, the time series design used population-level data, which should eliminate concern about individual-level confounders, unless these changed concurrently with the pandemic.[30] We had the availability of a birth registry with near-complete and timely capture of all provincial births in hospitals, at home, or in a birth centre.

Hospital-level summary data using random effects segmented regression analyses would have been beneficial to examine variation across sites and to account for characteristics such as birth volume, level of care, and region of the province. However, given the small birth volume of some sites, as well as the criteria for certain study outcomes, the denominators at the hospital level were too small, which would have led to instability in the analysis. One approach to increase denominators is to choose a wider time interval (e.g., monthly); however, this would have led to too few time intervals in the COVID-19 wave 1 period. Although we were unable to specifically explore variation across the province, the hospitals, clinicians, and maternal-newborn networks in Ontario ultimately collaborated to implement system-level changes, which would have diluted any initial variability in maternal-newborn care.

We were unable to examine longer term maternal-newborn outcomes because the majority of the registry data are collected up until discharge from hospital or midwifery care. Examining outcomes past the hospital stay (e.g., breastfeeding) would be helpful in evaluating pandemic effects once mother and baby are at home. Finally, we cannot rule out the possibility of type I error due to the many outcomes we examined.

CONCLUSION

Wave 1 of the COVID-19 pandemic led to system-level and clinical practice changes in Ontario maternal-newborn settings. Importantly, there is no evidence that these changes resulted in any contemporaneous increase in adverse perinatal outcomes, including stillbirth and preterm birth.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at 10.1016/j.jogc.2021.12.006.

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