

Preeclampsia and Severe Maternal Morbidity During the COVID-19 Pandemic: A Population-Based Cohort Study in Ontario, Canada



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ABSTRACT

Objective: Significant changes to the delivery of obstetrical care that occurred with the onset of the COVID-19 pandemic may be associated with higher risks of adverse maternal outcomes. We evaluated preeclampsia/HELLP (hemolysis, elevated liver enzymes and low platelets) syndrome and composite severe maternal morbidity (SMM) among pregnant people who gave birth during the COVID-19 pandemic and compared these data with

those of people who gave birth before the pandemic in Ontario, Canada.

Methods: This was a population-based, retrospective cohort study using linked administrative data sets from ICES. Data on pregnant people at ≥ 20 weeks gestation who gave birth between March 15, 2020, and September 30, 2021, were compared with those of pregnant people who gave birth within the same date range for the years 2015–2019. We used multivariable logistic regression to assess the effect of the pandemic period on the odds of preeclampsia/HELLP syndrome and composite SMM, adjusting for maternal baseline characteristics and comorbidities.

Results: There were no differences between the study periods in the adjusted odds ratios (aORs) for preeclampsia/HELLP syndrome among primiparous (aOR 1.00; 95% CI 0.91–1.11) and multiparous (aOR 0.94; 95% CI 0.81–1.09) patients and no differences for composite SMM (primiparous, aOR 1.00; 95% CI 0.95–1.05; multiparous, aOR 1.01; 95% CI 0.95–1.08).

Conclusion: Adverse maternal outcomes were not higher among pregnant people who gave birth during the first 18 months of the COVID-19 pandemic in Ontario, Canada, when compared with those who gave birth before the pandemic.

Keywords: pregnancy; COVID-19; pre-eclampsia; HELLP syndrome; pregnancy complications; cohort study; Ontario

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RÉSUMÉ

Objectif : La pandémie de COVID-19 a apporté des changements importants dans la prestation de soins obstétricaux, lesquels pourraient être associés à une augmentation du risque d'issues maternelles indésirables. Nous avons évalué le risque de prééclampsie et de syndrome HELLP (hémolyse, élévation des

enzymes hépatiques et faible numération plaquettaire) et l'indice composite de morbidité maternelle grave (MMG) chez les femmes enceintes qui ont accouché pendant la pandémie, et avons comparé ces données à celles des patientes qui ont accouché avant la pandémie en Ontario, au Canada.

Méthodologie : Cette étude de cohorte rétrospective populationnelle a été réalisée à partir d'ensembles de données administratives liées de l'ICES. Les données sur les personnes enceintes à ≥ 20 semaines d'aménorrhée qui ont accouché entre le 15 mars 2020 et le 30 septembre 2021 ont été comparées avec celles des personnes enceintes qui ont accouché dans cette même fenêtre pour la période de 2015 à 2019. Nous avons effectué une analyse de régression logistique multivariée pour évaluer les effets de la pandémie sur le risque de prééclampsie et de syndrome HELLP et l'indice composite de MMG avec un ajustement aux caractéristiques et comorbidités maternelles de départ.

Résultats : Aucune différence entre les périodes à l'étude n'a été relevée dans le rapport de cotes ajusté (RCa) pour la prééclampsie et le syndrome HELLP chez les patientes primipares (RCa : 1,00; intervalle de confiance [IC] à 95 % : 0,91–1,11) et multipares (RCa : 0,94; IC à 95 % : 0,81–1,09) ni pour l'indice composite de MMG (primipares, RCa : 1,00; IC à 95 % : 0,95–1,05; multipares, RCa : 1,01; IC à 95 % : 0,95–1,08).

Conclusion : Les issues maternelles indésirables n'étaient pas plus élevées chez les personnes enceintes qui ont accouché dans les 18 premiers mois de la pandémie en Ontario, au Canada, que chez celles qui ont accouché avant la pandémie.

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INTRODUCTION

The COVID-19 pandemic necessitated rapid changes to models of health care provision in order to reduce physical interactions and to mitigate the risks of severe acute respiratory syndrome corona virus-2 (SARS-CoV-2) viral transmission. Obstetrical care adaptations in response to the pandemic included the introduction of virtual care and the deferral or delay of in-person visits, obstetrical ultrasounds, and other maternal investigations.^{1,2} Health care seeking behaviour among pregnant patients changed during the pandemic as well, with fewer scheduled and unscheduled antenatal visits.² A systematic review of global health care adaptations across pregnancy, birth, and the postpartum period found overall reduced rates of in-person antenatal care attendance, pregnancy health screening, and hospital admission where urgent care was sought, along with delayed presentation to unscheduled triage visits and the intended place of birth with labour onset.² Coinciding with these changes, increased rates of adverse maternal outcomes, including the hypertensive

disorders of pregnancy, maternal depression, and maternal death, have been reported in several studies in both high income countries and low and middle income countries (LMIC).^{1,3,4} This suggests that adaptations to health care systems in response to the COVID-19 pandemic may have increased delays in the diagnosis or management of serious maternal conditions or in pregnant patients accessing obstetrical care. It is possible that such delays could be associated with the increased rates of severe maternal morbidity and mortality reported in some studies. A relationship between the pandemic onset and these and other maternal adverse outcomes has not been observed consistently in the literature, likely due in part to the variation in health care provision adaptations and other health system responses to the COVID-19 pandemic among different jurisdictions.^{3,5,6} Canadian estimates of the pandemic effects on maternal outcomes have not yet been reported but are vital in addressing this health crisis within the country and maintaining a safe and effective health care system for pregnant people. Our objective was to evaluate whether pregnant people in Ontario, Canada, who delivered during the first 18 months of the COVID-19 pandemic (from March 2020 to September 2021) experienced an increased risk of the hypertensive disorders of pregnancy, including the hemolysis, elevated liver enzyme, low platelets (HELLP) syndrome, and severe maternal morbidity (SMM), compared with a historical cohort.

METHODS

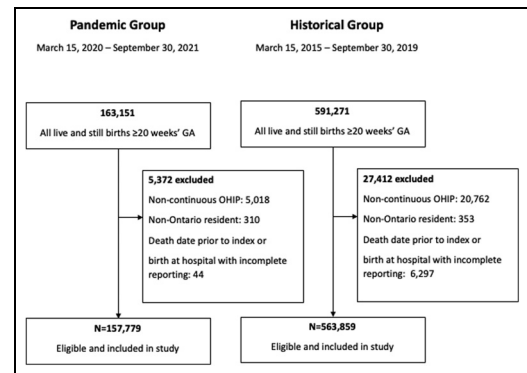
We performed a population-based retrospective cohort study using linked health administrative datasets for Ontario, Canada. All datasets were linked using unique encoded identifiers and analyzed at ICES, formerly known as the "Institute for Clinical Evaluative Sciences." We followed the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) reporting guideline ([online Appendix 1](#)).⁷ In Ontario, data on all patients admitted to hospital are captured in the Canadian Institute for Health Information Discharge Abstract Database. Pregnant people with an in-hospital birth at ≥ 20 weeks gestational age identified in the Linked Delivering Mother and Newborn (MOMBABY) dataset derived from Canadian Institute for Health Information Discharge Abstract Database were included in the study. Pregnant people who gave birth from March 15, 2020, to September 30, 2021 (pandemic group) were compared with pregnant people who gave birth from March 15, 2015, to September 30, 2019 (historical group). We chose March 15, 2020, as the starting date for births included in the pandemic group because the initial set of major public health and travel restrictions and

health care system adaptations in Ontario coincided with the first provincial lockdown in mid-March 2020.⁸ Maternal characteristics included age (continuous), parity (nulliparous vs. multiparous), singleton versus multiple gestation, medical comorbidities, assisted reproductive technology (ART; binary variable defined as the use of in vitro fertilization and associated technologies), neighborhood income quintile, and SARS-CoV-2 infection during pregnancy (binary). We assessed for preexisting hypertension and diabetes using the International Statistical Classification of Diseases and Related Health Problems, 10th revision codes reported in the Ontario Hypertension Dataset (HYPER) and Ontario Diabetes Dataset (ODD) validated ICES datasets, respectively.^{9,10} We adjusted for other preexisting comorbidities by including the Johns Hopkins aggregated diagnosis groups (ADG) comorbidity score (continuous), which is a validated predictor of mortality in the general adult population of Ontario.¹¹ All covariates were recorded at the time of birth, except for preexisting hypertension, diabetes, and the ADG comorbidity score, which were assessed in the 3 years preceding the onset of pregnancy.

The primary binary outcome was severe preeclampsia or HELLP syndrome from 20 weeks gestation through 42 days postpartum. Composite SMM was the secondary binary outcome and was comprised of conditions characterized by end-organ dysfunction or a high risk of maternal mortality that are associated with pregnancy, birth, or the postpartum period. The indicators used to define SMM have been previously validated for Canada and have been widely used to evaluate maternal morbidity.^{12–17} Outcomes were identified in the linked datasets at ICES using diagnostic and procedural codes from the International Statistical Classification of Diseases and Related Health Problems, 10th revision and the Canadian Classification of Health Interventions.^{18,19} In addition to the datasets already described, maternal demographic and age information were identified using the Registered Persons Database, and mode of delivery was identified using Canadian Classification of Health Interventions codes and physician billing codes within the Ontario Health Insurance Plan dataset. The [online Appendix 2](#) includes more information on the linked datasets and variables used in this study.

Crude proportions were calculated for preeclampsia/HELLP syndrome, composite SMM, and specific SMM types that could potentially be affected by care-provision changes during the pandemic. A standardized difference of >0.10 in the distributions of characteristics between pandemic and historical groups was considered significant. We performed multivariable logistic regression to examine the adjusted association between the primary exposure

Figure 1. Flow diagram of included pregnant people in the pandemic (2020–2021) and historical (2015–2019) study groups.



(pandemic vs. historical groups) and each outcome. A generalized estimating equations approach was used with an exchangeable correlation structure to account for clustering at the level of the institution where the birth occurred. We tested for interaction between pandemic group exposure and preexisting hypertension to account for the possibility of different care-provision practices for pregnant people with this risk factor. Analyses were stratified by parity and performed using SAS version 7.15 (SAS Institute). Statistical tests were 2-sided, with a P value < 0.05 considered significant.

The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a research ethics board. This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care. This study also received funding from the Canadian Institutes of Health Research.

RESULTS

The number of births was 157 779 during the pandemic period and 563 859 during the historical period (Figure). The distributions of baseline characteristics between pandemic and historical groups were similar (Table 1). The median maternal age was 32 years (interquartile range 28–35) for the pandemic group and 31 years (interquartile range 28–34) for the historical group. Preexisting diabetes had a prevalence of 2.6% for the pandemic group and 2.2% for historical group, and preexisting hypertension occurred in just over 2% of both groups. The distribution of ADG preexisting comorbidity scores was also consistent between groups. Pregnancy and birth variables were similar, with primiparous people comprising 50.7% of the

Table 1. Distributions of baseline characteristics of the study population by pandemic and historical periods

| Characteristic | Period; no. (%) ^a | |
|---------------------------------------|------------------------------|-------------------------|
| | Pandemic; n = 157 779 | Historical; n = 563 859 |
| Age, y | | |
| Mean ± SD | 31.42 ± 5.00 | 30.96 ± 5.20 |
| Median (IQR) | 32 (28–35) | 31 (28–34) |
| Area of residence | | |
| Urban | 141 289 (89.5) | 506 099 (89.8) |
| Rural | 16 225 (10.3) | 56 968 (10.1) |
| Missing | 265 (0.2) | 792 (0.1) |
| Neighborhood income quintile | | |
| 1 (lowest) | 32 560 (20.6) | 120 795 (21.4) |
| 2 | 31 628 (20.0) | 111 442 (19.8) |
| 3 | 33 848 (21.5) | 118 553 (21.0) |
| 4 | 32 876 (20.8) | 117 313 (20.8) |
| 5 (highest) | 26 512 (16.8) | 94 702 (16.8) |
| Missing | 355 (0.2) | 1054 (0.2) |
| ADG comorbidity score | | |
| 0 | 163 (0.1) | 650 (0.1) |
| 1–5 | 39 841 (25.3) | 135 210 (24.0) |
| 6–9 | 69 865 (44.3) | 251 403 (44.6) |
| ≥10 | 47 910 (30.4) | 176 596 (31.3) |
| Preexisting hypertension | 3331 (2.1) | 12 991 (2.3) |
| Preexisting diabetes | 4071 (2.6) | 12 635 (2.2) |
| Parity | | |
| Primiparous | 79 980 (50.7) | 273 956 (48.6) |
| Multiparous | 77 799 (49.3) | 289 903 (51.4) |
| ART | 5458 (3.5) | 17 953 (3.2) |
| Multiple gestation pregnancy | 2601 (1.6) | 10 001 (1.8) |
| Mode of delivery | | |
| Spontaneous vaginal | 93 861 (59.5) | 352 254 (62.5) |
| Operative vaginal | 13 301 (8.4) | 45 746 (8.1) |
| Cesarean | 50 605 (32.1) | 165 797 (29.4) |
| Missing | 12 (0.0) | 62 (0.0) |
| SARS-CoV-2 infection during pregnancy | | |
| Negative | 49 064 (31.1) | |
| Positive | 2743 (1.7) | |
| Unknown/not tested | 105 972 (67.2) | |
| SARS-CoV-2 infection at delivery | | |
| Negative | 16 116 (10.2) | |
| Positive | 256 (0.2) | |
| Unknown/not tested | 141 407 (89.6) | |

^aUnless otherwise specified.

ADG: aggregated diagnosis group; ART: assisted reproductive technology; IQR: interquartile range; SARS-CoV-2: severe acute respiratory syndrome coronavirus-2.

pandemic group and 48.6% of the historical group. Cesarean was the mode of delivery for 32.1% of pandemic pregnancies and 29.4% of historical pregnancies. Demographic variables had similar distributions between groups, including neighbourhood income quintile and

rurality. In the pandemic group, 1.7% had a confirmed positive SARS-CoV-2 test during pregnancy, and 0.2% had a positive test at the time of delivery, although most people were either not tested or had an unknown test status during the study timeframe (Table 1).

Table 2. Unadjusted proportions of severe preeclampsia/HELLP syndrome, composite SMM, and specific SMM types during pandemic (2020–2021) and historical (2015–2019) periods

| Outcome | Period; no. (%) | | Standardized difference |
|-------------------------------------|-----------------------|-------------------------|-------------------------|
| | Pandemic; n = 157 779 | Historical; n = 563 859 | |
| Preeclampsia/HELLP syndrome | 879 (0.6) | 3119 (0.6) | <0.10 |
| Composite SMM | 3752 (2.4) | 13 232 (2.3) | <0.10 |
| SMM type^a | | | |
| Complications of medical conditions | 169 (0.1) | 594 (0.1) | <0.10 |
| Maternal ARDS/ventilation | 149 (0.1) | 554 (0.1) | <0.10 |
| Maternal ICU admission | 551 (0.3) | 2009 (0.4) | <0.10 |
| Intrapartum hemorrhage | 80 (0.1) | 271 (0.0) | <0.10 |
| Postpartum hemorrhage | 1103 (0.7) | 3818 (0.7) | <0.10 |
| Sepsis | 382 (0.2) | 1780 (0.3) | <0.10 |
| Complications of anesthesia | 9 (0.0) | 53 (0.0) | <0.10 |
| Thromboembolism | 74 (0.0) | 259 (0.0) | <0.10 |
| Coagulopathy | 81 (0.1) | 258 (0.0) | <0.10 |
| Maternal death | ≤5 (0.0) | ≤5 (0.0) | <0.10 |

^aSMM types are not mutually exclusive.

ARDS: acute respiratory distress syndrome; HELLP syndrome: hemolysis, elevated liver enzymes, low platelets syndrome; ICU: intensive care unit; SMM: severe maternal morbidity.

There was no difference in preeclampsia/HELLP syndrome between pandemic (879 cases [0.6%]) and historical groups (3119 cases [0.6%]) and no differences in composite SMM or specific SMM types (Table 2). In the multivariable model, the adjusted odds ratio (aOR) for preeclampsia/HELLP syndrome among pregnant people in the pandemic group compared with pregnant people in the historical group was 1.00 (95% confidence interval [CI] 0.91–1.11) for primiparas and 0.94 (95% CI 0.81–1.09) for multiparas (Table 3). There was no evidence of interaction with preexisting hypertension (primiparous: $P = 0.85$, multiparous: $P = 0.61$). There were no differences in composite SMM between groups for primiparas (aOR 1.00; 95% CI 0.95–1.05) or multiparas (aOR 1.01; 95% CI 0.95–1.08) (Table 3). Maternal age, rurality, preexisting comorbidities, and the use of ART were all associated with increased odds of preeclampsia/HELLP syndrome and with composite SMM for both primiparas and multiparas. Pregnant people residing in the lowest income quintile areas were more likely to experience preeclampsia/HELLP syndrome and composite SMM compared with those residing in the highest quintile areas, for both primiparas and multiparas (Table 3).

DISCUSSION

We used population-level data for Ontario to extend our understanding of pandemic-era effects on adverse maternal outcomes. We found no increase in the risks of preeclampsia/HELLP syndrome or composite SMM

during the first 18 months of the COVID-19 pandemic after adjusting for maternal demographics and comorbidities, pregnancy variables, and delivery mode. We found no evidence of interaction between preexisting hypertension and exposure to the pandemic period.

Our findings are similar to earlier studies, including a single-centre study from a tertiary maternity centre in Ireland⁵ and a meta-analysis of maternal morbidity in high-income countries during the pandemic.³ The majority of studies included in this meta-analysis were from single centres and focused on perinatal outcomes.³ We expand the literature by using population-level data to evaluate maternal outcomes of preeclampsia/HELLP syndrome and composite SMM in Ontario, Canada. Preeclampsia/HELLP syndrome is among the most common causes of maternal morbidity and one of the most likely to recur in a subsequent pregnancy,^{13,20} and composite SMM is an important surveillance measure of maternal health that can be compared across jurisdictions,^{21–23} making these outcomes vital to track in relation to the ongoing COVID-19 pandemic. Although we found no differences in maternal outcomes during the first 18 months of the pandemic, higher risks of maternal death and hypertensive disorders have been reported in the meta-analysis by Chmielewska and colleagues³ with the inclusion of studies from LMICs. The ability of health systems to respond to additional resource demands necessitated by the pandemic may partly explain the differences observed between high-income countries and LMICs.

Table 3. Multivariable logistic regression models by parity for odds of primary and secondary outcomes, comparing pandemic (2020–2021) and historical (2015–2019) periods

| Outcome and variables | Primiparous | | Multiparous | |
|---|---------------------|------------------|---------------------|------------------|
| | Odds ratio (95% CI) | | Odds ratio (95% CI) | |
| | Unadjusted | Adjusted | Unadjusted | Adjusted |
| Preeclampsia/HELLP syndrome | | | | |
| Pandemic vs. historical period | 1.01 (0.91–1.12) | 1.00 (0.91–1.11) | 0.95 (0.82–1.11) | 0.94 (0.81–1.09) |
| Age, y | 1.03 (1.02–1.04) | 1.02 (1.01–1.03) | 1.06 (1.04–1.07) | 1.05 (1.03–1.06) |
| Rural vs. urban residence | 1.42 (1.16–1.74) | 1.46 (1.21–1.77) | 1.22 (0.95–1.57) | 1.31 (1.03–1.67) |
| Income quintile (ref: 5-highest) | | | | |
| 1 (lowest) | 1.16 (0.95–1.41) | 1.20 (1.00–1.44) | 1.42 (1.16–1.72) | 1.46 (1.23–1.73) |
| 2 | 0.99 (0.79–1.23) | 1.01 (0.82–1.25) | 1.20 (0.94–1.54) | 1.24 (0.99–1.55) |
| 3 | 1.17 (0.99–1.38) | 1.19 (1.01–1.39) | 1.02 (0.81–1.29) | 1.05 (0.85–1.29) |
| 4 | 1.14 (0.99–1.32) | 1.15 (1.00–1.31) | 1.03 (0.86–1.24) | 1.04 (0.88–1.22) |
| Preexisting hypertension | 3.17 (2.68–3.74) | 2.38 (1.96–2.88) | 4.94 (4.17–5.85) | 3.53 (2.98–4.18) |
| Preexisting diabetes | 2.89 (2.45–3.40) | 2.15 (1.84–2.52) | 2.70 (2.04–3.57) | 1.70 (1.29–2.24) |
| ADG comorbidity score | 1.05 (1.03–1.06) | 1.04 (1.02–1.05) | 1.09 (1.07–1.11) | 1.07 (1.06–1.09) |
| ART | 2.02 (1.63–2.50) | 1.72 (1.39–2.13) | 2.24 (1.65–3.06) | 1.76 (1.32–2.36) |
| Composite SMM | | | | |
| Pandemic vs. historical period | 0.99 (0.94–1.04) | 1.00 (0.95–1.05) | 0.99 (0.94–1.04) | 1.01 (0.95–1.08) |
| Age, y | 1.03 (1.03–1.04) | 1.03 (1.02–1.03) | 1.03 (1.02–1.03) | 1.03 (1.03–1.04) |
| Rural vs. urban residence | 1.20 (1.05–1.36) | 1.27 (1.12–1.44) | 1.25 (1.10–1.42) | 1.29 (1.14–1.46) |
| Income quintile (ref: 5-highest) | | | | |
| 1 (lowest) | 1.21 (1.08–1.36) | 1.26 (1.13–1.39) | 1.26 (1.14–1.39) | 1.44 (1.27–1.62) |
| 2 | 1.09 (0.96–1.23) | 1.11 (0.98–1.25) | 1.11 (0.99–1.25) | 1.23 (1.07–1.42) |
| 3 | 1.10 (1.00–1.22) | 1.11 (1.02–1.22) | 1.12 (1.03–1.22) | 1.13 (0.98–1.30) |
| 4 | 1.09 (1.01–1.17) | 1.08 (1.00–1.15) | 1.09 (1.02–1.17) | 1.11 (0.99–1.24) |
| Preexisting hypertension | 2.29 (1.99–2.63) | 1.71 (1.52–1.91) | 1.70 (1.52–1.91) | 1.70 (1.50–1.93) |
| Preexisting diabetes | 1.93 (1.70–2.18) | 1.42 (1.26–1.60) | 1.42 (1.25–1.60) | 1.43 (1.28–1.60) |
| ADG comorbidity score | 1.07 (1.05–1.09) | 1.07 (1.05–1.08) | 1.07 (1.05–1.08) | 1.09 (1.08–1.11) |
| ART | 2.11 (1.91–2.33) | 1.77 (1.60–1.97) | 1.78 (1.60–1.97) | 1.89 (1.58–2.28) |

ADG: aggregated diagnosis group; ART: assisted reproductive technology; HELLP syndrome: hemolysis, elevated liver enzymes, low platelets syndrome; SMM: severe maternal morbidity.

A significant risk factor for both preeclampsia/HELLP syndrome and composite SMM is social disadvantage, and the present study corroborates this well-established finding in both the historical and pandemic groups.^{14,17,24} Research increasingly points to the disproportionate risks of COVID-19 disease and associated adverse outcomes borne by people from socioeconomically disadvantaged backgrounds and marginalized and racialized groups.^{25–27} Obstetrical care adaptations implemented in response to the pandemic may further exacerbate inequities among these at-risk groups.^{2,28} How the social determinants of health contribute to adverse maternal outcomes during the COVID-19 pandemic represents a critical area for further research.

Our study was population-based and included all in-hospital births in Ontario, which amount to >97% of births in the province. We adjusted for preexisting comorbidities and ART and used validated outcome measures comparable to other work in the field of maternal morbidity. There were nonetheless some limitations with our study. We were unable to adjust for some maternal risk factors, such as body mass index and smoking, and did not include pregnancies that ended before 20 weeks gestation. A recent Canadian study found higher rates of postpartum depression and anxiety in people who gave birth during the pandemic compared with those who gave birth prior to the pandemic.²⁹ Our analysis was not able to comprehensively assess for mental illnesses; in particular, we could not account for conditions managed

in the outpatient setting that did not result in hospital admission. This represents an important area for future research and intervention. Adaptations to health care delivery occurred province-wide in Ontario with a synchronous onset that coincided with the first lockdown in March 2020. However, the variation among institutions and providers in how obstetrical care changes were implemented and whether certain patient subgroups experienced the effects of these adaptations differently were not assessed in this study. Seasonal trends in preeclampsia/HELLP and other types of SMM as well as fluctuations in COVID-19 incidence during the pandemic were not addressed in this study. Pandemic and historical groups were identified using corresponding calendar months to minimize differences based on the seasonality of our outcomes of interest. Despite these limitations, this study used robust population-based data to evaluate the effects of the COVID-19 pandemic on validated maternal outcomes. It provides evidence of the pandemic effects on maternal health in a high-income setting with publicly funded health care and is the first to report on this topic in Canada.

CONCLUSION

Our findings suggest that the changes in obstetrical care provision and other factors related to the pandemic have not resulted in increased risks of preeclampsia and HELLP syndrome or adverse maternal outcomes overall during the first 18 months of the COVID-19 pandemic. This is the first study to evaluate these associations in Canada. Future work will focus on the specific patterns of obstetrical care changes during the pandemic and whether these differed among at-risk populations.

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ICES (formerly, the Institute for Clinical Evaluative Sciences) is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information (CIHI) and Ministry of Health & Long-Term Care. However, the conclusions, opinions, and statements expressed in the material are solely those of the authors, and not of the bodies listed. No endorsement by these bodies is intended or should be inferred. ICES data use for this study is authorized under section 45 of Ontario's Personal Health Information Protection Act (PHIPA) and does not require review by a Research Ethics Board. K.E. had full access to data used in the study. J.W.S., A.E.S., and N.N.B. take responsibility for

the integrity of the data analysis. Data availability statement: The dataset from this study is held securely in coded form at ICES. While legal data sharing agreements between ICES and data providers (e.g., health care organizations and government) prohibit ICES from making the dataset publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS (email: das@ices.on.ca). The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification. Research ethics board approval number: ICES is a prescribed entity under Ontario's Personal Health Information Protection Act (PHIPA). Section 45 of PHIPA authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation, or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects that use data collected by ICES under section 45 of PHIPA, and use no other data, are exempt from REB review. The use of the data in this project is authorized under section 45 and approved by ICES' Privacy and Legal Office.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jogc.2022.03.008>.

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