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SARS-CoV-2 infection in pregnancy and infant outcomes in the first year of life: a retrospective cohort study

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Abstract

Background There are known maternal and obstetrical risks following SARS-CoV-2 infection in pregnancy, but the impact on offspring is not well known. The objective of this study was to examine offspring risks of hospitalization and emergency department visits in the first year of life following SARS-CoV-2 infection in pregnancy.

Methods This was a retrospective cohort study in Ontario, Canada of infants born from March 1, 2020 to December 31, 2021 using health administrative databases. The exposure group was defined by a positive SARS-CoV-2 PCR test in pregnancy, while the comparator group included pregnancies without a positive test recorded. The primary outcomes included all-cause offspring hospitalizations and emergency department (ED) visits in the first year of life. Poisson regression was used to adjust for maternal sociodemographic factors, medical and obstetrical history, and health behaviours. The main secondary outcome was risk of infections (including respiratory, gastrointestinal and otitis media infections) in the first year of life. A sensitivity analysis was conducted in which individuals with a negative SARS-CoV-2 test served as the comparator group.

Results There were 222,448 live births during the study period; following matching 45,958 pregnancies were included. Cases were matched on maternal age, geography, and last menstrual period date in a 10:1 ratio. The exposed group included 5,291 pregnancies and the comparator group included 40,667 pregnancies. There was no significant difference observed between groups in risk of hospitalization (aRR (95% CI): 1.10 (0.99–1.22)). Small increases in risk of both ED visits (aRR 1.12 (1.06–1.17)), and infections (aHR 1.16 (1.11–1.21)) were observed in the exposed group. When the comparator group was limited to pregnancies with a negative SARS-CoV-2 test, there was no difference in risk of ED visits, but the increased risk of infections persisted.

Conclusions A positive SARS-CoV-2 test in pregnancy was not associated with an increased risk of hospitalization in the offspring's first year, which may be reassuring to parents and healthcare providers. However, there may be a small increased risk of offspring infections.

Keywords COVID-19, Hospitalization, Pregnancy outcomes

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Background

COVID-19, the disease caused by the SARS-CoV-2 virus, continues to affect individuals worldwide, and while scientific knowledge of the illness has grown exponentially since it was first described in late 2019, questions remain regarding long-term repercussions of infection. In particular, the impact of the SARS-CoV-2 virus in pregnancy has been explored through large cohort studies and systematic reviews, but postnatal effects on infants exposed in utero are not well-described.

The risks of intensive care unit (ICU) admission and death are increased in those who are pregnant and infected with SARS-CoV-2 compared to those who are not pregnant and infected [1–4]. Pregnancies complicated by SARS-CoV-2 infection are also reported to have an increased risk of preeclampsia, preterm birth, and stillbirth [1, 5, 6]. Evidence to date regarding offspring outcomes is limited to the immediate neonatal period, with one study demonstrating an increased risk of admission to higher-level NICU, longer length of hospital stay, and greater need for ventilatory support in infants born to individuals with SARS-CoV-2 infection in pregnancy [7]. Beyond the early neonatal period, there is a paucity of evidence on the offspring effects.

As is observed for other pathogens, there may be long-term repercussions of maternal infection in pregnancy for the offspring. It is well established that some infections in pregnancy are teratogenic, producing profound congenital effects in offspring, for example as seen with ‘ToRCH’ infections (toxoplasmosis, rubella, cytomegalovirus, herpes virus, syphilis) [8–12]. Others pose a risk of vertical transmission and lifelong offspring infection, for example HIV and hepatitis B. Fortunately, most evidence indicates that the risks of vertical transmission and congenital anomalies attributable to SARS-CoV-2 in pregnancy are low [1, 13, 14].

Other offspring effects of maternal infection may be possible, with one study suggesting there is an increased risk of offspring hospitalization following urinary tract infections in pregnancy [15]. Recent studies of influenza in pregnancy have suggested a link with febrile seizures in early childhood [16, 17].

The objective of this study is to explore whether the impacts of SARS-CoV2 exposure in utero extend beyond the early neonatal period into the first year of life. We hypothesize that fetal exposure to SARS-CoV2 virus in pregnancy may be associated with an increased risk of all-cause hospitalization and emergency department (ED) visits in children up to 1 year of age, compared to children who have not been exposed in utero. Secondly, we hypothesize that SARS-CoV-2 exposure may be associated with an increased risk of infant infection in the same time frame.

Methods

Study setting, population and data sources

This was a population-based retrospective cohort study of pregnant individuals and their offspring born in hospital between March 1, 2020 to Dec 31, 2021 in Ontario, Canada. The study start date reflects approximately the time when SARS-CoV-2 began widely circulating in Canada, with a state of emergency declared in the province of Ontario on March 17, 2020. The study end date reflects when routine PCR testing for all suspected SARS-CoV-2 infections was stopped in the province. Data were obtained from ICES, a non-profit research institute based in Ontario, Canada whose legal status allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement [18].

The study cohort was assembled using the MOMBABY data set [19], which links birthing parents with hospital-born infants using the Maternal-Newborn Matching number, and sociodemographic information was ascertained from the Registered Persons Database [20]. Those with missing or invalid birth dates or not eligible for provincial health insurance were excluded. SARS-CoV2 infection was identified using the C19INTGR database [19], which records SARS-CoV-2 PCR test results in Ontario. In Ontario, all individuals with suspected SARS-CoV-2 infection due to symptoms or contact with an infected individual were tested using PCR until December 31, 2021. COVID-19 vaccination information was ascertained from the Ontario COVID-19 Vaccine Database (COVaxON). Hospitalization and ED visits were identified from the Canadian Institute for Health Information (CIHI) Discharge Abstract Database, and National Ambulatory Care Reporting System databases respectively [21]. Visits to outpatient primary care were ascertained via the Ontario Health Insurance Plan database. These datasets were linked using unique encoded identifiers and analyzed at ICES.

Exposure and outcomes

The exposed group included pregnancies with confirmed SARS-CoV2 infection, and the comparator group pregnancies without confirmed SARS-CoV2 infection, including those who tested negative and those who were not tested. The unexposed group was matched in an up to 10:1 ratio to the exposed group by maternal age (within ± 5 years), geography (using forward sortation area), and last menstrual period date (within ± 2 weeks).

The primary outcome included all-cause offspring hospitalizations (excluding the birth admission) and ED visits in the first year of life. Secondary outcomes included infant upper and lower respiratory tract infections, otitis media, gastrointestinal (GI) infections, and any of these

infections in the first year of life, diagnosed in hospital, ED, or in a primary care setting.

Covariates

Covariates were pre-selected based on clinical and epidemiological rationale and included maternal age, income quintile of the neighbourhood, age and labour force quintile of the neighbourhood [22], number of COVID-19 vaccines received prior to birth of infant, rurality, parity, prenatal care utilization index [23], pre-existing and gestational diabetes and hypertension; number of maternal hospitalizations and ED visits in the five years prior to the index birth, multiple birth, birth season, gestational age at birth, birthweight, infant sex, and small for gestational age (SGA, defined as birthweight less than the 10th percentile for gestational age and sex using the INTERGROWTH growth standard) [24] diagnosis, and large for gestational age (LGA, greater than 90th percentile for gestational age and sex using INTERGROWTH) diagnosis.

Statistical analyses

Analyses were conducted using SAS Enterprise Guide, version 8.3 (SAS Institute, Inc). Descriptive statistics were used to describe the characteristics of the exposed and unexposed groups. Continuous variables were described using medians and interquartile ranges (IQR) due to skewed data, while categorical variables were described using frequencies (n) and percentages (%). Standardized differences of 0.10 or greater were considered to be indicative of covariate imbalance between the exposed and unexposed groups. Poisson regression was used to assess the association between exposure and pediatric all-cause hospitalization and ED visits at 1 year of infant life, while adjusting for covariates. Time-to-event analyses for secondary outcomes were conducted using multivariable Cox proportional hazards regression models. A complete case analysis approach was used when modelling to handle missing data (< 1%).

We performed an a priori power calculation, estimated a sample size of at least 35,000. Using a background rate of 1% for infant hospitalization [25], we calculated > 80% power to detect a relative incidence of 1.2 and > 90% power to detect a relative incidence of 1.3.

Sensitivity analysis

To account for potential differences in access to SARS-CoV-2 PCR testing and health care services, sensitivity analyses for the primary and secondary outcomes were conducted in which only individuals with a negative SARS-CoV-2 test served as the unexposed group (test-negative design) [26].

Results

There were 222,448 live births between March 1, 2020 and December 31, 2021 that met all eligibility criteria. There were 5291 pregnancies with a positive SARS-CoV-2 test, matched to 40,667 pregnancies without a positive test (Fig. 1).

The median age of birthing parents in the study was 32 years (IQR 29–34 years), and the median gestational age at birth was 39 weeks (IQR 38–40 weeks). Maternal demographic characteristics were mostly similar between the two groups (Table 1). However, there were more individuals who did not receive any doses of the SARS-CoV-2 vaccine in the documented infection group compared to those without documented infection. The median number of ED visits and hospitalizations in the 5 years prior to the birth admission were slightly higher in the exposed group, compared to the unexposed group. A higher proportion of the exposed group were multiparous, compared to the unexposed group.

Obstetrical complications and birth outcomes in both exposed and unexposed groups were also similar (Table 2). The length of the birth admission was similar between groups.

Association between SARS-CoV-2 infection and outcomes

The mean (SD) number of all-cause hospitalizations excluding the birth admission was 0.12 (0.44) in the exposed group, and 0.11 (0.39) in the unexposed group (SMD 0.03). In the exposed and unexposed groups respectively, 8.3% and 7.9% of infants had one hospitalization (SMD 0.02). More than 90% of both groups did not have any hospitalizations (see Table 3).

Compared with unexposed infants, SARS-CoV-2 infection during pregnancy was associated with a small increase in the rate of hospitalization in the first year of life in the unadjusted model (Crude Rate Ratio (cRR) 1.13, 95% CI 1.02–1.25) (Table 4). After adjusting for covariates, the effect was slightly attenuated and no statistically significant difference was observed (Adjusted Rate Ratio (aRR) 1.10, 95% CI 0.99–1.22).

The mean (SD) number of all-cause infant ED visits in the first year of life was 0.66 (1.11) in the exposed group and 0.57 (1.02) in the unexposed group (SMD 0.08). There was at least one ED visit in 38.7% of the exposed group and 35.4% of the unexposed group. Table 3 further details number of ED visits by group. Compared with unexposed infants, SARS-CoV-2 infection during pregnancy was associated with a small increase in the rate of ED visits in the unadjusted model (aRR 1.13 (95% CI 1.08–1.19)), and this increased rate persisted after covariate adjustment (aRR 1.12 (95% CI 1.06–1.17)).

There was a small increase in risk of any infection (upper and lower respiratory tract infection, otitis media, or gastrointestinal infection) in offspring from

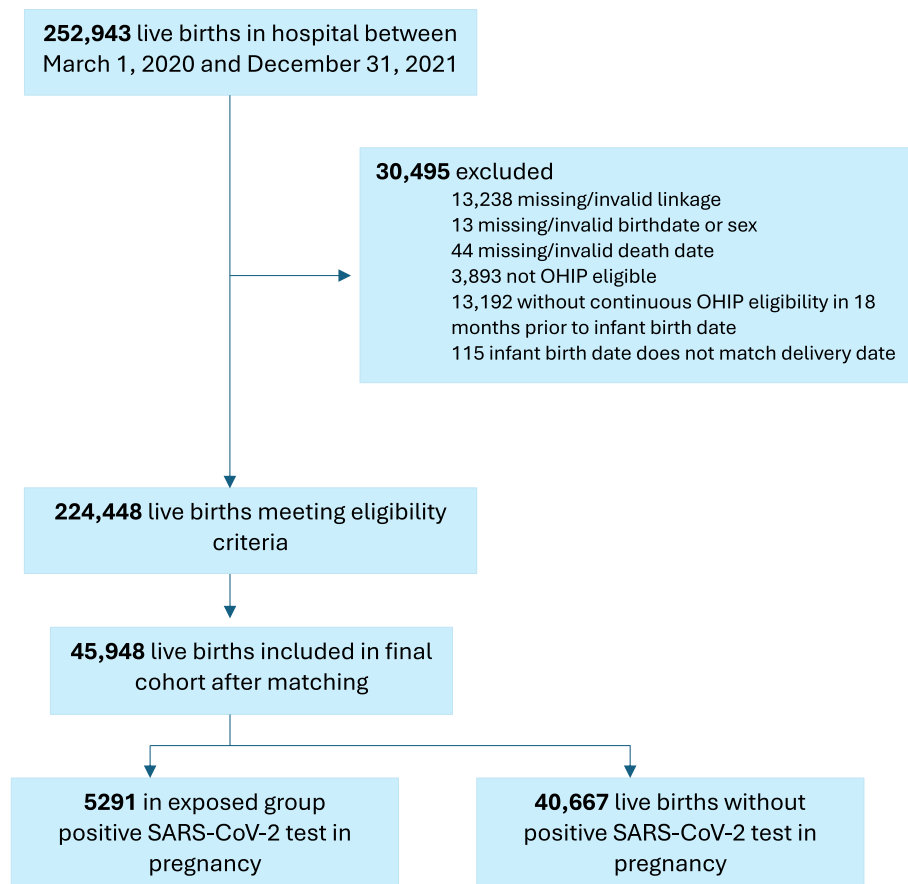


Fig. 1 Cohort flow chart illustrating the inclusion and exclusion criteria of participants in the study

pregnancies with a positive SARS-CoV-2 test compared to those without a positive test in the unadjusted model (crude Hazard Ratio (cHR) 1.16, 95% CI 1.11–1.20). The increased risk persisted after adjusting for covariates (adjusted HR (aHR) 1.16, 95% CI 1.11–1.21). In adjusted analyses of individual infection categories, there was an increased risk of upper respiratory tract infection (aHR 1.19, 95% CI 1.14–1.25), lower respiratory tract infection (aHR 1.20, 95% CI 1.10–1.30), and otitis media (aHR 1.28, 95% CI 1.16–1.41). There was no difference in the risk of gastrointestinal infection between groups, in either the crude (cHR 0.98, 95% CI 0.90–1.07) or adjusted models (aHR 0.99, 95% CI 0.91–1.08).

Sensitivity analyses

For our planned sensitivity analyses, 5068 pregnancies with a positive SARS-CoV-2 test, were matched to 25,212 pregnancies with a negative test to create the exposed and unexposed groups, respectively. Maternal demographics in both groups were similar to those observed in the main analysis. In this analysis, the rates of all-cause offspring hospitalization (aRR 1.05, 95% CI 0.94–1.18) and ED visits (aRR 1.04, 95% CI 0.99–1.10) were not significantly different between those who were exposed to

SARS-CoV-2 infection in pregnancy and those who were unexposed.

When pregnancies with a negative SARS-CoV-2 test were used as the unexposed group, results of analysis of infections were similar to those observed in the main analysis. Compared with unexposed infants, SARS-CoV-2 infection during pregnancy was associated with a small increase in the risk of infections in the first year of life, after covariate adjustment (aHR 1.08, 95% CI 1.04–1.13).

Discussion

In this retrospective cohort study of over 45,000 pregnancies in Ontario, Canada, a positive SARS-CoV-2 test in pregnancy was not associated with an increased rate of hospitalizations in the first year of life, although there was a small increase in the rate of respiratory tract infections and otitis media compared to those without a positive test.

Although there was a small increase in the rate of ED visits in the first year of life that persisted in adjusted analysis, when a negative SARS-CoV-2 test was used as the unexposed group in our planned sensitivity analysis there was no longer a significant difference. This suggests

Table 1 Maternal baseline characteristics in pregnancies with and without a positive SARS-CoV-2 test

	Positive SARS-CoV-2 Test (n=5,291)	No positive SARS-CoV-2 Test (n=40,667)	Standardized mean difference ^a
Total number of live births	5,377	217,047	
Number of live births after matching	5,291	40,667	
Median age (IQR), years	31 (28–34)	32 (29–34)	0.10
Neighbourhood Income Quintile, n (%)			
1 (lowest)	1,258 (23.8%)	7,991 (19.6%)	0.10
2	1,123 (21.2%)	8,740 (21.5%)	0.007
3	1,247 (23.6%)	9,691 (23.8%)	0.006
4	987 (18.7%)	8,234 (20.2%)	0.04
5 (highest)	667 (12.6%)	5,936 (14.6%)	0.058
Missing	9 (0.2%)	75 (0.2%)	0.003
Age and Labour Force Quintile ^b , n (%)			
1 (least marginalized)	2,114 (40.0%)	16,484 (40.5%)	0.01
2	1,149 (21.7%)	8,807 (21.7%)	0.001
3	843 (15.9%)	6,233 (15.3%)	0.02
4	630 (11.9%)	5,116 (12.6%)	0.02
5 (most marginalized)	516 (9.8%)	3,797 (9.3%)	0.01
Missing	39 (0.7%)	230 (0.6%)	0.02
Prenatal Care Utilization Index ^c , n (%)			
Intensive	56 (1.1%)	404 (1.0%)	0.006
Adequate	697 (13.2%)	6,006 (14.8%)	0.05
Intermediate	2,888 (54.6%)	22,193 (54.6%)	0
Inadequate	1,301 (24.6%)	8,930 (22.0%)	0.06
No care	349 (6.6%)	3,134 (7.7%)	0.04
Number of SARS-CoV-2 vaccinations at 14 days prior to birth, n (%)			
0	3,855 (72.9%)	26,162 (64.3%)	0.19
1	537 (10.1%)	4,685 (11.5%)	0.04
2+	899 (17.0%)	9,820 (24.1%)	0.18
Rurality, n (%)	270 (5.1%)	2,195 (5.4%)	0.01
Parity, n (%)			
Nulliparous	2,053 (38.8%)	17,787 (43.7%)	0.1
Multiparous	3,238 (61.2%)	22,880 (56.3%)	0.1
Pre-existing diabetes, n (%)	145 (2.7%)	785 (1.9%)	0.05
Pre-existing hypertension, n (%)	100 (1.9%)	775 (1.9%)	0.004

Table 1 (continued)

	Positive SARS-CoV-2 Test (n=5,291)	No positive SARS-CoV-2 Test (n=40,667)	Standardized mean difference ^a
Number of hospitalizations in 5 years prior to birth admission, median (IQR)	1 (0–1)	0 (0–1)	0.11
Number of emergency department visits in 5 years prior to birth admission, median (IQR)	1 (0–3)	1 (0–3)	0.21

^aA standardized mean difference greater than or equal to 0.10 is considered indicative of covariate imbalance between exposed and unexposed groups

^bThe Age and Labour Force Quintile is a dimension of the Ontario Marginalization Index (ON-Marg), and includes the proportion of the population who are aged 65 and older, the proportion of the population who are not participating in the labour force, and a dependency ratio [27].

^cThe Revised-Graduated Prenatal Care Utilization Index is a measure of adequacy of prenatal care provided to a birthing parent by healthcare providers during the prenatal period using the number of prenatal visits, gestational age of the newborn, and the date when prenatal care began [23].

that the association seen in our primary analysis may have been driven by selection bias due to health-seeking behaviour of parents. Namely, those who sought SARS-CoV-2 testing may have been more inclined to interact with the health care system, a behaviour that extended to care of the infant, and reflected by more ED visits.

This study demonstrates an increased risk of infections in infants of parents who had SARS-CoV-2 in pregnancy. There are both social and biologic explanations to consider. Those with a positive SARS-CoV-2 test in pregnancy may have more exposures to respiratory infections in general, due to parity, place of employment, or local population density. We attempted to control for such factors by including maternal age, neighbourhood income and labour force quintiles, geographic code (forward sortation area) and rurality in adjusted analysis.

An underlying biologic explanation for this is unproven. However, the multisystem inflammatory syndrome has been reported to occur in infants whose birthing parent had SARS-CoV-2 infection in pregnancy [28]. This raises the question of whether there may be long-term effects on such infants due to the rigorous immune response. Studies on the impact of influenza infection in pregnancy have suggested that the link to adverse childhood outcomes, such as seizures, may be mediated by virally induced hypoxia and placental inflammation [17]. More studies are needed to understand the mechanism by which maternal infection predisposes to childhood infection.

Of other studies documenting infant outcomes following in utero exposure to SARS-CoV-2, one other describes hospitalizations up to 6 months as a secondary outcome [29]. In this descriptive study of surveillance data from the United States, there were 3,967 pregnancies

Table 2 Obstetrical complications and birth outcomes in pregnancies with and without SARS-CoV-2 test

	Positive SARS-CoV-2 Test (n = 5,291)	No positive SARS-CoV-2 Test (n = 40,667)	Standardized mean difference
Multiple pregnancy, n (%)	158 (3.0%)	1,322 (3.3%)	0.02
Gestational diabetes, n (%)	667 (12.6%)	4,627 (11.4%)	0.04
Hypertensive disorder of pregnancy, n (%)	416 (7.9%)	3,159 (7.8%)	0.004
Gestational age at birth, weeks, median (IQR) weeks	39 (38–40)	39 (38–40)	0.05
Length of birth admission, median (IQR) days	1 (1–2)	1 (1–2)	0.03
Infant birth weight, g, median (IQR)	3300 (2960–3620)	3316 (2980–3650)	0.04
Infant sex female, n (%)	2,630 (49.7%)	19,791 (48.7%)	0.02
Small for gestational age < 3%ile at birth, n (%)	50 (0.9%)	386–390*	0.001
Small for gestational age < 10%ile at birth, n (%)	237 (4.5%)	1732–1736*	0.01
Large for gestational age, > 90%ile at birth, n (%)	977 (18.5%)	8129–8133*	0.04

*Precise number suppressed due to < 5 missing outcomes

Table 3 Outcomes in the first year of life for offspring of pregnancies

	Positive SARS-CoV-2 Test (n = 5,291)	No positive SARS-CoV-2 Test (n = 40,667)	Standardized mean difference
Number of ED visits, median (IQR)	0 (0–1)	0 (0–1)	0.08
Number of ED visits, n (%)			
0	3,241 (61.3%)	26,287 (64.6%)	0.07
1	1,252 (23.7%)	9,172 (22.6%)	0.026
2	446 (8.4%)	3,200 (7.9%)	0.01
≥ 3	352 (6.7%)	2,008 (4.9%)	0.073
Number of hospitalizations, median (IQR)	0 (0–0)	0 (0–0)	0.02
Number of hospitalizations, n (%)			
0	4,771 (90.2%)	36,921 (90.8%)	0.02
1	440 (8.3%)	3,210 (7.9%)	0.02
2	54 (1.0%)	400 (1.0%)	0.004
≥ 3	26 (0.5%)	136 (0.3%)	0.024
Any infection, n (%)	2,744 (51.9%)	18,944 (46.6%)	0.11
Upper respiratory tract infection	2,139 (40.4%)	14,281 (35.1%)	0.11
Lower respiratory tract infection	680 (12.9%)	4,268 (10.5%)	0.08
Gastrointestinal tract infection	579 (10.9%)	4,514 (11.1%)	0.005
Otitis media	510 (9.6%)	3,123 (7.7%)	0.07

Table 4 Comparing outcomes in offspring of pregnancies with a positive SARS-CoV-2 test vs control

Outcome	Relative risk/hazard ratio (95% confidence interval)
Main analysis, unadjusted comparison to no positive SARS-CoV-2 test (N = 45,958)	
Hospitalization	1.13 (1.02–1.25)
ED visit	1.13 (1.08–1.19)
Any infection	1.16 (1.11–1.20)
Upper respiratory tract infection	1.20 (1.14–1.25)
Lower respiratory tract infection	1.22 (1.12–1.32)
Gastrointestinal infection	0.98 (0.90–1.07)
Otitis media	1.27 (1.15–1.40)
Main analysis, adjusted ^a comparison to no positive SARS-CoV-2 test (N = 45,958)	
Hospitalization	1.10 (0.99–1.22)
ED visit	1.12 (1.06–1.17)
Any infection	1.16 (1.11–1.21)
Upper respiratory tract infection	1.19 (1.14–1.25)
Lower respiratory tract infection	1.20 (1.10–1.30)
Gastrointestinal infection	0.99 (0.91–1.08)
Otitis media	1.28 (1.16–1.41)
Sensitivity Analyses, unadjusted comparison to those with documented negative SARS-CoV-2 test (N = 30,280)	
Hospitalization	1.06 (0.95–1.19)
ED visit	1.04 (0.98–1.09)
Any Infection	1.07 (1.03–1.12)
Upper respiratory tract infection	1.11 (1.06–1.17)
Lower respiratory tract infection	1.16 (1.06–1.26)
Gastrointestinal infection	0.94 (0.86–1.04)
Otitis media	1.10 (1.0–1.23)
Sensitivity Analyses, adjusted ^a comparison to those with documented negative SARS-CoV-2 test (N = 30,280)	
Hospitalization	1.05 (0.94–1.18)
ED visit	1.04 (0.99–1.10)
Any Infection	1.08 (1.04–1.13)
Upper respiratory tract infection	1.12 (1.06–1.17)
Lower respiratory tract infection	1.15 (1.05–1.26)
Gastrointestinal infection	0.96 (0.88–1.06)
Otitis media	1.12 (1.01–1.24)

^aAdjusted for maternal age, neighbourhood income quintile, neighbourhood age and labour force quintile, vaccination status, prenatal care utilization index, rurality, parity, maternal diabetes or hypertension (gestational and pre-existing), maternal health care utilization in 5 years prior to birth admission, birth season, multiple birth, gestational age at birth, infant birth weight, infant sex, small for gestational age diagnosis, large for gestational age diagnosis

affected by SARS-CoV-2 included. The incidence of all-cause hospitalization through 6 months of age was 4.1%, with primary indications of non-SARS-CoV-2 acute respiratory illness, jaundice, and feeding issues. The study design did not include a comparator group, though the authors note that this rate of hospitalization was similar to historical cohorts. Our study supports this finding, as there was no increased risk of hospitalization using either

lack of positive SARS-CoV-2 test, or negative test as the comparator.

A 2022 case–control study suggested that full maternal vaccination (i.e. with 2 doses) against SARS-CoV-2 during pregnancy decreased the risk of infant hospitalization compared to no vaccination [30]. Similarly, a large population-based cohort study found that vaccination (at least one dose) decreased the rate of hospital admission up to 6 months of age [31]. The rate of full vaccination in our exposed cohort was 17%, which while less than the rate of vaccination in the comparator group (24%), may have been sufficient to protect against hospitalization in this study.

Beyond outcomes in the first year of life, other studies have examined the potential neurodevelopmental impact of SARS-CoV-2 in pregnancy on offspring. Some studies have suggested an increased risk of delay in fine motor and personal-social domains [32, 33], though others have found no difference in neurodevelopmental outcomes [34]. Important potential confounders that have been postulated include the higher risk of preterm birth in those with SARS-CoV-2 infection [35], parent-infant separation [36], and pandemic-era social changes [37]. A follow-up study examining neurodevelopmental outcomes is planned for this cohort.

The main strength of this study is its inclusion of live hospital births in the largest province of Canada during the early years of the COVID-19 pandemic, making this a significant study of infant health outcomes following birthing parent SARS-CoV-2 infection in pregnancy. The health administrative datasets available for linkage also allowed important covariates to be included in multivariate regression analysis.

A limitation of the study derives from the changing nature of the pandemic over the past several years. Most data on maternal SARS-CoV2 infection during pregnancy in this study derives from a pre-Omicron variant period; and information on the precise variant is not available from the C19INTGR database for this time. SARS-CoV-2 variants in wide circulation now are different from those affecting individuals in this study, and it has been demonstrated that severity of infection and vaccine protection differs by variant [38]. It is unclear how this may affect infant hospitalization, ED visits, and risk of infection. This may be an area of future research, however the decline in access to PCR confirmatory testing for SARS-CoV-2 may limit the sample size of such research.

Although the study group is large, it notably does not include non-hospital births, since the administrative database utilizes hospital diagnostic and physician billing codes. In the context of initial outbreak of the SARS-CoV-2 pandemic in 2020, the proportion of non-hospital births in Ontario increased to 2% [39]. This observation may have been due to choice, as birthing parents may

have attempted to avoid acquiring infections in the hospital setting, or due to circumstance, due to “social distancing” measures. The same context could also lead to parents unable or choosing not to bring infants to hospital. However, the overall proportion of non-hospital births (2%) is small compared to the overall study size, and thus may not substantially impact the results.

Retrospective database studies are limited in their ability to ascertain some variables. For example, we were unable to determine disease severity using the standard definitions of need for hospitalization since all included patients were hospitalized for birth. During the pandemic, it was briefly standard practice to swab all birthing parents at birth admission, further complicating assessment of disease severity.

Despite these limitations, population database studies such as this one are the only feasible type of study in the setting of a rapidly evolving pandemic.

Conclusions

In this population-based retrospective cohort study comparing infant health outcomes following pregnancies with a positive SARS-CoV-2 to those without a positive test, there was an increased risk of respiratory infections in the first year of life. However, this risk did not translate to increased risks of infant hospitalization or ED visits. This finding may motivate some birthing parents to take additional precautions in pregnancy to avoid SARS-CoV-2 infection and to increase vaccine uptake to minimize risk.

Abbreviations

aRR/HR	Adjusted relative risk/hazard ratio
cRR/HR	Crude relative risk/hazard ratio
CIHI	Canadian Institute for Health Information
ED	Emergency department
ICU	Intensive care unit
IQR	Interquartile range
LGA	Large for gestational age
SD	Standard deviation
SGA	Small for gestational age
SMD	Standardized mean difference

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Authors' contributions

KW contributed to interpretation of data and wrote the manuscript. RD contributed to design of the protocol, interpretation of data, and substantively revised the manuscript draft. MSQM contributed to design of the protocol and substantively revised the draft. AEC performed the acquisition and analysis of data. JB contributed to conception and design of the protocol, and interpretation of data. SH contributed to conception and design of the protocol, and interpretation of data. DEC contributed to conception and design of the protocol, interpretation of data, and revised the draft. All authors read and approved the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author (DEC) but restrictions apply to the availability of these data, which were used under license from ICES for the current study, and so are not publicly available. Data are, however, available from the corresponding author upon reasonable request and with permission from ICES. This document used data adapted from the Statistics Canada Postal Code^{OM} Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada.

Declarations

Ethics approval and consent to participate

Data previously collected for clinical purposes, or for research purposes conducted by a health information custodian or its agents, are securely transferred to Institute for Clinical Evaluative Sciences (ICES), an independent, not-for-profit corporation, named in the regulations accompanying Ontario's *Personal Health Information Protection Act 2004, SO 2004, c 3, Sch A* ("PHIPA"), for the purposes of carrying out evaluation, planning and monitoring of the health system and delivery of services, as described in Sect. 45(1) of PHIPA, and studies conducted for these purposes are exempt from the requirement to obtain research ethics board ("REB") review, according to Articles 2.4 and 2.5 of the TCP52.

By the nature of the data used for this project, individual consent from participants were waived in accordance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans, Article 5.5A(a) to (f). This is in keeping with the privacy and data management practices for evaluation, planning and monitoring projects conducted at ICES.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

- Allotey J, Stallings E, Bonet M, Yap M, Chatterjee S, Kew T, et al. Clinical manifestations, risk factors, and maternal and perinatal outcomes of coronavirus disease 2019 in pregnancy: living systematic review and meta-analysis. *BMJ*. 2020;370. Available from: Accessed 20Dec2023. <https://www.bmj.com/qa-proxy.mun.ca/content/370/bmj.m3320>
- McClymont E, Albert AY, Alton GD, Boucoiran I, Castillo E, Fell DB, et al. Association of SARS-CoV-2 infection during pregnancy with maternal and perinatal outcomes. *JAMA*. 2022;327(20):1983–91. Available from: <https://jamanetwork.com/qa2a-proxy.mun.ca/journals/jama/fullarticle/2792031>. Cited 2022 Sep 4.
- Mullins E, Hudak ML, Banerjee J, Getzlaff T, Townson J, Barnette K, et al. Pregnancy and neonatal outcomes of COVID-19: coreporting of common outcomes from PAN-COVID and AAP-SONPM registries. *Ultrasound Obstet Gynecol*. 2021;57(4):573–81.
- Chmielewska B, Barratt I, Townsend R, Kalafat E, van der Meulen J, Gurol-Urganci I, et al. Effects of the COVID-19 pandemic on maternal and perinatal outcomes: a systematic review and meta-analysis. *Lancet Glob Health*. 2021;9(6):e759–72.
- Wei SQ, Bilodeau-Bertrand M, Liu S, Auger N. The impact of COVID-19 on pregnancy outcomes: a systematic review and meta-analysis. *CMAJ*. 2021;193:E540–8.
- Villar J, Ariff S, Gunier RB, Thiruvengadam R, Rauch S, Kholin A, et al. Maternal and neonatal morbidity and mortality among pregnant women with and without COVID-19 infection: the INTERCOVID multinational cohort study. *JAMA Pediatr*. 2021;
- Wallace B, Chang D, O'Malley Olsen E, Flannery DD, Tong VT, Ellington S, et al. Critical care among newborns with and without a COVID-19 diagnosis, May 2020–February 2022. *J Perinatol*. 2023;43(6):766–74.
- Freitas DA, Souza-Santos R, Carvalho LMA, Barros WB, Neves LM, Brasil P, et al. Congenital Zika syndrome: a systematic review. *PLoS One*. 2020;15(12):e0242367.
- al-Haddad BJS, Oler E, Armistead B, Elsayed NA, Weinberger DR, Bernier R, et al. The fetal origins of mental illness. *Am J Obstet Gynecol*. 2019;221(6):549–62.
- Rac MWF, Revell PA, Eppes CS. Syphilis during pregnancy: a preventable threat to maternal-fetal health. *Am J Obstet Gynecol*. 2017;216(4):352–63.
- Fortin O, Mulkey SB. Neurodevelopmental outcomes in congenital and perinatal infections. *Curr Opin Infect Dis*. 2023;36(5):405–13.
- Nicloux M, Peterman L, Parodi M, Magny JF. Outcome and management of newborns with congenital cytomegalovirus infection. *Arch Pediatr*. 2020;27(3):160–5.
- Hughes BL, Sandoval GJ, Metz TD, Clifton RG, Grobman WA, Saade GR, et al. First- or second-trimester SARS-CoV-2 infection and subsequent pregnancy outcomes. *Am J Obstet Gynecol*. 2023;228(2):226.e1–226.e9.
- Kyle MH, Hussain M, Saltz V, Mollicone I, Bence M, Dumitriu D. Vertical Transmission and neonatal outcomes following maternal SARS-CoV-2 infection during pregnancy. 2022. Available from: . Accessed 20Dec2023. <http://journals.lww.com/clinicalobgyn>
- Cohen R, Gutvirtz G, Wainstock T, Sheiner E. Maternal urinary tract infection during pregnancy and long-term infectious morbidity of the offspring. *Early Hum Dev*. 2019;1(136):54–9.
- Oakley LL, Regan AK, Fell DB, Spruin S, Bakken IJ, Kwong JC, et al. Childhood seizures after prenatal exposure to maternal influenza infection: a population-based cohort study from Norway, Australia and Canada. *Arch Dis Child*. 2022;107(2):153–9. Available from: <https://adc-bmj.com.proxy.bib.uottawa.ca/content/107/2/153>. Cited 2025 Jan 16.
- Lee YF, Lin YH, Lin CH, Lin MC. Influenza infection during pregnancy and risk of seizures in offspring. *JAMA Netw Open*. 2024;7(9):e2434935–e2434935. Available from: <https://jamanetwork.com.proxy.bib.uottawa.ca/journals/jama-networkopen/fullarticle/2823877>. Cited 2025 Jan 16.
- Schull MJ, Azimae M, Marra M, Cartagena RG, Vermeulen MJ, Ho M, et al. ICES: Data, discovery, better health. *Int J Popul Data Sci*. 2019;4(2).
- ICES. ICES Data Dictionary. 2024. Available from: <https://datadictionary.ices.on.ca/Applications/DataDictionary/Default.aspx>. Cited 2024 Mar 12.
- Ontario Data Catalogue. Registered Persons Database (RPDB). Available from: <https://data.ontario.ca/dataset/registered-persons-database-rpdb>. Cited 2024 Apr 3.
- Canadian Institute for Health Information. CIHI Data Holdings. 2024. Available from: <https://www.cihi.ca/en/access-data-and-reports/data-holdings>. Cited 2024 Apr 5.
- van Ingen T, Matheson FI. The 2011 and 2016 iterations of the Ontario Marginalization Index: updates, consistency and a cross-sectional study of health outcome associations. *Can J Public Health*. 2022;113(2):260–71. Available from: <https://pubmed.ncbi.nlm.nih.gov.proxy.bib.uottawa.ca/34432255/>. Cited 2025 Jan 27.

23. Heaman MI, Newburn-Cook CV, Green CG, Elliott LJ, Helewa ME. Inadequate prenatal care and its association with adverse pregnancy outcomes: a comparison of indices. *BMC Pregnancy Childbirth*. 2008;1:8.
24. Villar J, Ismail LC, Victora CG, Ohuma EO, Bertino E, Altman DG, et al. International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21 st Project. 2014;384. www.thelancet.com.
25. To T, Terebessy E, Zhu J, Fong I, Liang J, Zhang K, et al. Did emergency department visits in infants and young children increase in the last decade? An Ontario, Canada study. *Pediatr Emerg Care*. 2022;38(4):E1173–8. Available from: <https://pubmed.ncbi.nlm.nih.gov.proxy.bib.uottawa.ca/34570077/>. Cited 2025 Jan 25.
26. Dean NE, Hogan JW, Schnitzer ME. Covid-19 Vaccine Effectiveness and the Test-Negative Design. *New Engl J Med*. 2021;385(15):1431–3. Available from: <http://www.nejm.org/doi/https://doi.org/10.1056/NEJMe2114651>.
27. Matheson F, Moloney G, van Ingen T. 2021 Ontario Marginalization Index: User Guide. Toronto; 2023.
28. Pawar R, Gavade V, Patil N, Mali V, Girwalkar A, Tarkasband V, et al. Neonatal multisystem inflammatory syndrome (MIS-N) associated with prenatal maternal sars-cov-2: a case series. *Children*. 2021;8(7).
29. Gosdin L, Wallace B, Lanzieri TM, Olsen M, Lewis EL, Chang DJ, et al. Six-month outcomes of infants born to people with SARS-CoV-2 in pregnancy ARTICLE. *Pediatrics*. 2022;150. Available from: . Accessed 28Dec2023. http://publications.aap.org/pediatrics/article-pdf/150/6/e2022059009/1408082/peds_2022059009.pdf
30. Halasa NB, Olson SM, Staat MA, Newhams MM, Price AM, Pannaraj PS, et al. Maternal vaccination and risk of hospitalization for Covid-19 among infants. *N Engl J Med*. 2022;387(2):109–19.
31. Jorgensen SCJ, Drover SSM, Fell DB, Austin PC, D'Souza R, Guttman A, et al. Newborn and early infant outcomes following maternal COVID-19 vaccination during pregnancy. *JAMA Pediatr*. 2023;177(12):1314–23.
32. Mulkey SB, Williams ME, Jadeed N, Zhang A, Israel S, DeBiasi RL. Neurodevelopment in infants with antenatal or early neonatal exposure to SARS-CoV-2. *Early Hum Dev*. 2022;1:175.
33. Cheng Y, Teng H, Xiao Y, Yao M, Yin J, Sun G. Impact of SARS-CoV-2 infection during pregnancy on infant neurobehavioral development: a case-control study. *Front Pediatr*. 2021;2(9):1393.
34. Wu T, Chen L, Wang Y, Shi H, Niu J, Yin X, et al. Effects of SARS-CoV-2 infection during late pregnancy on early childhood development: a prospective cohort study. 2021. Available from: www.frontiersin.org.
35. Edlow AG, Castro VM, Shook LL, Kaimal AJ, Perlis RH. Neurodevelopmental outcomes at 1 year in infants of mothers who tested positive for SARS-CoV-2 during pregnancy. *JAMA Netw Open*. 2022;5(6):e2215787–e2215787. Available from: <https://jamanetwork-com.qe2a-proxy.mun.ca/journals/jamanetworkopen/fullarticle/2793178>. Cited 2022 Sep 4.
36. Shuffrey LC, Firestein MR, Kyle MH, Fields A, Alcántara C, Amso D, et al. Association of birth during the COVID-19 pandemic with neurodevelopmental status at 6 months in infants with and without in utero exposure to maternal SARS-CoV-2 infection. *JAMA Pediatr*. 2022;176(6):e215563.
37. Hessami K, Norooznezhad AH, Monteiro S, Barrozo ER, Abdolmaleki AS, Arian SE, et al. COVID-19 pandemic and infant neurodevelopmental impairment: a systematic review and meta-analysis. *JAMA Netw Open*. 2022;5:E2238941 American Medical Association.
38. Schrag SJ, Verani JR, Dixon BE, Page JM, Butterfield KA, Gaglani M, et al. Estimation of COVID-19 mRNA vaccine effectiveness against medically attended COVID-19 in pregnancy during periods of Delta and Omicron variant predominance in the United States. *JAMA Netw Open*. 2022. <https://doi.org/10.1001/jamanetworkopen.2022.33273>.
39. Statistics Canada. Births, 2020. 2021. Available from: <https://www150.statcan.gc.ca/n1/daily-quotidien/210928/dq210928d-eng.htm>. Cited 2025 Jan 15.

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