BMJ Open

Investigating service delivery and perinatal outcomes during the low prevalence first year of COVID-19 in a multiethnic Australian population: a cohort study

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ABSTRACT

Objective Investigate the impact of the COVID-19 pandemic on perinatal outcomes in an Australian high migrant and low COVID-19 prevalent population to identify if COVID-19 driven health service changes and societal influences impact obstetric and perinatal outcomes.

Design Retrospective cohort study with pre COVID-19 period 1 January 2018–31 January 2020, and first year of global COVID-19 period 1 February 2020–31 January 2021. Multivariate logistic regression analysis was conducted adjusting for confounders including age, area-level socioeconomic status, gestation, parity, ethnicity and body mass index.

Setting Obstetric population attending three public hospitals including a major tertiary referral centre in Western Sydney, Australia.

Participants Women who delivered with singleton pregnancies over 20 weeks gestation. Ethnically diverse women, 66% overseas born. There were 34 103 births in the district that met inclusion criteria: before COVID-19 n=23 722, during COVID-19 n=10 381.

Main outcome measures Induction of labour, caesarean section delivery, iatrogenic and spontaneous preterm birth, small for gestational age (SGA), composite neonatal adverse outcome and full breastfeeding at hospital discharge.

Results During the first year of COVID-19, there was no change for induction of labour (adjusted OR, aOR 0.97; 95% CI 0.92 to 1.02, p=0.26) and a 25% increase in caesarean section births (aOR 1.25; 95% CI 1.19 to 1.32, p<0.001). During the COVID-19 period, we found no change in iatrogenic preterm births (aOR 0.94; 95% CI 0.80 to 1.09) but a 15% reduction in spontaneous preterm birth (aOR 0.85; 95% CI 0.75 to 0.97, p=0.02) and a 10% reduction in SGA infants at birth (aOR 0.90; 95% CI 0.82 to 0.99, p=0.02). Composite adverse neonatal outcomes were marginally higher (aOR 1.08; 95% CI 1.00 to 1.15, p=0.04) and full breastfeeding rates at hospital discharge reduced by 15% (aOR 0.85; 95% CI 0.80 to 0.90, p<0.001).

Conclusion Despite a low prevalence of COVID-19, both positive and adverse obstetric outcomes were observed

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The analysis provides the opportunity to evaluate the indirect effects of COVID-19 against a background of low COVID-19 prevalence in the local health district with a total of six women with COVID-19 during pregnancy for the study period.

⇒ The cohort comprised a large ethnically diverse population with similar exposure of restriction experience and service delivery changes.

⇒ Analysis for both iatrogenic and spontaneous preterm birth.

⇒ Missing some COVID-19-related confounders is a limitation such as physical activity levels, prevalence of pregnancy population working from home or missing planned overseas social support due to international border restrictions.

⇒ A limitation of the study is multiple outcomes were compared, however, our results are consistent with several other studies in different populations increasing the veracity of our findings.

that may be related to changes in service delivery and interaction with healthcare providers. Further research is suggested to understand the drivers for these changes.

INTRODUCTION

In the beginning of 2020, non-pharmaceutical interventions to reduce the spread of COVID-19 led to great changes in society such as lockdowns, enforced movement and travel restrictions.[1 2] There were also many changes to medical and maternity care around the world that are well documented, impacting direct care and social support.[3–6] Initial concerns of the impact of COVID-19 infection on pregnant women focused research on pregnancy outcomes for women who were infected and results varied, findings included increased COVID-19 infection

risk in ethnic minorities, and a rise in both preterm and caesarean births.[7–10] More recently perinatal research has assessed the indirect impact of the pandemic,[11] particularly the impact of lockdowns.[12–14] Indirect impact will vary significantly between countries and within country due to diverse drivers such as lockdown experiences, social distancing measures, COVID-19 prevalence, societal compliance, economic and healthcare access.[4 6 15]

Studies of the indirect effects of COVID-19 on pregnancy outcome have shown inconsistent results. A reduction in preterm birth in the general population during the pandemic has been reported by some authors but not others.[12 16–18] Differences in study design and other factors have led some authors to conclude that there is insufficient evidence to determine if preterm birth has been reduced during COVID-19.[19]

Maternity care in Australia during the first year of the pandemic in 2020 experienced a disparate range of changes from very little to significant alterations in service delivery, dependent on population and perceived risk in the community.[3 20] Little evidence exists for the impact of societal and service changes on a culturally diverse obstetric population who initially experienced minimal COVID-19 community transmission, a short lockdown period but experienced significant obstetric service and societal changes due to the pandemic.

In our study population, we hypothesise obstetric outcomes may have been impacted by the rapid changes in hospital service delivery as they shifted focus during the pandemic from patient-centred care to preservation of service and staff.[21] Western Sydney with its multicultural population is an ideal environment to examine the indirect effects of the response to the pandemic on perinatal outcomes given the setting of low COVID-19 case numbers. There was a total of 632 cases recorded of COVID-19 in the local health district for the study period. However, considerable preventative measures were implemented in the region including access to telehealth, ability to work from home, restrictions in healthcare settings such as mask wearing and health-screening questions on entry to all hospitals.[22]

We aim to identify indirect and pandemic-related morbidity in our large multiethnic Australian population and uncover potential drivers for both improved and adverse maternity care outcomes.

METHODS

We conducted a retrospective cohort study using routinely collected obstetric, medical and administrative data for women seeking antenatal care in the Western Sydney Local Health District. We compared birth outcomes greater than or equal to 20 weeks of gestation in the 2 years prior to the COVID-19 pandemic to the first year of the COVID-19 pandemic. The study period is defined as pre-COVID-19 1 January 2018–31 January 2020 to the first twelve months of the COVID-19 pandemic 1 February 2020–31st January 2021.

The state of New South Wales (NSW) has a population of approximately 8.2 million.[23] The three study hospitals serve a health district population of approximately one million people. For the study period, a total of 39 pregnant women had a confirmed COVID-19 diagnosis in NSW, six of these were in the study health district and none of these were admitted to hospital for COVID-19 complications. There were fewer than 60 COVID-19 related deaths recorded for the total population in NSW in the first year.[24] The prevalence of COVID-19 in the local community was also low (total 632 cases online supplemental figure 1).[25]

The study period was determined by the time when public awareness grew in NSW of the impending pandemic with official government announcements and a sharp rise and dominance of media coverage concerning COVID-19 from early February 2020.[26] The study period was after 30 January 2020 WHO announcement declaring COVID-19 as a public health emergency of international concern.[27] Public health order restrictions commenced on 16 March 2020 with restrictions on gathering of over 500 people in NSW to reduce the spread of COVID-19. The restrictions escalated on 30 March 2020, to 'hard lockdown' issuing of public health orders 'that a person must not, without reasonable excuse, leave the person's place of residence'.[27] The restrictions were present for approximately 7 weeks easing on 15 May 2020.

The short hard lockdown in NSW, was primarily enforced in greater Sydney, accompanied by increased restrictions and COVID-safe practices including all health facilities women and their families accessed. The restrictions for local maternity services included hospital entrance screening of all patients, staff and visitors including temperature checks, asking about recent travel and symptoms of COVID-19. Within the antenatal service, there was also an introduction of telehealth for the diabetes in pregnancy clinics, restrictions on visitors such as allowing only patients in waiting rooms, no support person during ultrasound and only one support person with no changing-over in the birth unit. The potential changes in background stress for women during the peripartum due to these restrictions, reduced social support and service delivery changes may potentially impact perinatal outcomes.[28] During this time, there were frequent changes to service delivery and some confusion regarding rules for patients reported by staff at the tertiary referral study Hospital.[21]

Women in the public health sector in NSW are triaged to their nearest public hospital for pregnancy care according to their home address and pregnancy complications. Therefore, during the pandemic period there would be limited changes in referrals pathways for the district obstetric population.

Community activities returned to near normal by July 2020 in NSW, however international and state borders continued to be disrupted with ongoing outbreaks emerging. Restrictions to visitors and other COVID-19 risk mitigation policies remained present for the maternity

services throughout the study period. COVID-19 vaccinations were not available in Australia during the study period.

Definitions

Routinely collected maternity data for singleton pregnancies greater than 20 weeks gestation was retrieved from the electronic maternal database. Terminations of pregnancy were not included in the database. Gestational age was determined and calculated in the electronic maternity system utilising the rules: use of last menstrual period (LMP) if regular, date was amended after available early ultrasound 6 weeks–13+6 weeks gestation. If ultrasound dating varies from LMP by more than 5 days, if irregular or uncertain LMP then ultrasound expected date of delivery was used.

Area-level socioeconomic status (SES) in our study was derived from the postcode address of participants during pregnancy as determined for that area by the last Australian census information (2016), informing the Index of Relative Socioeconomic Disadvantage. The index is based on households in that area using information on variables that include income, English fluency, education and employment status. A lower index score represents greater disadvantage.[29]

Outcomes of interest

Outcomes of interest were selected based on literature review, state obstetric benchmarking outcomes and outcomes that plausibly may be impacted by service delivery changes. Literature has reported criteria changes in some healthcare setting for induction of labour and overall induction rates changing, therefore, we included any induction via any method at all gestations in our outcomes of interest. We defined all vaginal births as one outcome inclusive of breech vaginal births. All preterm births were defined as less than 37 weeks gestation. Spontaneous preterm was defined as vaginal preterm births without an induction or caesarean section preterm births with a history of preterm labour. Iatrogenic preterm births were those initiated by care providers, defined as either a planned caesarean section with no preterm labour or an induction prior to 37 weeks gestation. Small for gestational age (SGA) is birth weight less than 10th centile assessed by the Fenton growth chart.[30] Combined adverse neonatal outcome included any of the following; stillbirth, admission to special care/neonatal intensive care unit (NICU), Apgar score under 7 at 5 min, or newborn resuscitation with intubation.

Data analysis and statistical methods

Demographic and obstetric characteristics of women were compared before and during the first year of COVID-19 using the χ^2, Fisher's exact or t-test where appropriate. Univariate logistic regression was applied to each characteristic to estimate unadjusted ORs. Then, three adjusted models were devised and implemented using multivariate logistic regression. Model 1 was for maternal characteristics and adjusted for maternal age, area-level SES, gestational age (except for the preterm birth outcome), parity, ethnicity, body mass index, smoking status and mental health status. Model 2 adjusted for model of pregnancy care and the variables from model 1. Model 3 adjusted for additional covariates that are clinically relevant for specific outcomes. For the caesarean section birth outcome, birth weight and induction of labour were added to the covariates from Models 1 and 2. For the preterm birth outcome, a composite gestational diabetes/hypertension variable was added to the covariates from models 1 and 2. For the breastfeeding outcome, mode of delivery, length of stay <24 hours, and preterm birth were added to the covariates from models 1 and 2. For each model, an adjusted OR (aOR) with a 95% CI was reported. P values less than 0.05 were considered statistically significant. The cohort was restricted to records with complete data on outcomes of interest. Missing indicator variables were utilised for covariates in the multivariate analyses. All statistical analyses were completed using Stata Special Edition V.14.2 (StataCorp).

Patient public involvement statement

This retrospective cohort study had no patient public involve in the design or analysis or dissemination of results.

RESULTS

Baseline characteristics

The pre-COVID-19 period had a total of 23 722 singleton births and during the first year of COVID-19 (period 1 February 2020–31 January 2021) there were 10 381 singleton births. The principle tertiary referral centre had the greatest number of births in the cohort (n=17 005; 49.9%), with the large secondary hospital comprising of 36.6% (n=12 467) of the cohort.

Women who birthed in the first year of COVID-19 were more likely to be Australian born (35.1% vs 32.9%), overweight or obese (45.8% vs 44.5%), under 35 years old (59.7% vs 50.6%), have a history of a mental illness (15% vs 13%), to present for their first comprehensive antenatal visit at <10 weeks gestation (80.8% vs 64.4%) and less likely to be privately insured (5.9% vs 6.9%) compared with the preceding 2 years (table 1). Women were admitted antenatally less often (10.1% vs 12.1%) and women who elected to have an early discharge postpartum at <24 hours, were higher from 15.5% during the pre-COVID period to 19.1% in the first year of COVID-19. Other demographic and pregnancy characteristics are documented in table 1.

Pregnancy complications and outcomes

There were no differences in overall median gestation age at birth between the two time periods (table 2). We did observe that the rate of preterm birth was lower during COVID-19 compared with the preceding period (7.2% vs 8.1%). We also observed a higher proportion of

Table 1 Women with a singleton pregnancy: maternal demographic characteristics and pregnancy outcomes first year of COVID-19 compared with pre-COVID in a NSW metropolitan health district

Characteristics	Pre-COVID-19 n=23 722, N (%)	COVID-19 n=10 381, N (%)	P value
Clinical and demographic characteristics			
Maternal age group years			
<20	38 (0.2)	46 (0.4)	<0.001
20–24	614 (2.6)	452 (3.1)	
25–34	11 335 (47.8)	5 835 (56.2)	
35–39	8 939 (37.7)	3 335 (32.1)	
>39	2 796 (11.8)	713 (6.9)	
Ethnicity			
South Asian	6047 (25.5)	2 950 (28.4)	<0.001
Caucasian/European	3 307 (13.9)	1 886 (18.1)	
South-East Asian	3249 (13.7)	1 357 (13.1)	
Middle Eastern	8116 (34.2)	3827 (36.9)	
Aboriginal Torres Strait Islander	338 (1.4)	188 (1.8)	
Unknown/missing*	2665 (11.2)	173 (1.7)	
Australian born	7 809 (32.9)	3 648 (35.1)	<0.001
SES disadvantage			
Quintile 1 (most disadvantaged)	5 367 (22.7)	2 361 (22.8)	0.04
Quintile 2	5 721 (24.1)	2 568 (24.8)	
Quintile 3	3 508 (14.8)	1 494 (14.4)	
Quintile 4	3 291 (13.9)	1 528 (14.7)	
Quintile 5 (least disadvantaged)	5 809 (24.6)	2 416 (23.3)	
BMI (kg/m^2) at booking			
<18.50	1 116 (4.7)	417 (4.5)	0.02
18.5–24.9	11 981 (50.5)	5 207 (50.2)	
25.0–29.9	6 317 (26.3)	2 875 (27.3)	
≥30.0	4 308 (18.2)	1 922 (18.5)	
Nulliparous	10 331 (43.6)	4 475 (43.1)	0.45
Assisted conception	1 050 (4.4)	471 (4.5)	0.65
Current smoking at booking	1 380 (5.8)	619 (6.0)	0.60
Disclosed domestic violence	340 (1.5)	141 (1.5)	0.69
Diagnosed mental illness	3 083 (13.0)	1 552 (15.0)	<0.001
History of hypertension	844 (3.6)	327 (3.2)	0.06
History of diabetes (T1DM, T2DM)	265 (1.3)	114 (1.3)	0.93
History of gestational diabetes	1555 (6.6)	738 (7.1)	0.06
Health service characteristics			
<10 weeks gestation first comprehensive assessment	15 221 (64.4)	8360 (80.8)	<0.001
Model of care			
Low-risk hospital	15 210 (64.1)	6768 (65.2)	<0.01
Hospital complex medical	6 775 (28.6)	3096 (29.4)	
Private maternity	1 635 (6.9)	611 (5.9)	
No antenatal care	102 (0.4)	38 (0.4)	
Antenatal admission to hospital	2 863 (12.1)	1 044 (10.1)	<0.001
Postnatal maternal length of stay <one day	3 674 (15.5)	2 000 (19.1)	<0.001

Continued

Table 1 Continued

Characteristics	Pre-COVID-19 n=23 722, N (%)	COVID-19 n=10 381, N (%)	P value
Postnatal maternal length of stay (days, median IQR)	2.02 (1.51)	2.00 (1.68)	<0.001

Pre-COVID-19=1 January 2018–31 January 2020, COVID-19 = 1 February 2020–31 January 2021.
Low-risk hospital: Midwifery care and shared antenatal care (general Practitioner/family doctor); Hospital complex medical care: Hospital based medical and high-risk clinic; Private maternity care: obstetrician and privately practicing midwife.
T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus
*Missing due to ethnicity as routine collection introduced mid-2018.
BMI, body mass index; NSW, New South Wales; SES, Socio Economic Status (Index of Relative Socio-economic Disadvantage); T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

births at or after 41 weeks gestation during the first year of COVID-19 (10.0% vs 9.0%). We identified a reduction in all vaginal births (66.6% vs 69.6%) including reduced vaginal breech births (0.7% vs 0.9%). This corresponded with the caesarean section rate increasing during the first year of the COVID-19 pandemic (33.4% vs 30.5%)

Table 2 Pregnancy outcomes in a low-prevalence COVID-19 high-migrant Australian urban population

Pregnancy complications	Pre-COVID-19 N=23 722, N (%)	COVID-19 n=10 381, N (%)	P value
Timing of birth			
Gestational age (weeks) median (IQR)	39.2 (1.8)	39.2 (1.8)	0.25
<28 weeks	301 (1.3)	128 (1.2)	<0.001
28–32 weeks	232 (1.0)	84 (0.8)	
<37 weeks	1439 (6.1)	539 (5.2)	
37+weeks	21 748 (91.7)	9630 (92.8)	
Mode of delivery			
Vaginal birth	13 931 (58.8)	5819 (56.1)	<0.001
Instrumental	2340 (9.9)	1016 (9.8)	
Vaginal breech	204 (0.9)	76 (0.7)	
Caesarean section	7224 (30.5)	3465 (33.4)	
Onset of labour			
Induction	7095 (29.9)	3666 (35.3)	<0.001
Birth weight			
Appropriate for gestational age	20 071 (85.1)	28 884 (85.5)	0.39
Large for gestational age	1676 (7.1)	784 (7.6)	0.11
Small for gestational age	1832 (7.8)	713 (6.9)	0.01
Adverse birth outcomes			
Stillbirth	227 (1.0)	95 (0.9)	0.71
Apgar<7 at 5 min	662 (2.8)	257 (2.5)	0.10
Intubation resuscitation at birth	262 (1.1)	100 (1.0)	0.24
Admission to NICU	3851 (16.2)	1743 (16.8)	0.23
Composite adverse neonatal	4261 (18.2)	1907 (18.3)	0.41
Neonatal feeding			
Skin to skin at birth	16 454 (69.4)	7961 (76.7)	0.02
Feeding within 1 hour	14 353 (60.5)	6424 (61.9)	0.02
Fully breastfeeding at discharge	15 620 (65.8)	6410 (62.1)	<0.001

Pre-COVID=1 January 2018–31 January 2020, COVID-19 =1 February 2020–31 January 2021.
Composite adverse neonatal includes any: stillbirth, admission to NICU, Apgar score under 7 at 5 min, or newborn resuscitation with intubation.
NICU, neonatal intensive care unit.

(table 2). There was an overall higher rate of induction of labour (35.3% vs 29.9%) and a lower rate of SGA births (6.9% vs 7.8%). We found no change for adverse birth outcomes including for stillbirth (0.9% vs 1.0%) or admissions to special care/NICU (16.8% vs 16.2%) (table 2).

In adjusted analysis, no difference was identified for labour inductions during the COVID-19 period compared with the pre-COVID period (aOR 0.97; 95% CI 0.92 to 1.02). There was a 25% increase in caesarean section births during the pandemic first year in our health district (aOR 1.25; 95% CI 1.19 to 1.32) (table 3). The rate of spontaneous preterm births was reduced by 15% (aOR 0.85; 95% CI 0.78 to 0.95) and no change was found for iatrogenic preterm births (aOR 0.94; 95% CI 0.80 to 1.09) (table 3). Adjusted models also uncovered a 10% reduction for SGA infants at birth during the COVID-19 period (aOR 0.90; 95% CI 0.82 to 0.99). We found a marginal increase for a combined adverse neonatal outcome during the COVID-19 period (aOR 1.08; 95% CI 1.00 to 1.15) (table 3).

In our study population, the first year of the pandemic impacted breastfeeding when compared with the previous 2 years. When adjusted for several confounders including birth weight, mode of delivery, and prematurity, we found a 15% reduction for women fully breastfeeding their infant at discharge (aOR 0.85; 95% CI 0.80 to 0.90) (table 3). There was no difference in effect size between model 1 and the fully adjusted model that included birth weight, mode of delivery, length of stay <24 hours and gestational age/preterm variable. Notably, there was a higher rate during the COVID-19 period in both breast-feeding within 1 hour (61.9% vs 60.5%, p=0.02) after birth and maternal/infant skin to skin contact at birth (76.7% vs 69.4%, p=0.02) (table 2).

DISCUSSION

In a health district with low COVID-19 prevalence but affected by public health measures and process changes to service delivery, we found no differences in the rate of induction of labour, a reduction in spontaneous preterm and SGA births with no change in iatrogenic preterm births during the first year of COVID-19. There was also a significant increase in caesarean section births and a reduction in women fully breastfeeding at hospital discharge during this period compared with the previous 2 years. We identified a marginal increase in the rate of severe adverse neonatal composite outcome. In the study population, only six women were recorded to have experienced COVID-19 infection during pregnancy, therefore, the outcome changes identified in this study are likely related to the indirect effects of COVID-19.

A strength of the study is the population experienced similar exposure to COVID-19 restrictions and maternity care service delivery changes. The multiethnic population with an even distribution between national SES quintiles strengthens the generalisability of our findings to other high-income populations with universal health coverage such as the UK. A more homogeneous population may provide a possible explanation of changes to be specific cultural drivers however the diversity of the study population supports the explanation to likely be societal and service delivery related. A limitation is the difficulty of identifying all changing population drivers, however, adjustment was made for known factors.

There may have been other confounders we were not able to capture that may impact on obstetric outcomes such as level of physical activity. Potentially some women may have benefited from more time to exercise with associated reduced infection risk through exercise-mediated protective immune response,[31] while other women who felt unwell may have had the opportunity to rest at home. There may potentially be a uniquely cumulative improved immune environment for pregnant women during the COVID-19 period. Underlying factors such as consistent diet stabilising the microbiome and less maternal inflammatory triggers or burden from exposure to environmental and infectious factors may be the reason for improved spontaneous preterm birth rate and SGA outcomes.

It is difficult to capture individual responses to the threat of COVID-19 despite low prevalence in the community for this cohort. However, recent qualitative research at one study hospital found clinicians felt some groups of women benefited from the COVID-19 restrictions with less stress and protected family time. However, migrant women were seen to have experienced isolation and anxiety due to loss of significant practical and social support from overseas relatives unable to visit due to COVID-19-related international border closures.[21 32] The impact of the loss of expected support from relatives due to COVID-19 travel restrictions was not measured in our study and is a limitation.

Similar to other studies, we document a reduction in preterm birth.[12 17 18 33] The lack of delineation between iatrogenic and spontaneous preterm birth in some research has been an issue when comparing results and attempts to identify potential drivers.[19] A strength of our study is we were able to present the data and identified that only spontaneous preterm birth was reduced for the study period. However, recent updated preterm birth meta-analysis by Yang *et al* found in unadjusted analysis preterm birth was reduced for both spontaneous and iatrogenic only in single centre studies, but not in national studies.[6] Local district level data and population characteristics may have less variation in obstetric service delivery confounders and other factors that increase the uniformity of experience for women and may account for the difference between large national level data and some single centre research. Local, more granular data for obstetric outcomes during the COVID-19 pandemic may assist in understanding drivers for improved and adverse obstetric outcomes. The stable iatrogenic preterm birth rate is a positive finding and reflects no change in clinical management for this important obstetric outcome. This may partly be associated with the ongoing understanding

Table 3 OR for maternal and neonatal pregnancy outcomes during the first year of COVID-19 compared with the previous 2 years in an Australian metropolitan health district

Outcome	Sample size	Unadj. OR	P value	Model 1 OR	P value	Model 2 OR	P value	Model 3 OR	P value
Induction of labour	34 082	0.90 (0.86,0.94)	<0.001	0.97 (0.92,1.02)	0.30	0.97 (0.92,1.02)	0.26	–	–
Caesarean birth	34 063	1.14 (1.09,1.20)	<0.001	1.24 (1.17,1.30)	<0.001	1.23 (1.17,1.30)	<0.001	1.25 (1.19,1.32)	<0.001
Preterm birth	34 080	0.86 (0.79,0.94)	0.00	0.91 (0.83,0.99)	0.05	0.91 (0.83,0.99)	0.03	0.88 (0.80,0.97)	0.01
Spontaneous preterm birth	34 080	0.76 (0.67,0.85)	<0.001	0.88 (0.77,0.99)	0.04	0.88 (0.77,0.99)	0.04	0.85 (0.75,0.97)	0.02
Small for gestational age at birth	33 880	0.88 (0.81,0.96)	0.01	0.90 (0.82,0.99)	0.03	0.90 (0.82,0.99)	0.02	–	–
Composite adverse neonatal outcome	33 632	1.03 (0.97,1.09)	0.38	1.08 (1.00,1.15)	0.03	1.08 (1.00,1.15)	0.04	–	–
Full breastfeeding at hospital discharge	31 113	0.86 (0.81,0.90)	<0.001	0.85 (0.80,0.90)	<0.001	0.85 (0.81,0.90)	<0.001	0.85 (0.80,0.90)	<0.001

COVID=1 February 2020–31 January 2021 (n=10 381), pre-COVID=1 January 2018–31 January 2020 (n=23 722) .

Composite adverse neonatal includes any: stillbirth, admission to NICU, Apgar score under 7 at 5 min or newborn resuscitation with intubation.

Variables adjusted for in each model:

Model 1: Maternal characteristics: Includes maternal age, area-level socioeconomic status (Index of Relative Socio-economic Disadvantage) quintile, gestational age, parity, ethnicity, BMI (numeric), smoking status and mental health status.

Model 2: Model of care: Model 1 variables and model of pregnancy care variable.

For preterm birth outcome the models are not adjusted for gestational age.

Model 3 outcome of interest: Includes models 1 and 2 covariates and additional covariates as listed below.

Caesarean section birth: birth weight and induction of labour.

Preterm birth: composite maternal complications variable (gestational diabetes or hypertensive disorders of pregnancy).

Breastfeeding: birthweight, mode of delivery, length of stay <24 hours and gestational age/preterm.

BMI, body mass index; NICU, neonatal intensive care unit.

of the adverse outcomes associated with late preterm births and recent national initiatives such as 'every week counts' that has occurred over the study period.[34]

Shah *et al* in a Canadian population study, found no reduction in preterm births, however, they did demonstrate preterm birth variation over time and between districts.[35] Our study covers the complete first year of the pandemic, reducing the possibility of a result based on a chance normal short-term variation.

It has been postulated that the causative mechanism for a reduction in preterm births during the COVID-19 period is reduced infection and maternal physical activity throughout lockdown.[36] In our population, these potential causative factors for a reduction in spontaneous preterm birth, may have existed in our health district during the short lockdown and likely persisted beyond the lockdown period. Some infection mitigation behaviours may have been driven by our high migrant population who received advice from overseas relatives in areas experiencing high rates of COVID-19. Encouraging suitable exercise[31] and simple hygiene measures such as appropriate hand washing, are public health measures that may reduce infection. Hand hygiene historically has been poorly done and with increased awareness and compliance, may assist with decreasing preterm births.[37 38]

We found women were presenting earlier to their family doctors for a first pregnancy visit and referral to tertiary hospital care. This may have been due to anxiety about the pregnancy and the unknown risk of COVID-19 infection to a fetus. The benefits of this early health provider contact may be correct dietary advice, provide opportunity for early aspirin prescription and other pregnancy care that may contribute to some of the improved pregnancy outcomes including preterm birth and SGA for this cohort. It is possible that the drivers for the reduction of spontaneous preterm birth and SGA are similar and multifactorial. They may include the opportunity for partners and pregnant women to work from home with the associated reduction in stress.

The increase in caesarean section births in this study is a concerning finding that may indicate changes in clinical decision making during the COVID-19 period of a lower threshold trigger for immediate delivery. However, other factors may also be involved such as less surveillance during pregnancy with maternal reluctance to present or be in hospitals as demonstrated by the increase in early discharge. Another human factor that may be involved in the rise in caesarean section birth is the difficulty of midwives in birth unit to develop a rapport with the women in their care to adequately assess their non-verbal cues, recent studies have identified midwives report a loss of 'women-centred care' during the COVID-19 pandemic.[20 21] Clinician may rely more on electronic 'socially distant' continuous cardiotocography (CTG) monitoring for fetal assessment. Evidence suggests increased CTG monitoring leads to higher caesarean section rates.[39 40] The increase in caesarean section births also have known immediate and long-term

associated morbidity for women and their infants, therefore measures to counter the rise in caesarean births are recommended.[41]

There was a marginal increase in the composite adverse neonatal outcome largely driven by the increase in neonatal admissions. Although it is beyond the scope of this study to determine the causes for the increased admission, there was no alteration in admission criteria for the neonatal or special care nursery during the study period. However, the increase in caesarean birth may have contributed through the associated known increased risk of NICU admission with a caesarean section birth.[41 42]

Similar to our study, a prospective Italian study found a 28% reduction in full breastfeeding at discharge in a region with high COVID-19 prevalence.[43] We identified that during the COVID-19 period there was an improvement in practices that support breastfeeding immediately after birth; maternal-infant skin to skin contact and breastfeeding within the first hour. Birth unit protocols changed during the COVID-19 period, with only one support person allowed at the birth. The improvement in skin to skin and breastfeeding in the first hour may potentially be due to midwives identifying that woman were feeling more isolated and provided more one-to one support in the birth room improving these important breastfeeding outcomes. There may be several factors that contribute to less exclusive breastfeeding at discharge in our study. Intuitively the reduction in breastfeeding should be linked with the increase in early discharge however the 25% reduction in full breastfeeding was present for both model 2 and the final model that adjusted for variables including early discharge. Other factors are therefore more likely influencing this outcome. Due to reduced visitors, women may have felt they needed to bring formula into the hospital in case they had difficulty with breastfeeding, therefore it was available and more likely to be used. There may also have been reduced opportunities for staff to provide postnatal breastfeeding support due to concerns of COVID-19 infection risk by both staff and patients, staffing shortages and increased staff workload during the COVID-19 period. It is well acknowledged the introduction of formula and bottle feeding in the early postnatal period has significant consequences for infant long-term health and reduces total length of breastfeeding.[44–46] Providing adequate lactation support antenatally, at birth and postnatally with staff shortages during the pandemic is problematic but important for both short-term and long-term metabolic maternal and infant health.[44 47 48]

Although recent literature has focused on the impact of COVID-19 disease and pregnancy, the indirect impact of the worldwide pandemic may not be fully realised for many years. There is increasing evidence of the impact of exposure to disasters including pandemics, on long-term health consequences. A recent systematic review concluded fetal and maternal exposure to natural disasters including pandemics resulted in increased cardiometabolic risk in both.[49] Understanding a pandemic population with a low

prevalence of COVID-19 but subject to changes in maternity care and societal stress, may assist in future investigations of drivers for cardiometabolic health.

CONCLUSIONS

In a low COVID-19 prevalent population, this study found no change in inductions of labour or iatrogenic preterm births. However, an increase in caesarean section births, a reduction in SGA and spontaneous preterm births was identified. The benefit to women, their families and the community of reduced SGA and preterm birth is long-lasting, including improved cardiometobolic lifetime risk for both women and their infants.[42] The drivers for these changes in perinatal outcomes during the COVID-19 first year may be difficult to identify but may be a reduction in maternal inflammatory triggers. However, the results from this study in a cohort primarily exposed only to COVID-19-related service and societal changes, provides unique opportunity to generate evidence of these changes on pregnancy complications. The significant reduction in breastfeeding at discharge may be more easily addressed now identified. Funding appropriate intervention strategies is imperative both in the antenatal and postnatal periods to improve breastfeeding outcomes. Revealing all drivers for obstetric changes during the pandemic may be difficult to ascertain, further research in this high migrant cohort with higher prevalence of COVID-19 cases may reveal evidence for more specific drivers.

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