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Widespread implementation of a low-cost telehealth service in the delivery of antenatal care during the COVID-19 pandemic: an interrupted time-series analysis



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Summary

Background Little evidence is available on the use of telehealth for antenatal care. In response to the COVID-19 pandemic, we developed and implemented a new antenatal care schedule integrating telehealth across all models of pregnancy care. To inform this clinical initiative, we aimed to assess the effectiveness and safety of telehealth in antenatal care.

Methods We analysed routinely collected health data on all women giving birth at Monash Health, a large health service in Victoria (Australia), using an interrupted time-series design. We assessed the impact of telehealth integration into antenatal care from March 23, 2020, across low-risk and high-risk care models. Allowing a 1-month implementation period from March 23, 2020, we compared the first 3 months of telehealth integrated care delivered between April 20 and July 26, 2020, with conventional care delivered between Jan 1, 2018, and March 22, 2020. The primary outcomes were detection and outcomes of fetal growth restriction, pre-eclampsia, and gestational diabetes. Secondary outcomes were stillbirth, neonatal intensive care unit admission, and preterm birth (birth before 37 weeks' gestation).

Findings Between Jan 1, 2018, and March 22, 2020, 20 031 women gave birth at Monash Health during the conventional care period and 2292 women gave birth during the telehealth integrated care period. Of 20 154 antenatal consultations provided in the integrated care period, 10 731 (53%) were delivered via telehealth. Overall, compared with the conventional care period, no significant differences were identified in the integrated care period with regard to the number of babies with fetal growth restriction (birthweight below the 3rd percentile; 2% in the integrated care period vs 2% in the conventional care period, $p=0.72$, for low-risk care models; 5% in the integrated care period vs 5% in the conventional care period, $p=0.50$ for high-risk care models), number of stillbirths (1% vs 1%, $p=0.79$; 2% vs 2%, $p=0.70$), or pregnancies complicated by pre-eclampsia (3% vs 3%, $p=0.70$; 9% vs 7%, $p=0.15$), or gestational diabetes (22% vs 22%, $p=0.89$; 30% vs 26%, $p=0.06$). Interrupted time-series analysis showed a significant reduction in preterm birth among women in high-risk models (-0.68% change in incidence per week [95% CI -1.37 to -0.002]; $p=0.049$), but no significant differences were identified in other outcome measures for low-risk or high-risk care models after telehealth integration compared with conventional care.

Interpretation Telehealth integrated antenatal care enabled the reduction of in-person consultations by 50% without compromising pregnancy outcomes. This care model can help to minimise in-person interactions during the COVID-19 pandemic, but should also be considered in post-pandemic health-care models.

Funding None.

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Introduction

In March, 2020, health-care systems around the world had to rapidly adjust to cope in response to the COVID-19 pandemic. Services for many subacute aspects of health care were cancelled or completely shifted to telehealth for care delivery; however, maternity care presented a unique challenge, since it cannot be cancelled nor converted to a completely digital format. In Australia, the antenatal care schedule has remained largely unchanged since introduction by the UK Government in 1929,¹ with the majority of antenatal appointments occurring within the hospital environment, where up to 96% of women in Australia give birth.² In response to concerns that hospitals

would be overwhelmed by COVID-19 cases, antenatal care delivery had to be adapted to protect pregnant women and staff from unnecessary exposure to SARS-CoV-2.

On March 13, 2020, the Australian Government announced a temporary change in public health funding through the Medicare Benefits Schedule to support telehealth use in health-care delivery. Telehealth models have previously been implemented in high-cost settings that have extensive technological infrastructure and support systems in place, or in specific patient groups who live remote to specialist care.^{3,4}

Little evidence is available on telehealth use in antenatal care delivery;^{3,5} thus, in response to the COVID-19

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Research in context

Evidence before this study

Telehealth has been implemented for the provision of pregnancy care in high-income, low-income and, middle-income countries. We searched PubMed and Ovid databases from database inception to March, 2020, for articles published in English, using the search terms “telehealth” OR “telemedicine” AND “pregnancy” OR “antenatal care” OR “obstetrics” OR “maternity”. Studies or reviews that focused specifically on the use of telehealth or telemedicine for the delivery of routine antenatal care were identified from abstract review. A 2020 systematic review found that targeted telehealth interventions have been associated with improved pregnancy outcomes, such as smoking cessation and higher breastfeeding rates. The use of telehealth interventions has also been associated with a reduced number of unplanned in-person visits in high-risk pregnancies, while maintaining similar pregnancy outcomes. This review identified 19 studies done in low-risk pregnancies (n=6827) and 13 studies in high-risk pregnancies (n=1514); however, the majority of included studies focused on targeted use of telehealth, such as for smoking cessation, health and wellbeing in pregnancy, influenza vaccinations, or diabetes management. Three studies were done in high-risk pregnancies alone (n=353) that assessed the use of telehealth to minimise in-person antenatal attendances. All three studies engaged considerable infrastructure comprised of web-based support tools for the management of blood sugar levels in gestational diabetes, or remote monitoring devices, such as blood glucose meters, blood pressure monitors, and pulse oximetry monitors. The use of these tools across the three studies was associated with a reduction in the number of unscheduled visits. None of the included studies specifically assessed the virtual delivery of routine antenatal care using telehealth. However, virtual obstetric services have been developed, predominately within the USA. Although evidence from these programmes indicate that women provided with virtual care had similar pregnancy

outcomes to those given conventional care and patient satisfaction with virtual care is good, these models often incorporated additional technological infrastructure to support home monitoring and were used in small patient populations.

Added value of this study

The widespread integration of telehealth into the delivery of antenatal care for both low-risk and high-risk pregnancy care models is achievable. To our knowledge, this is the first low-cost model of telehealth integrated antenatal care. We found that telehealth integrated antenatal care was achievable in a publicly funded health-care system. Rapid replacement of around 50% of in-person antenatal consultations with virtual telehealth visits was not associated with a change in adverse pregnancy outcomes or complications when compared with conventional antenatal care. Although the motivation for this change in care was driven by the COVID-19 pandemic, pregnancy outcomes were not influenced directly by COVID-19 in pregnancy since no COVID-19 cases were reported in our study population during the study period.

Implications of all the available evidence

Telehealth can be incorporated into antenatal care delivery for both low-risk and high-risk pregnancies, not only for targeted strategies such as diabetes management and smoking cessation, but also for routine antenatal care visits. Our findings indicate that antenatal care delivered using telehealth is likely to result in the same or improved outcomes when compared with conventionally delivered care; thus, future research is needed to ensure these findings are maintained over a longer period and after the COVID-19 pandemic. Existing literature indicates that telehealth applications are associated with a high level of patient satisfaction. Although this model of care will assist with the development of resilient, personalised health systems, the cost-effectiveness of telehealth in antenatal care remains to be determined.

pandemic, in the Australian state of Victoria a large health-care network developed a new integrated antenatal care schedule incorporating telehealth for consultation delivery via voice calls or video calls across all models of pregnancy care. On March 23, 2020, this integrated antenatal care schedule was implemented across three maternity hospitals within the Victorian health-care system, with the aim of reducing in-person consultations by up to 66%, while maintaining a high standard of antenatal care.

Little evidence was available to inform this clinical initiative; thus, we aimed to assess the uptake and safety of telehealth integrated antenatal care for low-risk and high-risk pregnancies. Since physical examination is not possible during telehealth consultations, we hypothesised whether the use of telehealth integrated antenatal care might adversely impact on the ability to detect common complications of pregnancy, particularly those contingent

on physical examination, such as pre-eclampsia and fetal growth restriction.

Although this new antenatal care schedule is crucial during the current COVID-19 pandemic, evaluation of the telehealth integrated care model might assist other health services considering such a programme, particularly with the observed resurgence in COVID-19 cases in many countries. Additionally, this evaluation might guide the future use of telehealth integrated antenatal care as part of building resilient health systems better placed to withstand epidemics while providing more individualised patient care.

Methods

Study design

We used an interrupted time-series analysis to compare telehealth integrated antenatal care with conventionally delivered care on pregnancy outcomes across a large

health service in Victoria, Australia. Monash Health is the largest publicly funded maternity service in Melbourne (VIC, Australia), consisting of two secondary and one tertiary referral hospitals. Monash Health provides care for approximately 10 000 births with around 100 000 antenatal consultations done annually. This research was approved by Monash Health Human Research Ethics Committee (RES-20-0000300Q-64284); the requirement for individual participant consent was waived due to the use of de-identified data. The findings of this study were reported in accordance with the RECORD guidelines.⁶

Data sources

Births that occurred at or after 20 weeks' gestation or with a birthweight of 400 g or higher, if gestation was uncertain, between Jan 1, 2018, and July 26, 2020, were included in the analysis. Data were extracted from the Birthing Outcomes System (Melbourne Clinical and Translational Sciences, Melbourne, VIC, Australia) raw database. The Birthing Outcomes System is an electronic database used to document maternal clinical information; antenatal, intrapartum and post-partum details; and pregnancy outcomes. The routinely collected health outcome data had minimal missing data, with missing data for the following variables: birthweight (n=1 [$<1\%$]), neonatal intensive care unit (NICU) admission (n=302 [1%]), and body-mass index (BMI; n=1499 [7%]). The missing data were excluded from their respective analyses. Data on antenatal appointments and types were obtained from the Monash Health business intelligence portal. Low-risk care models included midwifery-led, shared care (with hospital and general practitioner appointments) and collaborative care (with obstetrician and midwifery appointments) models. Obstetric specialist-led care was defined as a high-risk care model.

Procedures

A multidisciplinary team of obstetric, midwifery, and general practice providers developed a telehealth integrated antenatal care schedule (figure 1). Telehealth

consultations were delivered by video call (Healthdirect Australia, Haymarket, NSW, Australia) or via telephone, on the basis of patient preference and a decision support tool (appendix). Telehealth consultations were supplemented with a suite of patient and staff information sheets, and systems to support remote blood pressure checks and fetal growth assessments. Blood pressure was self-checked on purchased automated blood pressure monitors, with local health providers, or at the time of hospital ultrasound assessments. Remote monitoring of fetal growth involved the introduction of self-measured symphyseal-fundal heights weekly from 24 weeks' gestation plotted on provided fetal growth charts supported by educational material, and ultrasound assessment of fetal growth was done in hospital according to national clinical care recommendations.^{7,8} Women were screened regularly for gestational diabetes via an oral glucose tolerance test and if positive monitored blood glucose levels during the conventional care period; endocrinology consultations were delivered via telehealth. We collected information on pregnancy outcomes following telehealth implementation between April 20 and July 26, 2020. Data were extracted from the Birthing Outcomes System raw database by the health information team, who cleaned and validated data, which was provided to investigators as an Excel spreadsheet for all births within the requested time period for all variables requested, including baseline maternal demographics, maternal age, BMI, parity, and smoking status. We also collected data on the number and type of antenatal consultations done each week. Telehealth appointments were defined as those done via telephone or videoconferencing. The number of appointments missed for in-person and telehealth appointments was also recorded.

Conventional antenatal care at Monash Health was provided in accordance with the National Health and Medical Research Council guidelines on antenatal care in uncomplicated pregnancies,⁸ which involves ten antenatal consultations delivered in person across pregnancy. Women with pregnancy complications could

See Online for appendix

Low-risk care models										
	First trimester		Second trimester		Third trimester					
Telehealth	Midwifery assessment clinic	16 weeks' gestation	22 weeks' gestation- first consultation with doctor		31 weeks' gestation	34 weeks' gestation		38 weeks' gestation		
In person				28 weeks' gestation			36 weeks' gestation		≥40 weeks' gestation	
High-risk care models										
	First trimester		Second trimester		Third trimester					
Telehealth	Midwifery assessment clinic	First consultation with doctor		22 weeks' gestation	31 weeks' gestation	34 weeks' gestation				
In person			16-18 weeks' gestation		28 weeks' gestation			36 weeks' gestation	38 weeks' gestation	≥40 weeks' gestation

Figure 1: Telehealth integrated antenatal care schedule for low-risk and high-risk models of care

have more consultations depending on clinical need. We collected information for all women who gave birth at Monash Health between Jan 1, 2018, and March 22, 2020, which was defined as the conventional care period. Integrated care incorporating telehealth was implemented on March 23, 2020. The period March 23–April 19, 2020, was defined as the implementation period. The period April 20–July 26, 2020, was defined as the integrated care period.

Outcomes

The primary outcome was the safety of telehealth integrated care compared with conventional care for the detection and management of pre-eclampsia, fetal growth restriction, and gestational diabetes.

For fetal growth restriction, singleton birthweight percentiles (<3rd and <10th percentiles) were determined using local population charts.⁹ A health service performance indicator for undiagnosed fetal growth restriction was used, defined as the proportion of babies with a birthweight below the 3rd percentile born at or after 40 weeks' gestation divided by the number of babies with a birthweight below the 3rd percentile born at or after 32 weeks' gestation.¹⁰ Additionally, we determined the number of singleton pregnancies induced for suspected fetal growth restriction. To ensure any improvements in rates of fetal growth restriction

were not the result of an increase in early-term births, we assessed the proportion of women who were induced for suspected fetal growth restriction before 39 weeks' gestation who delivered a baby with a birthweight above the 10th percentile.

For pre-eclampsia detection and management, we assessed the proportion of women diagnosed with pre-eclampsia; gestation at birth; and the incidence of severe pre-eclamptic complications, defined as a composite of eclampsia, placental abruption, haemolysis, elevated liver enzymes, Haemolysis, Elevated Liver enzymes and Low Platelets syndrome, acute pulmonary oedema, admission to an intensive care unit, acute kidney injury requiring dialysis, and stillbirth. Pre-eclampsia was defined in accordance with the International Society for the Study of Hypertension in Pregnancy's guideline.¹¹

To assess gestational diabetes detection and management, we analysed the proportion of women with gestational diabetes who required insulin, and the incidence of macrosomia, defined as a birthweight above the 97th percentile. Gestational diabetes was diagnosed in accordance with the Australasian Diabetes in Pregnancy Society guidelines.¹²

Secondary outcomes were: stillbirth; NICU admission; and preterm birth (birth before 37 weeks' gestation). Stillbirth was defined as the death of a baby from 20 weeks' gestation, or with a birthweight of 400 g or more if gestational age was unknown.

Statistical analysis

Due to the rapid implementation of this programme during the COVID-19 pandemic, we did no power calculations, but the outcomes for all women over this time period were reported.

Continuous outcomes were presented as mean (SD) for normally distributed variables and median (IQR) for skewed data. Baseline characteristics were described for the conventional, implementation, and integrated care periods. The incidence of pre-eclampsia, fetal growth restriction, and gestational diabetes in the three time periods were described, and we compared differences between the conventional and integrated care periods using a χ^2 test. We calculated weekly incidence of dichotomous outcomes (singletons with birthweight <10th percentile, singletons with birthweight <3rd percentile, singletons with birthweight <3rd percentile born at or after 40 weeks' gestation, singletons induced for suspected fetal growth restriction, singletons induced at <39 weeks for suspected fetal growth restriction with birthweight >10th percentile, women diagnosed with pre-eclampsia, women diagnosed with gestational diabetes [all who required insulin and women with a baby with macrosomia (birthweight >97th percentile)], stillbirth, NICU admission, and preterm birth [<37 weeks' gestation]) stratified by model of care (low risk or high risk) and did an interrupted time-series analysis using a Prais–Winsten generalised

	Conventional care (n=20 031)	Implementation period (n=685)	Integrated care (n=2292)	p value
Age, years	31-29 (5-19)	31-36 (5-04)	31-61 (5-31)	0-03
Body-mass index, kg/m ²	25 (22-29)	25 (22-30)	25 (22-29)	0-08
Smoking in pregnancy	1253 (6%)	46 (7%)	147 (6%)	0-86
Nulliparous	7983 (40%)	271 (40%)	894 (39%)	0-73
Multiple pregnancy	375 (2%)	11 (2%)	51 (2%)	0-43
Maternal region of birth				
Australia	8363 (42%)	292 (43%)	1012 (44%)	0-06
Africa	813 (4%)	23 (3%)	109 (5%)	..
Southern Asia	5961 (30%)	209 (31%)	642 (28%)	..
Southeast and eastern Asia	3158 (16%)	109 (16%)	363 (16%)	..
Central and western Asia	266 (1%)	7 (1%)	30 (1%)	..
Europe	907 (5%)	32 (5%)	72 (3%)	..
Other	563 (3%)	13 (2%)	64 (3%)	..
Antenatal visits				
In person	165256/165263 (99-9%)	3667/5443 (68%)	9423/20154 (47%)	<0-0001
Telehealth	107/165263 (0-06%)	1776/5443 (33%)	10731/20154 (53%)	..
Appointments not attended	8538/165263 (5%)	500/5443 (9%)	1589/20154 (8%)	<0-0001
In person*	8537/165256 (5%)	358/3667 (10%)	682/9423 (7%)	<0-0001
Telehealth*	1/107 (1%)	142/1776 (8%)	907/10731 (8%)	0-02

Data are mean (SD), median (IQR), n (%), or n/N (%). *Denominators reflect the total number of appointments of that type offered during the period.

Table 1: Maternal and antenatal care characteristics in the conventional and telehealth integrated care periods

least-squares regression-based approach, accounting for autocorrelation of the residuals and added robust SEs to determine any changes in each of the outcomes after telehealth implementation.¹³ We did not correct for seasonality. We also assessed the Durbin–Watson statistic as an indicator of how well the model corrected for autocorrelation with a value of 2 indicating no autocorrelation within the model; all models met this assessment of accounting for autocorrelation. The coefficients reported were the pre-trend slope (rate of change in incidence of respective outcomes per week in the conventional care period [Jan 1, 2018—March 22, 2020]), the intervention slope (difference in rate of change in incidence of respective outcomes between April 20 and July 26, 2020, relative to the conventional care period), and the post-trend slope (rate of change in incidence of respective outcomes per week in the integration period [April 20—July 26, 2020]).

To minimise selection and misclassification bias, all women who attended antenatal care at Monash Health were assessed after giving birth. We used routinely collected health outcome data, to minimise the risk of missing data. In allowing an implementation period, misclassification bias was minimised, since women identified with pre-eclampsia and fetal growth restriction in the conventional care period would have given birth during the implementation period.

Two-tailed *p* values of less than 0.05 were considered to indicate statistical significance. All statistical analyses were done using Stata IC (version 12.0).

Role of the funding source

There was no funding source for this study.

Results

Between Jan 1, 2018, and March 22, 2020, 20031 women gave birth at Monash Health with conventional care. Telehealth was integrated into antenatal care delivery across Monash Health on March 23, 2020; thus we assessed comparative outcomes for 2292 women who gave birth between April 20 and July 26, 2020. Thus, the total observational study period assessed outcomes from 23 008 births, comparing all women who gave birth during the 3-month telehealth integrated care with those who gave birth in the 26 months before telehealth implementation.

Women who gave birth during the telehealth integrated care period were slightly older (31.61 *vs* 31.29 years; *p*=0.03) than those who gave birth during the conventional care period. No other significant differences between the groups were observed for BMI, smoking, parity, or region of birth (table 1).

During the study period, the mean number of antenatal consultations done remained stable at approximately 1400 per week. However, the proportion of consultations delivered via telehealth increased rapidly during the implementation period, with a mean of 766 telehealth

consultations done per week (766 [53%] of 1400 consultations via telehealth *vs* 0.96 [0.06%] consultations during the conventional care period; table 1, figure 2A). Most of these consultations were by video call with 5% done via telephone (data not shown). In low-risk care models women received a mean of five (56%) of nine visits by telehealth, whereas women in high-risk models received four (40%) of ten visits via telehealth (figure 2B).

The total number of appointments that women did not attend was significantly higher in the integrated care period than the conventional care period (1589 [8%] of 20 154 consultations *vs* 8538 [5%] of 165 263 consultations; *p*<0.0001; table 1). However, during the integrated care period, the overall number of appointments that were not attended was similar for both telehealth and in-person consultations (figure 3). A higher number of in-person consultations were missed than telehealth consultations in high-risk care models (figure 3A), whereas the number of telehealth consultations missed was higher than in-person consultations in low-risk care models (figure 3B).

Regarding fetal growth restriction, no significant differences were identified in the proportion of babies born with a birthweight below the 3rd percentile in the integrated care period when compared with the

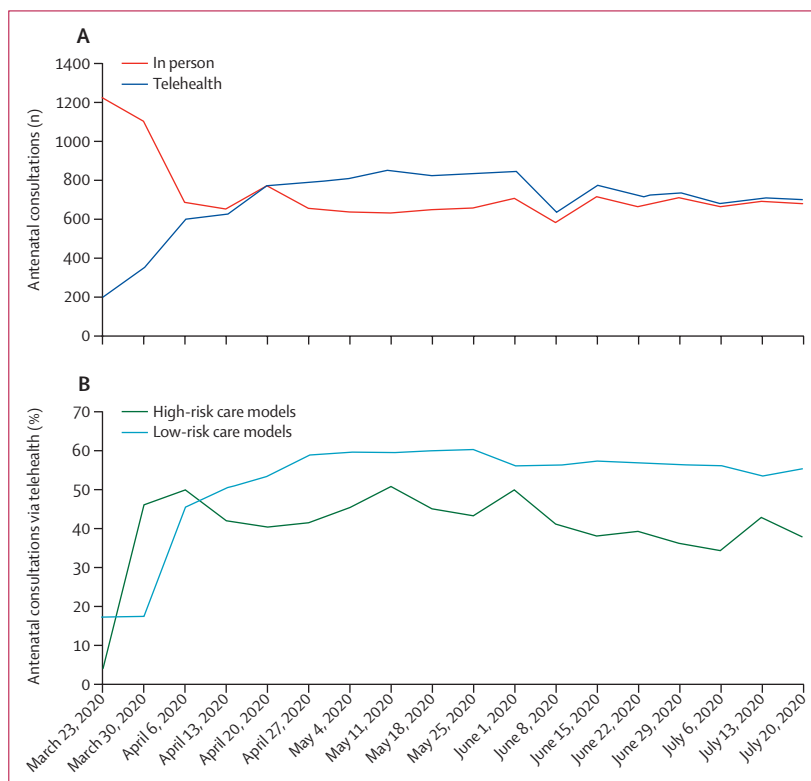


Figure 2: Number of in-person and telehealth consultations delivered per week after telehealth implementation on March 23, 2020

Absolute number of in-person and telehealth consultations (A) and the percentage of antenatal consultations delivered by telehealth for low-risk and high-risk care models (B) between March 23 and July 20, 2020. The implementation period was defined as March 23–April 19, 2020, and the integrated care period was defined as the period April 20–July 26, 2020.

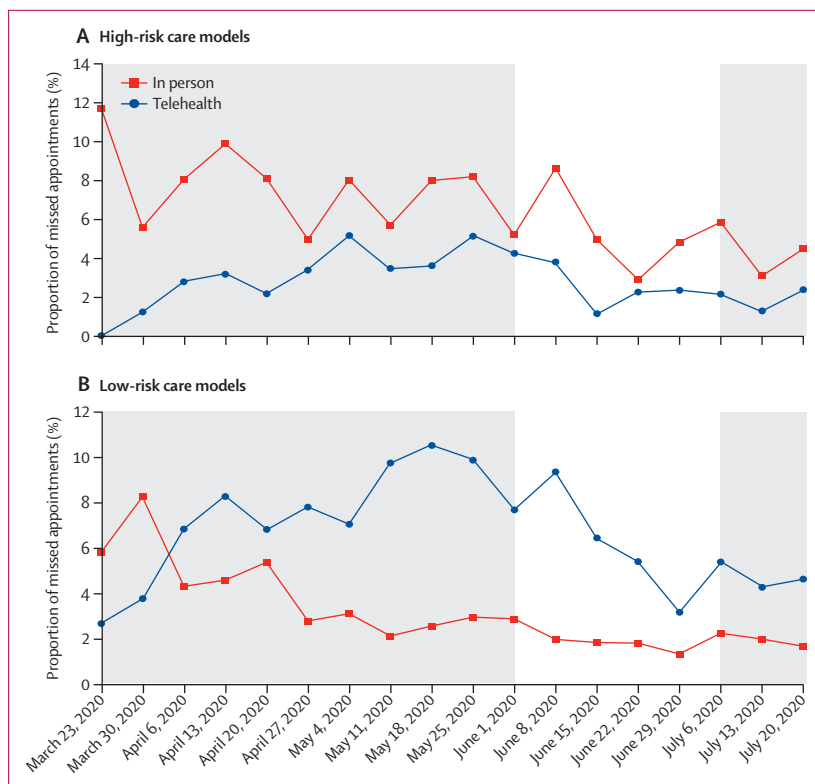


Figure 3: Proportion of consultations not attended per week following telehealth implementation
Proportion of missed appointments for in-person and telehealth consultations for high-risk care models (A) and low-risk care models (B). Shaded areas indicate the periods of community lockdown in Melbourne (VIC, Australia) during the COVID-19 pandemic.

conventional care period for low-risk care models (39 [2%] of 1767 singleton births in the integrated care period vs 322 [2%] of 15 470 singleton births in the conventional care period; $p=0.72$) or high-risk models (25 [5%] of 474 singleton births vs 192 [5%] of 4186 singleton births; $p=0.50$). No significant differences were identified in the proportion of babies born with a birthweight below the 10th percentile in the integrated care period when compared with the conventional care period for low-risk care models (167 [10%] of 1767 singleton births in the integrated care period vs 1506 [10%] of 15 470 singleton births in the conventional care period; $p=0.71$) or high-risk care models (61 [13%] of 474 singleton births vs 580 [14%] of 4186 singleton births; $p=0.55$; table 2). In interrupted time-series analysis, no significant differences were identified in the rate of change per week in the number of babies born with a birthweight below the 3rd percentile after the introduction of telehealth compared with the conventional care period in low-risk care models (0.06% change per week [95% CI -0.07 to 0.20]; $p=0.37$) or high-risk care models (-0.14% change per week [-0.41 to 0.13]; $p=0.31$; table 3). Similarly, no significant differences were identified in the number of babies born with a birthweight below the 3rd percentile born at or after

40 weeks' gestation for the conventional care period and integrated care period (tables 2, 3). Compared with the conventional care period, no differences in the number of women who were induced for suspected fetal growth restriction per week were identified during the telehealth integrated care period for low-risk care models (-0.19 [95% CI -0.40 to 0.03]) or high-risk care models (-0.008 [-0.37 to 0.36]), or for the number of women who were induced before 39 weeks resulting in a baby with a birthweight above the 10th percentile (table 3).

Additionally, no significant differences were identified in the incidence of stillbirth overall between the integrated and conventional care periods (1% in the integrated care period vs 1% in the conventional care period, $p=0.79$ for the low-risk care models; 2% vs 2%, $p=0.70$ for high-risk care models), or when crude rates were assessed for either care model (table 2). A 0.22% reduction in the number of stillbirths per week was observed after the integration of telehealth in high-risk care models when compared with conventional care (95% CI -0.47 to 0.03; $p=0.09$), but this difference was not statistically significant (table 3).

Compared with the conventional care period, in the implementation period, an initial decline was observed in the number of women diagnosed with pre-eclampsia in both low-risk care models (six [1%] of 536 women in the implementation period vs 455 [3%] of 15 493 women in the conventional care period) and high-risk care models (six [4%] of 149 women vs 328 [7%] of 4538 women; table 2). However, the number of pre-eclampsia diagnoses during the integrated care period was similar to that in the conventional care period (49 [3%] of 1768 women in low-risk care models and 47 [9%] of 524 women in high-risk care models; table 2). For pregnancies complicated by pre-eclampsia, no significant difference in the median gestation at birth was identified after telehealth integration when compared with conventional care for women in low-risk care models (38.4 weeks [IQR 37.3–39.3] vs 38.2 weeks [37.2–39.3]; $p=0.27$) or women in high-risk care models (37.1 weeks [32.6–38.1] vs 36.8 weeks [34.2–38.0]; $p=0.99$; table 2). The number of women with pre-eclampsia who had severe complications in the integrated care period was too low to make any conclusive inferences, but was similar to that for the conventional care period for the low-risk care model (two [4%] of 49 women in the integrated care period vs 20 [4%] of 455 women in the conventional care period; $p=0.94$) and high-risk care models (two [4%] of 47 women vs 23 [7%] of 328 women; $p=0.48$; table 2). No significant differences in the number of pre-eclampsia diagnoses per week were identified after the implementation of telehealth in low-risk care models (0.15% change per week [95% CI -0.03 to 0.34]; $p=0.10$) or high-risk care models (0.20% [-0.31 to 0.70]; $p=0.44$) when compared with the pre-trend slope for the conventional care period (table 3).

	Conventional care period	Implementation period	Integrated care period	p value*
Low-risk care models				
Fetal growth restriction				
Singletons with birthweight <10th percentile	1506/15 470 (10%)	58/535 (11%)	167/1767 (10%)	0.71
Singletons with birthweight <3rd percentile	322/15 470 (2%)	12/535 (2%)	39/1767 (2%)	0.72
Singletons with birthweight <3rd percentile born at or after 40 weeks' gestation†	74/306 (24%)	1/11 (9%)	8/34 (24%)	0.93
Singletons induced for suspected fetal growth restriction	665/15 470 (4%)	32/535 (6%)	82/1767 (5%)	0.50
Singletons induced at <39 weeks for suspected fetal growth restriction with birthweight >10th percentile‡	213/13 705 (2%)	5/471 (1%)	28/1579 (2%)	0.51
Pre-eclampsia				
Women diagnosed with pre-eclampsia	455/15 493 (3%)	6/536 (1%)	49/1768 (3%)	0.70
Gestation at delivery, weeks	38.2 (37.2–39.3)	38.3 (37.6–39.1)	38.4 (37.3–39.3)	0.27
Women with pre-eclampsia with severe complication§	20/455 (4%)	0	2/49 (4%)	0.94
Gestational diabetes				
Women diagnosed with gestational diabetes	3405/15 493 (22%)	113/536 (21%)	386/1768 (22%)	0.89
Requiring insulin	1242/3405 (36%)	43/113 (38%)	127/386 (33%)	0.12
Baby with macrosomia at birth (birthweight >97th percentile)	384/3405 (11%)	13/113 (12%)	33/386 (9%)	0.10
Perinatal morbidity or mortality¶				
Stillbirth	105/15 516 (1%)	1/537 (<1%)	11/1768 (1%)	0.79
NICU admission	237/15 516 (2%)	10/537 (2%)	29/1768 (2%)	0.60
Preterm birth (<37 weeks' gestation)	869/15 516 (6%)	30/537 (6%)	82/1768 (4%)	0.10
High-risk care models				
Fetal growth restriction				
Singletons with birthweight <10th percentile	580/4186 (14%)	30/139 (22%)	61/474 (13%)	0.55
Singletons with birthweight <3rd percentile	192/4186 (5%)	14/139 (10%)	25/474 (5%)	0.50
Singletons with birthweight <3rd percentile born at or after 40 weeks' gestation†	17/161 (11%)	1/11 (9%)	1/19 (5%)	0.47
Singletons induced for suspected fetal growth restriction	207/4186 (5%)	7/139 (5%)	30/474 (6%)	0.19
Singletons induced at <39 weeks for suspected fetal growth restriction with birthweight >10th percentile‡	56/3217 (2%)	1/98 (1%)	5/368 (1%)	0.55
Pre-eclampsia				
Women diagnosed with pre-eclampsia	328/4538 (7%)	6/149 (4%)	47/524 (9%)	0.15
Gestation at delivery, weeks	36.8 (34.2–38.0)	37 (35.4–38.4)	37.1 (32.6–38.1)	0.99
Women with pre-eclampsia with severe complication§	23/328 (7%)	0	2/47 (4%)	0.48
Gestational diabetes				
Women diagnosed with gestational diabetes	1178/4538 (26%)	41/149 (28%)	156/524 (30%)	0.06
Requiring insulin	584/1178 (50%)	22/41 (54%)	78/156 (50%)	0.92
Baby with macrosomia at birth (birthweight >97th percentile)	194/1178 (16%)	7/41 (17%)	27/156 (17%)	0.79
Perinatal morbidity or mortality¶				
Stillbirth	99/4897 (2%)	2/159 (1%)	13/574 (2%)	0.70
NICU admission	723/4897 (15%)	23/159 (14%)	101/574 (18%)	0.01
Preterm birth (<37 weeks' gestation)	1307/4897 (27%)	42/159 (26%)	164/574 (29%)	0.34

Data are n/N (%) or median (IQR). The conventional care period was defined as Jan 1, 2018, to March 22, 2020, the implementation period as March 23 to April 19, 2020, and the integrated care period as April 20 to July 26, 2020. NICU=neonatal intensive care unit. *Conventional care period versus integrated care period. †Calculated as number of singleton babies born with a birthweight below the 3rd percentile at or after 40 weeks' gestation divided by number of babies born with a birthweight below the 3rd percentile after 32 weeks' gestation. ‡Calculated as number of babies induced before 39 weeks' gestation for suspected fetal growth restriction with birthweight above the 10th percentile divided by the number of babies born after 35 weeks' gestation with a birthweight above the 10th percentile. §Severe complication from pre-eclampsia defined as a composite of haemolysis, elevated liver enzymes and low platelets syndrome, eclampsia, placental abruption, pulmonary oedema, and stillbirth. ¶Denominator is all babies.

Table 2: Maternal and neonatal complications in low-risk and high-risk care models

An increase in the incidence of gestational diabetes diagnosed in high-risk care models was observed after telehealth implementation, but this difference was not

significant (156 [30%] of 524 women in the integrated care period vs 1178 [26%] of 4538 women in the conventional care period; $p=0.06$), and no increase was

	Pre-trend slope*	p value	Intervention†	p value	Post-trend slope‡	p value
Low-risk care models						
Fetal growth restriction						
Singletons with birthweight <10th percentile	-0.006% (-0.21 to 0.008)	0.42	-0.002% (-0.37 to 0.36)	0.99	-0.083% (-0.38 to -0.35)	0.96
Singletons with birthweight <3rd percentile	-0.003% (-0.009 to 0.003)	0.26	0.06% (-0.07 to 0.20)	0.37	0.06% (-0.08 to 0.19)	0.39
Singletons with birthweight <3rd percentile born at or after 40 weeks' gestation	-0.04% (-0.18 to 0.09)	0.57	-0.58% (-3.48 to 2.33)	0.70	-0.61 (-3.51 to 2.28)	0.68
Singletons induced for suspected fetal growth restriction	-0.009% (-0.02 to 0.001)	0.08	-0.19% (-0.40 to 0.03)	0.09	-0.19% (-0.41 to 0.02)	0.08
Singletons induced at <39 weeks for suspected fetal growth restriction with birthweight >10th percentile	-0.02% (-0.36 to -0.04)	0.013	-0.25% (-3.51 to 3.02)	0.88	-0.45% (-3.70 to 2.80)	0.78
Pre-eclampsia						
Women diagnosed with pre-eclampsia	-0.001% (-0.001 to 0.009)	0.83	0.15% (-0.03 to 0.34)	0.10	0.15% (-0.03 to 0.32)	0.10
Gestational diabetes						
Women diagnosed with gestational diabetes	0.04% (0.016 to 0.054)	<0.001	-0.02% (-0.52 to 0.47)	0.93	0.01% (-0.48 to 0.50)	0.95
Requiring insulin	-0.04% (-0.09 to 0.02)	0.18	0.72% (-0.42 to 1.85)	0.21	0.68% (-0.44 to 1.81)	0.23
Baby with macrosomia at birth (birthweight >97th percentile)	-0.05% (-0.09 to -0.21)	0.001	0.55% (-0.26 to 1.36)	0.18	0.49% (-0.31 to 1.30)	0.22
Perinatal morbidity or mortality						
Stillbirth	0.001% (-0.002 to 0.005)	0.48	0.02% (-0.04 to 0.09)	0.52	0.02% (-0.04 to 0.08)	0.50
NICU admission	0.006% (-0.0003 to 0.01)	0.06	0.03% (-0.10 to 0.15)	0.69	0.03% (-0.09 to 0.15)	0.62
Preterm birth (<37 weeks' gestation)	0.003% (-0.008 to 0.01)	0.62	0.12% (-0.10 to 0.35)	0.29	0.12% (-0.09 to 0.35)	0.27
High-risk care models						
Fetal growth restriction						
Singletons with birthweight <10th percentile	0.0005% (-0.03 to 0.03)	0.98	-0.14% (-0.91 to 0.63)	0.73	-0.14% (-0.90 to 0.63)	0.73
Singletons with birthweight <3rd percentile	0.01% (-0.003 to 0.03)	0.10	-0.14% (-0.41 to 0.13)	0.31	-0.12% (-0.39 to 0.14)	0.36
Singletons with birthweight <3rd percentile born at or after 40 weeks' gestation	-0.03% (-0.19 to 0.12)	0.66	0.55% (-0.48 to 1.57)	0.30	0.51% (-0.51 to 1.53)	0.32
Singletons induced for suspected fetal growth restriction	0.002% (-0.15 to 0.02)	0.76	-0.008% (-0.37 to 0.36)	0.97	-0.01% (-0.37 to 0.36)	0.98
Singletons induced <39 weeks for suspected fetal growth restriction with birthweight >10th percentile	0.03% (-0.19 to 0.25)	0.80	-0.70% (-6.47 to 5.08)	0.81	-0.67% (-6.44 to 5.10)	0.82
Pre-eclampsia						
Women diagnosed with pre-eclampsia	-0.003% (-0.03 to 0.02)	0.79	0.20% (-0.31 to 0.70)	0.44	0.19% (-0.31 to 0.71)	0.44
Gestational diabetes						
Women diagnosed with gestational diabetes	0.04% (-0.001 to 0.74)	0.06	0.38% (-0.51 to 1.27)	0.40	0.42% (-0.47 to 1.31)	0.34
Requiring insulin	0.13% (0.02 to 0.25)	0.03	-0.51% (3.49 to 2.46)	0.73	-0.38% (-3.35 to 2.59)	0.80
Baby with macrosomia at birth (birthweight >97th percentile)	-0.03% (-0.12 to 0.06)	0.47	-0.72% (-2.85 to 1.41)	0.51	-0.75% (-2.88 to 1.38)	0.49
Perinatal morbidity or mortality						
Stillbirth	0.002% (-0.008 to 0.01)	0.70	-0.22% (-0.47 to 0.03)	0.09	-0.22% (-0.47 to 0.03)	0.09
NICU admission	-0.0003% (-0.03 to 0.03)	0.98	-0.44% (-1.04 to 0.16)	0.15	-0.43% (-1.04 to 0.16)	0.15
Preterm birth (<37 weeks' gestation)	-0.03% (-0.07 to 0.006)	0.10	-0.68% (-1.37 to -0.002)	0.049	-0.71% (-1.40 to -0.03)	0.04

Data are percentage change per week (95% CI). NICU=neonatal intensive care unit. *Change in rate of respective outcomes per week during the conventional care period. †Change in incidence of respective outcomes per week during the telehealth integration period compared with the conventional care period. ‡Change in rate of respective outcomes per week during the integrated care period.

Table 3: Interrupted time-series analysis for maternal and neonatal outcomes in conventional and integrated care periods for low-risk and high-risk care models

observed among women in low-risk care models (386 [22%] of 1768 women vs 3405 [22%] of 15493; $p=0.89$; table 2). No changes were observed in the proportion of women with gestational diabetes requiring insulin or giving birth to a baby with a birthweight above the 97th percentile in the low-risk or high-risk care models (table 2). Across the conventional care period, a small increase in the number of women diagnosed with gestational diabetes per week was observed in low-risk care models (0.04% increase [95% CI 0.02–0.05]; $p<0.001$), with no significant change observed following the introduction of telehealth ($p=0.93$; table 3). Similarly, in high-risk care models, the number of women with gestational diabetes requiring insulin increased by 0.13% per week (95% CI 0.02–0.25; $p=0.03$) in the conventional care period, but this increase was not significantly altered with telehealth integration ($p=0.73$; table 3).

No significant differences were identified in the proportion of babies requiring NICU admission born to women in the low-risk models of care (29 [2%] of 1768 babies in the integrated care period vs 237 [2%] of 15516 babies in the conventional care period; $p=0.60$; table 2), or the weekly change in rate of NICU admission in the conventional or integrated care periods. Among women in high-risk care models, a significantly higher proportion of babies were admitted to NICU in the integrated care period than in the conventional period (101 [18%] of 574 babies vs 723 [15%] of 4897 babies; $p=0.01$; table 2); however, in interrupted time-series analysis no significant differences in the rate of weekly NICU admission were identified after telehealth integration compared with conventional care (–0.44% change per week [95% CI –1.04 to 0.16]; $p=0.15$; table 3).

The proportion of babies born preterm was similar for all time periods for both low-risk care models (82 [4%] of 1768 babies in the integrated care period vs 869 [6%] of 15516 babies in the conventional care period; $p=0.10$) and high-risk care models (164 [29%] of 574 babies vs 1307 [27%] of 4897 babies; $p=0.34$; table 2). However, for women in high-risk care models, the number of preterm births reduced by 0.68% per week (95% CI –1.37 to –0.002; $p=0.049$) after telehealth integration compared with the conventional care period (table 3).

Discussion

We found that our telehealth programme delivered around 50% of antenatal consultations via telehealth without affecting the detection and management of common pregnancy complications, including pre-eclampsia, fetal growth restriction, and gestational diabetes, when compared with conventionally delivered antenatal care.

The COVID-19 pandemic has been the catalyst for change in antenatal care delivery, prompting reduced in-person interactions, but also stimulating funding for telehealth services by the Australian Government.¹⁴ Investment in telehealth integration into health care has

been suggested not only to enhance preparedness for disasters,¹⁵ particularly when infrastructure remains intact, as observed in the current pandemic,¹⁶ but also to improve the delivery of patient-centred care.¹⁷ Evidence in many areas of medicine shows that care delivered via telehealth results in similar health outcomes to traditional in-person consultations.¹⁸ In this study, we showed that pregnancy outcomes following the implementation of telehealth in antenatal care seem to be similar to those with conventional in-person care.

Although telehealth has been increasingly used in the 21st century, particularly to access specialist care for individuals who live in rural or remote areas, and has been shown to result in similar or improved clinical outcomes to in-person delivered care,¹⁸ telehealth has seldom been used in antenatal care.^{5,18,19} The available literature has mainly focused on the use of telemonitoring or mobile health applications for targeted approaches, such as smoking cessation, influenza vaccination, blood pressure monitoring, blood sugar level monitoring, and wellness checks.^{4,19–26} In developing our programme, regular antenatal consultations were maintained because fewer consultations have been associated with increased incidence of adverse pregnancy outcomes, patient anxiety, and dissatisfaction with care.^{27,28} Therefore, telehealth was integrated into this schedule to maintain regular consultations, but to reduce the need for in-person attendance. We were able to leverage a telehealth system already in use at our health service for the delivery of paediatric telehealth consultations and modify the system for antenatal care. We recognised that a key limitation of telehealth is the inability to do physical examinations, which are essential in antenatal care for detecting hypertensive disorders of pregnancy and aberrant fetal growth; thus we also implemented low-cost measures to support these assessments in settings remote from hospital.

Home blood pressure monitoring has the potential to reduce iatrogenic intervention. A 2020 systematic review found that home blood pressure monitoring was associated with reduced incidence of antenatal admission, pre-eclampsia diagnosis, and induction of labour.²⁴ We observed an initial decrease in the number of pregnancies diagnosed with pre-eclampsia during population lockdown between March 16 and March 31, 2020, in Melbourne, when reductions in hospital attendances to pregnancy assessment units and emergency departments were observed. After lockdown was ended in the state of Victoria on May 31, 2020, a return to baseline was observed for women in low-risk models of care and an increased incidence of pre-eclampsia in women in high-risk models of care initially. Since the data presented was obtained for women who gave birth at hospital during this time, true diagnoses of pre-eclampsia would not have been missed. Furthermore, although the incidence of pre-eclampsia does not inform the timing of diagnosis and whether this was delayed through the use of telehealth, the gestation at

birth remained similar to the conventional care period. Considering the reduction in the incidence of preterm births during the initial stages of the COVID-19 pandemic,²⁹ it would be interesting to further assess whether this similar reduction in pre-eclampsia incidence was also more widely observed.

Detection of fetal growth restriction is challenging. Our health system predominately uses symphyseal-fundal height measurements for tracking fetal growth across pregnancy, in accordance with current recommended practice for low-risk pregnancies.⁸ Insufficient evidence exists regarding the ability of symphyseal-fundal height measurements to detect fetal growth restriction, with this approach detecting 12–15% of babies with growth restriction in low-risk pregnancies.³⁰ Similar symphyseal-fundal heights results are obtained regardless of whether measurements are done by a health-care professional or self-measured.³¹ No increases in undetected fetal growth restriction pregnancies or a change in the incidence of stillbirths—for which undetected fetal growth restriction is a major risk factor—were observed.³² This has also not been achieved at the cost of increased iatrogenic intervention, with the balance measure of birth of appropriately grown babies before 39 weeks' gestation remaining stable for women in both low-risk and high-risk models of pregnancy care. Universal third trimester growth surveillance is more accurate for the identification of fetal growth restriction in the low-risk population than symphyseal-fundal heights; thus implementation of such an approach might further assist in reducing poor outcomes associated with fetal growth restriction.³³ There have been concerns that this approach might increase iatrogenic intervention; however, the use of universal third trimester growth surveillance in combination with telehealth has not been assessed previously.

Gestational diabetes was assessed as a surrogate marker of clinical care since diabetic management in pregnancy seems to be unaffected by the mode of care delivery,²⁶ which was supported by the finding that the incidence of insulin-requiring gestational diabetes and macrosomia in the population remained stable across all time periods.

A similar number of missed appointments were observed for both in-person and telehealth consultations; however, the influencing factors for this might differ. In-person consultations might have been impacted by concerns of COVID-19 exposure and challenges with attending during lockdown, whereas challenges with technology, communication of appointments, and issues regarding access might have influenced attendance at telehealth consultations.³⁴ To better understand factors that might have influenced missed appointments and identify population groups for whom telehealth might not be suitable, an in-depth review of consumer characteristics is needed. The number of missed appointments in the telehealth integrated period in the

last 4 weeks of the study period were lower than that in the conventional care period.

The strengths of this study are the uniformity of implementation of telehealth integrated care across a large health service, with large numbers of births assessed in both the conventional and integrated care periods, which strengthened the findings with minimal missing data. The large sample size is likely to have reduced the impact of bias, since all women assessed would have had telehealth integrated in their pregnancy care, with the exception of women who declined telehealth or could not be contacted for a telehealth consultation, or who had not had antenatal care, but attended the hospital for birth. Furthermore, the outcomes assessed were routinely collected data from all women who gave birth at the health service, enabling reliable assessment across time to review the effect of health-care changes on pregnancy outcomes. We are confident about the safety of this approach for the delivery of antenatal care, since there were no recorded COVID-19 cases in pregnancy in Victoria during the telehealth integrated care period. As such, any potential influence that COVID-19 in pregnancy might have had on these outcomes did not further bias or influence the results. We believe our findings are widely generalisable for implementation or adaptation to other health services, since the population included were highly heterogeneous and video call technology is now widely and cheaply available.

Limitations of this study relate to its retrospective nature; however, the major risk of selection bias was minimised since all consecutive pregnancies were included in the analysis. Since the study period consisted of the first 3 months following implementation of integrated antenatal care, there is the possibility that further differences in outcomes might continue to change and become more apparent over time, particularly for endpoints, such as stillbirth, which were likely to be underpowered. Furthermore, the possible influence of concomitant measures associated with the COVID-19 pandemic and population lockdown on the findings of the interrupted time-series analysis cannot be excluded. Important variables yet to be assessed, such as detection of family violence, might have been affected by the pandemic and rate of detection via telehealth, and this warrants ongoing evaluation. Furthermore, since more than 95% of telehealth consultations were done by video call, these findings might not be generalisable to systems that solely use voice calls.

Considering these encouraging initial findings, this method of antenatal care delivery will continue, thereby enabling future evaluation to provide greater certainty as to the safety of this approach. Many changes have occurred during the pandemic, such that although the number of COVID-19 cases in Melbourne were low during the evaluation period, the impact of lockdown, physical distancing, and heightened anxiety might also influence changes observed. Consumer evaluation of both staff and patient satisfaction with this programme,

including its acceptance by diverse multicultural and socioeconomic groups, and cost-effectiveness will be crucial to inform its ongoing use. Assessment of telehealth programmes in antenatal care delivery for women in rural or remote regions of the USA indicate that the programmes have been well received by patients and health-care practitioners.³⁵ Additionally, although cost-effectiveness data in antenatal care are scarce,³ the potential to reduce economic disruption of conventional antenatal care for patients exists, through minimising travel time and costs, and reducing potential loss of income due to non-attendance at work.

In conclusion, we successfully integrated telehealth into antenatal care delivery at a large publicly funded health-care network, utilising many low-cost interventions, making our findings widely applicable to a range of health-care settings. Although telehealth was implemented during a global health crisis, which facilitated the rapid development and uptake of telehealth, this programme might provide many benefits for the future delivery of antenatal care and minimise risk in future epidemics. We have shown that such an approach seems to be safe for continuing to achieve a high standard of pregnancy care.

Contributors

KRP, AR, KP, MLG, KB, HD, RF, AES, and RJH designed the intervention. KRP, AR, KP, KB, HD, RF, AES, AS, and RJH were involved in implementation of telehealth integrated care. KRP, BWM, and RJH designed the study. MT collected primary data. KRP, MT, and MD-T did data analysis. KRP and MD-T verified the data. KRP, DLR, EMW, BWM, and RJH interpreted the findings. KRP wrote the primary manuscript and all authors contributed to the final submitted manuscript.

Declaration of interests

BWM is a consultant for Guerbet, and has received research grants from Guerbet and Merck. KRP has received consultancy fees from Janssen. All other authors declare no competing interests.

Data sharing

De-identified individual participant data is available on request from Monash Health Human Research Ethics Committee (research@monashhealth.org.au).

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