Effect of telehealth-integrated antenatal care on pregnancy outcomes in Australia: an interrupted time-series analysis

Kaarthikayinie Thirugnanasundralingam, Miranda Davies-Tuck, Daniel L Rolnik, Maya Reddy, Ben W Mol, Ryan Hodges, Kirsten R Palmer

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Department of Obstetrics and Gynaecology, Monash University, Melbourne, VIC, Australia (K Thirugnanasundralingam BMedSc MD[Hons], D L Rolnik PhD, M Reddy PhD, Prof B W Mol PhD, R Hodges PhD, K R Palmer PhD); **The Ritchie Centre, Hudson Institute of Medical Research, Melbourne, VIC, Australia** (M Davies-Tuck PhD); **Monash Women's, Monash Health, Melbourne, VIC, Australia** (D L Rolnik, M Reddy, Prof B W Mol, R Hodges, K R Palmer); **Aberdeen Centre for Women's Health Research, University of Aberdeen, Aberdeen, UK** (Prof B W Mol)

Correspondence to: Assoc Prof Kirsten Palmer, Department of Obstetrics and Gynaecology, Monash University, Melbourne, 3169 VIC, Australia **kirsten.palmer@monash.edu**

Summary

Background During the COVID-19 pandemic, rapid integration of telehealth into antenatal care occurred to support ongoing maternity care. A programme of this scale had not been previously implemented. We evaluated whether telehealth-integrated antenatal care in an Australian public health system could achieve pregnancy outcomes comparable to those of conventional care to assess its safety and efficacy.

Methods Routinely collected data for individuals who gave birth at Monash Health (Melbourne, VIC, Australia) during a conventional care period (Jan 1, 2018, to March 22, 2020) and telehealth-integrated period (April 20, 2020, to April 25, 2021) were analysed. We included all births that occurred at 20 weeks' gestation or later or with a birthweight of at least 400 g (if duration of gestation was unknown). We excluded multiple births, births for which private antenatal care was received, and births to individuals transferred from other hospitals or who had no antenatal care. Baseline demographics, telehealth uptake, and pregnancy complications (related to pre-eclampsia, fetal growth restriction [FGR], gestational diabetes, stillbirth, neonatal intensive care [NICU] admission, and preterm birth [<37 weeks' gestation]) were compared using comparative statistics and an interrupted time-series analysis. Results were stratified by care stream, with high-risk models consisting of obstetric specialist-led care, and all other streams categorised as low-risk models. The impact of the integrated period on outcomes was also assessed with stratification by parity.

Findings 17 873 births occurred in the conventional period and 8131 in the integrated period. Compared with the conventional period, women giving birth during the integrated period were slightly older (30·63 years *vs* 30·88 years) and had slightly higher BMI (25·52 kg/m² *vs* 26·14 kg/m²), and more Australian-born women gave birth during the integrated period (37·37% *vs* 39·79%). There were no significant differences in smoking status or parity between the two groups. 107 (0·08%) of 129 514 antenatal consultations in the conventional period and 34 444 (45·94%) of 74 982 in the integrated period were delivered by telehealth. No significant differences between the conventional and integrated periods were seen in median gestational age at pre-eclampsia diagnosis (low-risk models 37·4 weeks in the conventional period *vs* 37·1 weeks in the integrated period, difference –0·3 weeks [–0·7 to 0·1]; high-risk models 35·5 weeks *vs* 36·3 weeks, difference 0·3 weeks [–0·3 to 1·1]), incidence of FGR below the 3rd birthweight percentile (low-risk models 1·62% *vs* 1·74%, difference 0·12 percentage points [–0·26 to 0·50]; high-risk 4·04% *vs* 4·13%, difference 0·089 percentage points [–1·08 to 1·26]), and incidence of preterm birth (low-risk models 4·99% *vs* 5·01%, difference 0·02% [–0·62 to 0·66]; high-risk models 15·76% *vs* 14·43%, difference –1·33% [–3·42 to 0·77]). Parity did not affect these findings. Interrupted time-series analysis showed a significant reduction in induction of labour for singletons with suspected FGR among women in low-risk models during the integrated period (–0·04% change per week [95% CI –0·07 to –0·01], p=0·0040), and NICU admission declined after telehealth integration (low-risk models –0·02% change per week [–0·03 to –0·003], p=0·018; high-risk models –0·10% change per week, –0·19 to –0·001; p=0·047). No significant differences in stillbirth rates were observed. The proportion of women diagnosed with gestational diabetes was significantly higher in the integrated period compared with the conventional period for both low-risk care models (22·28% *vs* 25·13%, difference 2·85 percentage points [1·60 to 4·11]) and high-risk care models (28·70% *vs* 34·02%, difference 5·32 percentage points [2·57 to 8·07]). However overall, when compared with the conventional period, there was no significant difference in proportion of women with gestational diabetes requiring insulin therapy (low-risk models 8·08% *vs* 7·73%, difference –0·35 percentage points [–1·13 *vs* 0·44]; high-risk models 14·81% *vs* 15·71%, difference 0·89 percentage points [–1·23 to 3·02]), or proportion of women with gestational diabetes who gave birth to a baby with macrosomia in the integrated period (low-risk models 3·16% *vs* 2·33%, difference –0·83 percentage points [–1·77 to 0·12]; high-risk models 5·58% *vs* 4·81%, difference –0·77 percentage points [–3·06 to 1·52]).

Interpretation Telehealth-integrated antenatal care replaced around 46% of in-person consultations without compromising pregnancy outcomes. It might be associated with a reduction in labour induction for suspected FGR, particularly for women in low-risk models, without compromising FGR detection or perinatal morbidity. These findings support the ongoing use of telehealth in providing flexible antenatal care.

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Introduction

Antenatal care improves perinatal outcomes; however, consensus on the ideal frequency, timing, and mode of visits is lacking.[1] WHO recommends a minimum of eight contacts with health-care providers throughout pregnancy, although the mode of consultation is not stipulated.[2] Australian models of antenatal care are derived from UK legislation conceived in 1929 and, with the exception of innovation in screening, have remained largely unchanged.

The COVID-19 pandemic necessitated health service transformation to maintain health-care provision. Urgency to modify care delivery arose to protect pregnant women and health-care workers from viral exposure while maintaining essential maternity care. In March, 2020, the largest maternity service in Victoria, Australia, rapidly implemented a telehealth-integrated antenatal schedule, aiming to deliver 50% of consultations virtually. Implementation was facilitated by temporary changes to public health funding by the Australian Government.

Although telehealth has been successfully used for targeted pregnancy interventions, such as reduction of gestational weight gain[3] and management of gestational diabetes,[4] little evidence is available to inform its use in routine antenatal care. Concerns exist that telehealth could adversely affect the detection and management of pregnancy complications, particularly those contingent on physical examination, such as pre-eclampsia and fetal growth restriction (FGR). Although the existing literature does not support these concerns,[5,6] interpretation of this

Research in context

Evidence before this study

PubMed and OVID databases were searched from inception to March 31, 2021, for articles published in English, using the terms "telehealth" or "telemedicine" AND "pregnancy" or "antenatal care" OR "prenatal care" OR "obstetrics" OR "maternity". While telehealth has been successfully leveraged for targeted interventions in pregnancy, including management of gestational diabetes and reduction in gestational weight gain, abstract review identified few studies that had evaluated telehealth in the provision of routine antenatal care.
A 2019 randomised controlled trial found that use of telehealth for routine antenatal care was associated with greater patient satisfaction and adhered to national guidelines for pregnancy care (n=300). However, judicious interpretation is required as studies are limited by small populations and likely to be underpowered to detect differences in rarer perinatal outcomes. Studies have also used significant infrastructure, such as home blood pressure monitors and handheld doppler ultrasound devices to support telehealth programmes, limiting the affordability and generalisability of such models. Telehealth might help to achieve greater person-centred care through overcoming geographical and financial barriers that might limit attendance in person. It is for this reason that telehealth has been used as an outreach model for rural settings both in Australia and globally. Urgency to reform care delivery during the COVID-19 pandemic has driven more widespread use, enabling broader evaluation of telehealth for routine antenatal care. Our initial 3-month evaluation showed that telehealth could achieve similar outcomes to conventionally delivered care (n=2292).

Added value of this study

To our knowledge, this is the largest evaluation of the use of telehealth in routine antenatal care across all pregnancy care models. Our schedule was used for 8131 pregnancies within a population of culturally and linguistically diverse women. Across 12 months, we delivered 45·94% of consultations via video-supported telehealth, with no significant changes in pregnancy complications, pre-eclampsia, fetal growth restriction, preterm birth, or stillbirth, compared with conventional care. Rates of Gestational Diabetes, however, did significantly increase over the 12 months. Although this change in practice was driven by urgency to reform care delivery due to the COVID-19 pandemic, low disease prevalence within the studied population means that findings are unlikely to have been influenced by COVID-19 itself. Implementation of this low-cost programme within a publicly funded health service also increases generalisability across a broad range of health-care settings.

Implications of all the available evidence

In driving widespread implementation of telehealth into maternity services, the COVID-19 pandemic has provided an opportunity to re-evaluate antenatal care delivery. The lack of significant difference in adverse outcomes relating to pre-eclampsia, fetal growth restriction, and perinatal morbidity established in this interrupted time-series analysis provides encouraging evidence to inform the ongoing use of hybrid antenatal care models. Evidence of safety from structured, reproducible telehealth-integrated programmes in combination with evaluation of patient satisfaction and cost-effectiveness analysis will assist in the long overdue redesign of traditional maternity care into more personalised, responsive, and resilient care models. These changes could have considerable value, particularly with the ongoing effects of the COVID-19 pandemic globally. Earlier literature indicated that hybrid antenatal schedules are met with satisfaction across a range of patient groups, but further research is needed to determine whether similar outcomes can be achieved outside the context of a global pandemic, where funding, motivation, and acceptability might differ.

evidence is hampered by small population sizes with insufficient power to detect effects on rare perinatal outcomes.

We aimed to evaluate telehealth-integrated antenatal care (referred to as integrated care) for 12 months after its implementation, providing a larger population to explore the effects of telehealth on pregnancy outcomes in low-risk and high-risk care models.

Methods

Study design

We conducted an interrupted time-series analysis comparing key pregnancy outcomes during a period of conventional care (Jan 1, 2018, to March 22, 2020; 116 weeks) with those achieved during a period of integrated care (April 20, 2020 to April 25, 2021; 52 weeks), allowing for a 1-month implementation period (March 23 to April 19, 2020; 4 weeks). The study was done at Monash Health, a public health service in Melbourne (VIC, Australia) comprising one tertiary referral (Monash Medical Centre) and two secondary hospitals (Casey Hospital and Dandenong Hospital). The service provides maternity care for around 10 000 births per year, with approximately 100 000 antenatal consultations occurring annually.

This research was approved by the Monash Health human ethics review committee (RES21-0000-295Q), which included approval to use routinely collected healthcare data without individual patient consent. Findings are presented in accordance with STROBE guidelines.

Participants

We analysed all singleton pregnancies in women who received antenatal care at the health service and gave birth between Jan 1, 2018, and April 25, 2021, that were delivered at 20 weeks' gestation or later or had a birthweight of at least 400 g (if duration of gestation was unknown). Exclusion criteria were multiple births, births for which private antenatal care was received, and births to women who had not planned to give birth at Monash Health (consisting of transfers from non-Monash Health hospitals, and those with no antenatal care). Those who gave birth during the implementation period were excluded from analyses to minimise misclassification bias, as they received little telehealth care as part of their antenatal care.

Antenatal care models

During the conventional care period, women received ten in-person consultations throughout pregnancy, with additional visits according to clinical need in line with national guidelines.[7] Integrated care was provided as previously outlined.[6] Telehealth appointments were delivered via telephone or videoconference and were supported by remote monitoring protocols for blood pressure and self-measured symphyseal-fundal height, as previously detailed.[6] Routine screening for gestational diabetes was done throughout the study by oral glucose-tolerance testing. However, endocrinology consultations for women with gestational diabetes were done virtually during the integrated period.

Low-risk models were defined as midwifery-led, shared care (hospital and general practitioner), and collaborative care (combined midwifery and obstetric care). High-risk models were obstetric specialist-led care. Suitability for midwifery-led care was determined according to national guidelines,[8] while those requiring specialist-led care included those with complex medical comorbidities, obstetric complications, or general health concerns. All other women were eligible for collaborative-care or shared-care pathways.

Data sources and extraction

Routinely collected data were extracted from the Birthing Outcomes System (version 6.0; Management Consultants and Technology Services, Melbourne, VIC, Australia) and the Monash Health Business Intelligence platform, as previously detailed.[5] Gestational age of the fetus at the time of pre-eclampsia diagnosis was obtained through review of electronic and scanned medical records.

Maternal demographic variables extracted included age, BMI, smoking status, parity, region of birth, interpreter requirement, including sign language (yes or no), and postcode to determine Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) score.

Outcomes

The main outcomes pertained to the detection and management of pre-eclampsia, FGR, and gestational diabetes as markers of safety of the telehealth programme. For pre-eclampsia, safety was measured as the delay in diagnosis of pre-eclampsia and the incidence of severe pre-eclamptic complications. Telehealth implementation was evaluated through analysis of antenatal clinic attendance data. Patterns of attendance between periods with and without population lockdown were compared to understand the effects of COVID-19 restrictions on care uptake.

Antenatal clinic appointment data included appointment number, mode (telehealth or in person), and attendance details, with non-attendance defined as a booked appointment unattended by the patient.

Pre-eclampsia was defined in accordance with the International Society for the Study of Hypertension in Pregnancy criteria.[10] Gestational age at diagnosis of pre-eclampsia, latency (interval between diagnosis of pre-eclampsia and birth), and incidence of severe pre-eclamptic complications (a composite of eclampsia; haemolysis, elevated liver enzymes, and low platelets syndrome; placental abruption; acute pulmonary oedema; and stillbirth) were assessed.

FGR was defined according to the 3rd and 10th birthweight percentiles, determined from local

	Conventional period (N=17 873)	Integrated period (N=8131)	Difference (95% CI)*
Age, years	30·63 (5·14)	30·88 (5·16)	0·24 (0·11 to 0·39)
BMI, kg/m²	25·52 (1·25), N=17 828	26·14 (1·24), N=8122	0·62 (0·45 to 0·78)
Smoking during pregnancy	1073/17 873 (6·00%)	482/8131 (5·93%)	−0·08 (−0·70 to 0·54)
Nulliparity	6969/17 873 (38·99%)	3158/8131 (38·84%)	−0·15 (−1·43 to 1·13)
Maternal region of birth			
Australia	6662/17 873 (37·27%)	3235/8131 (39·79%)	2·51 (1·23 to 3·79)
Oceania†	580/17 873 (3·25%)	245/8131 (3·01%)	−0·23 (−0·69 to 0·22)
Asia	8602/17 873 (48·13%)	3859/8131 (47·46%)	−0·67 (−1·98 to 0·64)
Europe	797/17 873 (4·46%)	274/8131 (3·37%)	−1·09 (−1·58 to −0·59)
Africa	739/17 873 (4·13%)	328/8131 (4·03%)	−0·10 (−0·62 to 0·42)
Americas	161/17 873 (0·90%)	60/8131 (0·74%)	−0·16 (−0·39 to 0·07)
Other‡	321/17 873 (1·80%)	131/8131 (1·61%)	−0·18 (−0·52 to 0·15)
Not stated	30/17 873 (0·17%)	6/8131 (0·07%)	−0·09 (−0·18 to −0·001)
SEIFA-IRSAD score (2016)[9]			
1st decile (most disadvantaged)	3413/17 868 (19·10%)	1517/8131 (18·66%)	−0·44 (−1·47 to 0·58)
10th decile (least disadvantaged)	396/17 868 (2·22%)	171/8131 (2·10%)	−0·11 (−0·49 to 0·27)
Antenatal consultations offered			
In person	129 407/129 514 (99·92%)	40 538/74 982 (54·06%)	−45·85 (−46·21 to −45·50)
Not attended§	6792/129 407 (5·25%)	2266/40 538 (5·59%)	0·34 (0·09 to 0·60)
Telehealth	107/129 514 (0·08%)	34 444/74 982 (45·94%)	45·85 (45·50 to 46·21)
Not attended§	1/107 (0·93%)	2338/34 444 (6·79%)	5·85 (4·01 to 7·70)

Data are mean (SD), n/N (%), or difference (95% CI). SEIFA-IRSAD=Socio-Economic Indexes for Areas Index of Relative Socio-economic Advantage and Disadvantage. *Mean or percentage points difference in integrated period versus conventional period. †Includes New Zealand and Norfolk Island. ‡Includes Micronesia, Polynesia, and Melanesia. §Denominators reflect the total number of appointments of that type offered during the period.

Table 1: **Maternal baseline characteristics in the conventional and integrated periods**

population charts customised for sex.[11] Incidence of induction of labour for suspected FGR, incidence of undetected FGR (defined as birthweight <3rd percentile at ≥40 weeks' gestation divided by the number of babies with a birthweight <3rd percentile born at ≥32 weeks' gestation),[12] and incidence of unnecessary early-term induction of labour (defined as induction for suspected FGR at <39 weeks' gestation with birthweight ≥10th percentile among all babies born at >35 weeks' gestation with birthweight ≥10th percentile),[13] were calculated.

Gestational diabetes was diagnosed according to the Australasian Diabetes in Pregnancy Society guidelines.[14] We calculated the proportion of individuals with gestational diabetes, proportion who required insulin, and the incidence of macrosomia at birth (birthweight >97th percentile)[11] among babies born to an individual with gestational diabetes.

Perinatal outcomes, including gestational age at birth, birthweight, preterm birth (<37 weeks' gestation), stillbirth, and need for neonatal intensive care unit (NICU) admission were assessed. Stillbirth was defined as the death before birth of a baby born at 20 weeks' gestation or more or weighing at least 400 g.

Statistical analysis

Power calculations were not done due to the emerging pandemic and necessity for rapid implementation of integrated care. We included all singleton pregnancies registered at Monash Health during the study period, enabling a whole-population assessment.

Appointment data, including mode, number per week, and attendance rates were compared between conventional and integrated periods with descriptive statistics. To analyse telehealth uptake, the proportion of appointments by mode and non-attendance rates were evaluated during the integrated period with and without population lockdown. To analyse engagement with telehealth care, descriptive analysis of population characteristics was done to assess those attending all scheduled appointments compared with those with non-attendance of at least one antenatal appointment by mode (in-person only, telehealth only, or both) during the integrated period. A further comparison was done to assess whether those missing solely in-person consultations differed to those missing solely telehealth appointments. Differences in population characteristics and outcome rates, separated into low-risk and high-risk care models, were compared between the conventional and integrated periods by use of the χ^2 test, independent *t* test, or Mann-Whitney *U* test.

The effect of the integrated period on outcomes was also assessed with stratification by parity. Differences and 95% CIs were assessed with use of *t* tests or the Hodges-Lehmann method. Incidence of each binary outcome per week and the mean values of continuous variables per 2 weeks were calculated to account for weeks in which the outcome incidence was zero. An interrupted time-series analysis using a Prais-Winsten generalised least-squares regression-based approach was done to compare the conventional and integrated periods, excluding the 4-week implementation period. Low-risk and high-risk care groups were modelled separately. Analyses were not corrected for seasonality. Autocorrelation of residuals was accounted for by including the autocorrelation value of 1 in the model. Robust standard errors were included in our model to address the autocorrelation of the variance values of our outcome, for each level of the predictor. Coefficients reported include the pre-trend slope (rate of change in weekly incidence of outcomes in the conventional period), the intervention slope (difference in rate of change in incidence of outcomes during the integrated period relative to the conventional period), and the post-trend slope (weekly rate of change in incidence of outcomes during the integrated period). The intervention coefficient indicates whether integrated care resulted in a divergence in the level and trend of each pregnancy outcome when compared with conventional period trends. Analyses were done with Stata 17 (standard edition). The threshold for statistical significance was set to $p<0·05$.

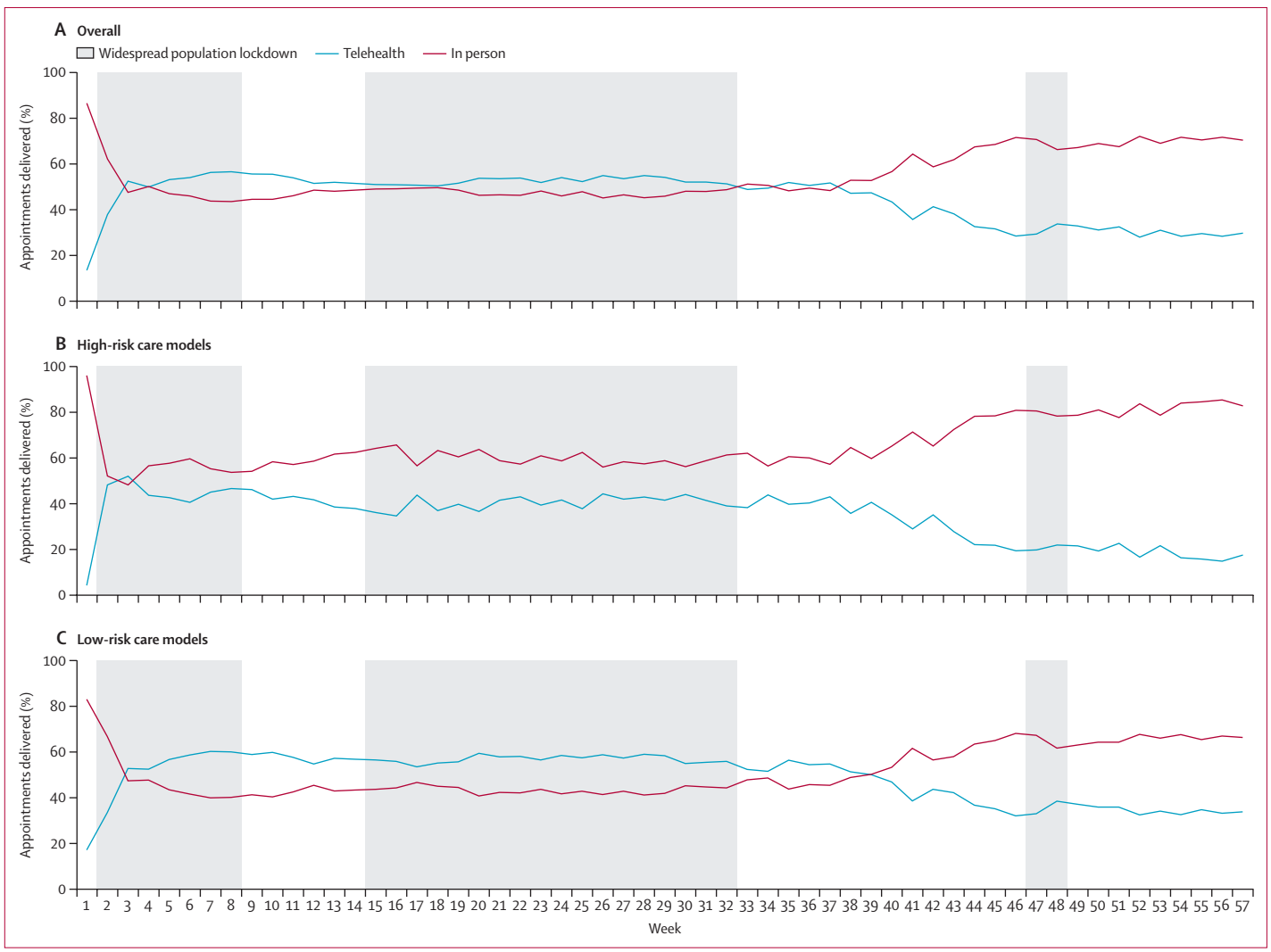

Figure 1: **Weekly proportions of in-person and telehealth antenatal appointments delivered**
Weekly proportion of antenatal appointments for in-person and telehealth consultations across all care models (A), high-risk care models (B), and low-risk care models (C), after implementation of telehealth-integrated antenatal care on April 23, 2020. Shaded areas indicate periods of widespread population lockdown in Melbourne (VIC, Australia) during the COVID-19 pandemic: March 30 to May 12, 2020; June 31 to Oct 27, 2020; and Feb 12 to Feb 17, 2021.

Role of the funding source
There was no funding source for this study.

Results
Between Jan 1, 2018, and April 25, 2021, there were 29741 births, of which 26004 (17873 during the conventional care period and 8131 during the integrated care period) were included in the analysis (appendix p 1). Among the mothers included, 10127 were nulliparous (8553 in low-risk and 1574 in high-risk care models) and 15877 were multiparous (12433 in low-risk and 3444 in high-risk care models). During the integrated care period, ten women were diagnosed with COVID-19. Baseline characteristics are presented in table 1. Data were complete, with few missing variables (birthweight [0·01% missing], NICU admission [1·09%], BMI [0·20%], sex of baby [0·06%], and gestational age at pre-eclampsia diagnosis [0·10%]).

During the integrated period, 74982 antenatal consultations were provided: 34444 (45·94%) via telehealth (99·45% by videoconference) and 40538 (54·05%) in person. In comparison, 129407 (99·92%) of 129514 antenatal consultations during the conventional period were in person, with most (96·26%) of the 107 telehealth appointments during the conventional period done by telephone.

Telehealth was rapidly implemented (figure 1), replacing 52·7% of antenatal consultations (698 of 1325 per week; 56·7% in low-risk and 40·9% in high-risk models) in the first 33 weeks of the integrated period,

See Online for appendix

Figure 2: **Non-attendance rates per week following telehealth implementation**
Proportion of missed appointments for in-person and telehealth consultations for all care models (A), high-risk care models (B), and low-risk care models (C). The purple horizontal line indicates the baseline non-attendance rate of 5·2% during the conventional period (Jan 1, 2018, to March 22, 2020). Shaded areas indicate periods of widespread population lockdown in Melbourne (VIC, Australia) during the COVID-19 pandemic: March 30 to May 12, 2020; June 31 to Oct 27, 2020; and Feb 12 to Feb 17, 2021.

coinciding with a period of major population lockdowns. As movement restrictions lifted in the last 20 weeks of the study, the mean proportion of telehealth consultations decreased to 34·0% (452 of 1331 consultations per week; 37·8% in low-risk and 23·6% in high-risk models). Overall, 49·6% of appointments in low-risk and 34·4% in high-risk models were conducted virtually during the integrated period.

The conventional period average weekly non-attendance rate of 5·2% rose to 6·1% in the integrated period (p<0·0010; figure 2), driven by significantly increased rates of non-attendance in the integrated period for both telehealth appointments (non-attendance 6·79%; 5·85 percentage points [95% CI 4·01 to 7·70] increase *vs* conventional period) and in-person consultations (5·59%; 0·34 percentage points [0·09 to 0·60]; table 1). Compared with in-person appointments, a greater proportion of telehealth visits were not attended in the integrated period in both low-risk models (5·9% *vs* 4·7%) and high-risk models (8·9% *vs* 7·8%; figure 2). Characteristics associated with non-attendance regardless of appointment mode were younger maternal age, smoking, multiparity, socioeconomic disadvantage, origin from Oceania and other southwest Pacific regions, need for an interpreter, and having been assigned to a high-risk care model (all p<0·01; appendix pp 6–7). Compared with those who missed in-person appointments only, those who solely missed telehealth appointments were less likely to be nulliparous (30·84% *vs* 35·98%; difference 5·14 percentage points [0·36 to 9·93]), in a high-risk care model (22·32% *vs* 27·34%; 5·01 percentage points [0·63 to 9·40]), or at the extremes of socioeconomic

disadvantage (21·29 *vs* 25·94%; 4·65 percentage points [0·34 to 8·96]) or advantage (0·65% *vs* 1·95%; 1·31 percentage points [0·15 to 2·47]; appendix p 8).

Pre-eclampsia rates were similar during the conventional and integrated periods for low-risk and high-risk care models, with no significant difference in gestational

	Conventional period	Integrated period	Difference (95% CI)*	p value
Low-risk care models				
Pre-eclampsia				
Women diagnosed with pre-eclampsia	397/14 504 (2·74%)	162/6482 (2·50%)	−0·24 (−0·70 to 0·23)	0·32
Median gestational age at birth, weeks†	38·2 (37·2 to 39·3)	38·1 (37·0 to 39·1)	−0·1 (−0·4 to 0·1)	0·38
Median gestational age at diagnosis, weeks†	37·4 (36·0 to 38·6)	37·1 (35·35 to 38·5)	−0·3 (−0·7 to 0·1)	0·27
Median latency period, days†‡	3 (1 to 8)	3 (1 to 9)	0 (0 to 1)	0·27
Severe complications§	131/14 504 (0·90%)	76/6482 (1·17%)	0·27 (−0·035 to 0·57)	0·068
Severe complications in women diagnosed with pre-eclampsia	21/397 (5·29%)	11/162 (6·79%)	1·50 (−2·96 to 5·96)	0·49
Gestational diabetes				
Women diagnosed with gestational diabetes	3231/14 504 (22·28%)	1629/6482 (25·13%)	2·85 (1·60 to 4·11)	<0·0010
Individuals with gestational diabetes requiring insulin	1172/14 504 (8·08%)	501/6482 (7·73%)	−0·35 (−1·13 to 0·44)	0·39
With macrosomia of baby at birth (birthweight >97th percentile)	102/3230 (3·16%)	38/1629 (2·33%)	−0·83 (−1·77 to 0·12)	0·11
FGR				
Median birthweight, g	3360 (3031·5 to 3670)	3370 (3070 to 3685·5)	10 (0 to 30)	0·066
Median gestational age at birth, weeks	39·2 (38·3 to 40·1)	39·2 (38·3 to 40·1)	0·0 (0·0 to 0·0)	0·85
Singletons with birthweight <10th percentile	1333/14 492 (9·20%)	567/6478 (8·75%)	−0·45 (−1·28 to 0·39)	0·30
Singletons with birthweight <3rd percentile	235/14 492 (1·62%)	113/6478 (1·74%)	0·12 (−0·26 to 0·50)	0·52
Induction of labour for suspected FGR	535/14 504 (3·69%)	196/6482 (3·02%)	−0·66 (−1·18 to −0·15)	0·015
Undetected FGR¶	65/227 (28·63%)	22/107 (20·56%)	−8·07 (−17·73 to 1·58)	0·12
Unnecessary early-term induction of labour for suspected FGR‖	168/12 943 (1·30%)	47/5806 (0·81%)	−0·49 (−0·79 to −0·19)	0·0037
Perinatal morbidity and mortality				
Preterm birth (<37 weeks' gestation)	724/14 504 (4·99%)	325/6482 (5·01%)	0·02 (−0·62 to 0·66)	0·95
NICU admission	195/14 415 (1·35%)	77/6378 (1·21%)	−0·15 (−0·47 to 0·18)	0·40
Stillbirth	89/14 504 (0·61%); 6·1 per 1000	49/6482 (0·76%); 7·6 per 1000	0·14 (−0·10 to 0·39)	0·24
Fetal death in utero	55/14504 (0·38%); 3·8 per 1000	32/6482 (0·49%); 4·9 per 1000	0·11 (−0·08 to 0·31)	0·23
Termination of pregnancy	34/14504 (0·23%); 2·3 per 1000	17/6482 (0·26%); 2·6 per 1000	0·03 (−0·12 to 0·28)	0·71
High-risk care models				
Pre-eclampsia				
Women diagnosed with pre-eclampsia	217/3369 (6·44%)	93/1649 (5·64%)	−0·80 (−2·19 to 0·59)	0·27
Median gestational age at birth, weeks†	37·1 (34·6 to 38·2)	37·3 (36·2 to 38·2)	0·3 (−0·1 to 0·9)	0·16
Median gestational age at diagnosis, weeks†	35·5 (32·25 to 37·3)	36·3 (33·4 to 37·3)	0·3 (−0·3 to 1·1)	0·33
Median latency period, days†‡	5 (1 to 13)	4 (1 to 13)	0 (−1 to 1)	0·58
Severe complications§	83/3369 (2·46%)	32/1649 (1·94%)	−0·52 (−1·37 to 0·32)	0·24
Severe complications in women diagnosed with pre-eclampsia	20/217 (9·22%)	8/93 (8·60%)	−0·61 (−7·49 to 6·26)	0·86
Gestational diabetes				
Individuals diagnosed with gestational diabetes	967/3369 (28·70%)	561/1649 (34·02%)	5·32 (2·57 to 8·07)	<0·0010
Individuals with gestational diabetes requiring insulin	499/3369 (14·81%)	259/1649 (15·71%)	0·89 (−1·23 to 3·02)	0·41
With macrosomia of baby at birth (birthweight >97th percentile)	54/967 (5·58%)	27/561 (4·81%)	−0·77 (−3·06 to 1·52)	0·52
FGR				
Median birthweight, g	3210 (2790 to 3590)	3260 (2850 to 3620)	45 (10 to 80)	0·017
Median gestational age at birth, weeks	38·4 (37·4 to 39·4)	38·5 (37·5 to 39·3)	0·0 (0·0 to 0·10)	0·55
Singletons with birthweight <10th percentile	438/3369 (13·00%)	210/1648 (12·74%)	−0·26 (−2·23 to 1·71)	0·80
Singletons with birthweight <3rd percentile	136/3369 (4·04%)	68/1648 (4·13%)	0·089 (−1·08 to 1·26)	0·88
Induction of labour for suspected FGR	142/3369 (4·21%)	69/1649 (4·18%)	−0·031 (−1·21 to 1·15)	0·96
Undetected FGR¶	11/108 (10·19%)	5/59 (8·47%)	−1·71 (−10·82 to 7·40)	0·72
Unnecessary early-term induction of labour for suspected FGR‖	32/2704 (1·18%)	19/1342 (1·42%)	0·23 (−0·52 to 0·98)	0·53

(Table 2 continues on next page)

	Conventional period	Integrated period	Difference (95% CI)*	p value
(Continued from previous page)				
Perinatal morbidity and mortality				
Preterm birth (<37 weeks' gestation)	531/3369 (15·76%)	238/1649 (14·43%)	–1·33 (–3·42 to 0·77)	0·22
NICU admission	335/3315 (10·11%)	186/1608 (11·57%)	1·46 (–0·41 to 3·33)	0·12
Stillbirth	51/3369 (1·51%); 15·1 per 1000	17/1649 (1·03%); 10·3 per 1000	–0·48 (–1·12 to 0·16)	0·17
Fetal death in utero	32/3369 (0·95%); 9·5 per 1000	14/1649 (0·95%); 8·5 per 1000	–0·10 (–0·65 to 0·45)	0·72
Termination of pregnancy	19/3369 (0·56%); 5·6 per 1000	3/1649 (0·18%); 1·8 per 1000	–0·38 (–0·71 to –0·06)	0·054

Data are n/N (%), median (IQR), or difference (95% CI). Number per 1000 births is also shown for stillbirth outcomes. The conventional period was from Jan 1, 2018, to March 22, 2020. The integrated period was from April 20, 2020 to April 25, 2021. FGR=fetal growth restriction. NICU=neonatal intensive care unit. *Mean or percentage points difference in integrated period versus conventional period. †Women diagnosed with antenatal or intrapartum pre-eclampsia. ‡Latency period defined as the interval between diagnosis of pre-eclampsia and delivery. §Severe complication was defined as a composite of haemolysis, elevated liver enzymes and low platelets syndrome, eclampsia, placental abruption, stillbirth, and acute pulmonary oedema. ¶Defined as singletons with birthweight <3rd percentile born at ≥40 weeks' gestation; incidence calculated as the percentage of babies born at ≥40 weeks' gestation with birthweight <3rd percentile among all babies born at ≥32 weeks' gestation with birthweight <3rd percentile. ||Defined as induction of labour at <39 weeks' gestation for suspected FGR with birthweight ≥10th percentile; incidence calculated as the percentage of babies induced for suspected FGR at <39 weeks' gestation with birthweight ≥10th percentile among all babies born at >35 weeks' gestation with birthweight ≥10th percentile).

Table 2: **Maternal and neonatal outcomes for low-risk and high-risk care models**

age at diagnosis, gestational age at birth, latency, or rates of severe complications for individuals with pre-eclampsia (table 2). These same findings were seen regardless of parity (appendix pp 9–12). Gestational age at diagnosis of pre-eclampsia continued to decline in low-risk models throughout the integrated period (–0·05% change per week [95% CI –0·10 to 0·006]; p=0·086), with no change in high-risk models (0·07% change per week [–0·11 to 0·25]; p=0·424). Rate of change over time in the latency between pre-eclampsia diagnosis and birth, and proportion of births associated with severe pre-eclamptic complications also remained unchanged (table 3; appendix p 4).

In high-risk models, median birthweight was significantly higher during the integrated period (3260 g) than the conventional period (3210 g; difference 45 g [95% CI 10 to 80]; table 2). This difference appears to be mostly driven by high-risk multiparous pregnancies (3256 g *vs* 3320 g; 50 g [95% CI 4 to 90]; appendix p 11). Gestational age at birth remained unchanged in all models (table 2). Although we found no difference in the proportion of babies with a birthweight below the 3rd percentile in low-risk care models (1·62% in the conventional period *vs* 1·74% in the integrated period; difference 0·12 percentage points [–0·26 to 0·50]) or high-risk care models (4·04% *vs* 4·13%, 0·089 percentage points [–1·08 to 1·26]), the proportion who underwent induction of labour for suspected FGR was significantly lower in the integrated period in low-risk models (3·69% *vs* 3·02%, –0·66 percentage points [–1·18 to –0·15]). Similar findings were observed for the balance measure of unnecessary early-term induced labour for suspected FGR of a baby born at or above the 10th birthweight percentile (low-risk models 1·30% *vs* 0·81%, difference –0·49 percentage points [–0·79 to –0·19]; table 2). This significant reduction in the unnecessary early-term induction of labour for suspected FGR was seen in both nulliparous (1·53% *vs* 0·97%, –0·56 percentage points [–1·09 to –0·035]) and multiparous low-risk pregnancies with integrated care (1·15% *vs* 0·71%, –0·44 percentage points [–0·80 to –0·08]; appendix pp 9–12). No other significant differences in FGR detection or outcomes based on parity were observed. Compared with conventional care, the number of inductions for suspected FGR declined by 0·04% per week following telehealth integration in low-risk models (–0·07 to –0·01; p=0·0040), with a similar, although non-significant, rate seen in high-risk models (–0·04% weekly change [–0·09 to 0·02], p=0·204; table 3; appendix p 2).

Significantly more individuals were diagnosed with gestational diabetes in the integrated period than in the conventional period for low-risk care models (22·28% *vs* 25·13%, difference 2·85 percentage points [95% CI 1·60 to 4·11]) and high-risk models (28·70% *vs* 34·02%, 5·32 percentage points [2·57 to 8·07]; table 2). This rise was seen regardless of parity in low-risk models, while in high-risk models it was observed only in multiparous women (28·30% *vs* 36·06%; 7·76 percentage points [4·41 to 11·11]; appendix p 7). The proportions of individuals with gestational diabetes treated with insulin or who gave birth to a baby with macrosomia did not differ significantly overall (table 2); however, in low-risk nulliparous pregnancies, the rate of macrosomia was significantly reduced in the integrated period (2·25% *vs* 0·85%, –1·40 percentage points [–2·52 to –0·28]; appendix p 9). The weekly rate of change for individuals with gestational diabetes giving birth to macrosomic babies was 0·06% (0·006 to 0·12; p=0·031) in low-risk models after telehealth integration compared with conventional care (table 3; appendix p 3).

Although no significant differences were observed in the crude rates of babies requiring NICU admission in either care model (table 2), significant reductions in NICU admission rates of –0·02% change per week

(95% CI –0·03 to –0·003; p=0·018) in low-risk models and –0·10% change per week (–0·19 to –0·001; p=0·047) in high-risk models was observed following telehealth integration (table 3; appendix p 5), a notable departure from increasing trends observed within the conventional period. This trend was not clearly driven by changes in

	Pre-trend slope*		Level change†		Post-trend slope‡		Intervention§	
	Change (95% CI)	p value	Change (95% CI)	p value	Change (95% CI)	p value	Change (95% CI)	p value
Low-risk care models								
Pre-eclampsia								
Women diagnosed with pre-eclampsia	–0·004% (–0·01 to 0·007)	0·483	0·014% (–1·02 to 1·05)	0·979	0·001% (–0·03 to 0·03)	0·972	0·003% (–0·03 to 0·04)	0·841
Mean gestational age at diagnosis, weeks¶	–0·01 (–0·03 to –0·004)	0·116	0·99 (0·10 to 1·88)	0·029	–0·06 (–0·11 to –0·01)	0·017	–0·05 (–0·10 to 0·006)	0·086
Mean gestational age at diagnosis, days¶	–0·11 (–0·24 to 0·02)	0·106	7·16 (0·93 to 13·4)	0·025	–0·44 (–0·79 to –0·09)	0·014	–0·33 (–0·71 to 0·04)	0·078
Mean gestational age at birth, weeks¶	–0·01 (–0·02 to 0·005)	0·230	0·60 (0·05 to 1·15)	0·033	–0·03 (–0·07 to –0·004)	0·025	–0·03 (–0·06 to 0·006)	0·106
Mean latency period, days‖	0·05 (–0·02 to 0·12)	0·150	–2·75 (–6·86 to 1·37)	0·188	0·19 (–0·06 to 0·43)	0·133	0·13 (–0·12 to 0·39)	0·293
Severe complication in women diagnosed with pre-eclampsia	0·0004% (–0·001 to 0·002)	0·651	0·095% (–0·16 to 0·35)	0·458	–0·003% (–0·01 to 0·004)	0·395	–0·004% (–0·01 to 0·004)	0·355
Gestational diabetes								
Individuals diagnosed with gestational diabetes	0·03% (0·01 to 0·05)	0·0020	–2·67% (–5·40 to 0·62)	0·055	0·14% (0·07 to 0·21)	<0·0010	0·11% (0·03 to 0·18)	0·0050
Individuals with gestational diabetes requiring insulin	–0·0003% (–0·02 to 0·01)	0·965	–0·71% (–2·43 to 1·01)	0·415	0·02% (–0·03 to 0·06)	0·504	0·02% (–0·03 to 0·07)	0·516
With macrosomia of baby at birth (birthweight >97th percentile)	–0·03% (–0·04 to –0·01)	0·0010	–0·34% (–1·97 to 1·28)	0·675	0·04% (–0·02 to 0·09)	0·186	0·06% (0·006 to 0·12)	0·031
FGR								
Singletons with birthweight <10th percentile	–0·002% (–0·02 to 0·01)	0·795	0·58% (–0·90 to 2·06)	0·440	–0·04% (–0·08 to 0·01)	0·128	–0·03% (–0·08 to 0·01)	0·169
Singletons with birthweight <3rd percentile	–0·003% (–0·01 to 0·004)	0·430	0·62% (–0·08 to 1·32)	0·083	–0·01% (–0·03 to 0·006)	0·186	–0·009% (–0·03 to 0·01)	0·340
Induction of labour for suspected FGR	–0·008% (–0·02 to 0·003)	0·159	1·22% (–0·04 to 2·47)	0·057	–0·05% (–0·08 to –0·02)	<0·0010	–0·04% (–0·07 to –0·01)	0·0040
Undetected FGR**	–0·09% (–0·25 to 0·07)	0·274	6·96% (–11·6 to 25·5)	0·459	–0·29% (–0·76 to 0·18)	0·228	–0·20% (–0·70 to 0·30)	0·428
Unnecessary early-term induction of labour for suspected FGR††	–0·006% (–0·01 to –0·001)	0·020	0·17% (–0·41 to 0·76)	0·558	–0·01% (–0·03 to 0·003)	0·120	–0·006% (–0·02 to 0·01)	0·479
Perinatal morbidity and mortality								
Preterm birth (<37 weeks' gestation)	0·00009% (–0·01 to 0·01)	0·986	–0·48% (–1·85 to 0·88)	0·487	0·02% (–0·02 to 0·06)	0·324	0·02% (–0·02 to 0·06)	0·344
NICU admission	0·005% (–0·0003 to 0·01)	0·065	–0·07% (–0·64 to 0·49)	0·800	–0·01% (–0·03 to 0·0006)	0·061	–0·02% (–0·03 to –0·003)	0·018
Stillbirth	0·0007% (–0·002 to 0·004)	0·664	–0·08% (–0·54 to 0·37)	0·722	0·008% (–0·007 to 0·02)	0·297	0·007% (–0·008 to 0·02)	0·355
High-risk care models								
Pre-eclampsia								
Women diagnosed with pre-eclampsia	0·002% (–0·02 to 0·03)	0·865	0·36% (–2·66 to 3·39)	0·814	–0·05% (–0·13 to 0·03)	0·207	–0·05% (–0·14 to 0·03)	0·207
Mean gestational age at diagnosis, weeks¶	0·015 (–0·03 to 0·06)	0·499	–1·32 (–4·52 to 1·87)	0·412	0·09 (–0·08 to 0·26)	0·313	0·07 (–0·11 to 0·25)	0·424
Mean gestational age at diagnosis, days¶	0·11 (–0·21 to 0·43)	0·491	–9·36 (–31·8 to 13·0)	0·408	0·61 (–0·58 to 1·80)	0·313	0·50 (–0·74 to 1·74)	0·427
Mean gestational age at birth, weeks¶	0·02 (–0·02 to 0·06)	0·367	–1·09 (–3·89 to 1·70)	0·439	0·07 (–0·08 to 0·23)	0·347	0·06 (–0·10 to 0·21)	0·492
Mean latency period, days‖	–0·002 (–0·15 to 0·15)	0·977	2·15 (–6·28 to 10·6)	0·613	–0·09 (–0·49 to 0·32)	0·674	–0·08 (–0·52 to 0·35)	0·700
Severe complication in women diagnosed with pre-eclampsia	–0·004% (–0·01 to 0·003)	0·284	0·39% (–0·45 to 1·22)	0·361	–0·01% (–0·03 to 0·01)	0·353	–0·007% (–0·03 to 0·02)	0·545

(Table 3 continues on next page)

	Pre-trend slope*		Level change†		Post-trend slope‡		Intervention§	
	Change (95% CI)	p value	Change (95% CI)	p value	Change (95% CI)	p value	Change (95% CI)	p value
(Continued from previous page)								
Gestational diabetes								
Individuals diagnosed with gestational diabetes	0·02% (–0·03 to 0·07)	0·513	0·74% (–5·62 to 7·09)	0·820	0·11% (–0·04 to 0·27)	0·161	0·09% (–0·07 to 0·26)	0·256
Individuals with gestational diabetes requiring insulin	0·04% (0·001 to 0·08)	0·044	–0·67% (–5·37 to 4·02)	0·777	–0·04% (–0·15 to 0·08)	0·545	–0·08% (–0·20 to 0·05)	0·220
With macrosomia of baby at birth (birthweight >97th percentile)	–0·03% (–0·07 to 0·010)	0·133	1·83% (–3·11 to 6·78)	0·465	–0·03% (–0·15 to 0·09)	0·624	0·0009% (–0·13 to 0·13)	0·990
FGR								
Singletons with birthweight <10th percentile	0·01% (–0·02 to 0·05)	0·406	–1·51% (–4·99 to 1·98)	0·395	0·03% (–0·06 to 0·12)	0·539	0·02% (–0·08 to 0·11)	0·754
Singletons with birthweight <3rd percentile	0·02% (0·0008 to 0·04)	0·040	–0·61 (–2·59 to 1·37)	0·543	–0·01% (–0·06 to 0·04)	0·651	–0·03% (–0·08 to 0·02)	0·252
Induction of labour for suspected FGR	0·004% (–0·01 to 0·02)	0·667	0·58% (–1·60 to 2·76)	0·600	–0·03% (–0·08 to 0·02)	0·232	–0·04% (–0·09 to 0·02)	0·204
Undetected FGR**	–0·06% (–0·22 to 0·09)	0·422	–1·78% (–12·3 to 8·76)	0·739	0·10% (–0·12 to 0·31)	0·372	0·16% (–0·10 to 0·42)	0·232
Unnecessary early-term induction of labour for suspected FGR††	–0·002% (–0·02 to 0·01)	0·813	0·30% (–1·48 to 2·08)	0·740	–0·003% (–0·05 to 0·04)	0·909	–0·0008% (–0·05 to 0·05)	0·974
Perinatal morbidity and mortality								
Preterm birth (<37 weeks' gestation)	–0·003% (–0·05 to 0·04)	0·876	0·22% (–4·18 to 4·61)	0·922	–0·047% (–0·15 to 0·06)	0·389	–0·04% (–0·16 to 0·07)	0·459
NICU admission	0·003% (–0·03 to 0·04)	0·845	3·58% (0·10 to 7·05)	0·044	–0·09% (–0·19 to –0·004)	0·042	–0·10% (–0·19 to –0·001)	0·047
Stillbirth	0·01% (–0·004 to 0·02)	0·149	–0·68% (–2·60 to 1·25)	0·488	–0·009% (–0·06 to 0·04)	0·745	–0·02% (–0·07 to 0·04)	0·499

Interrupted time-series data are presented as % change per week (95% CI), except where specified. Values are given to 2 decimal places, or 1 significant figure for values >–0·01 and <0·01. FGR=fetal growth restriction. NICU=neonatal intensive care unit. *Change in rate of outcomes per week during the conventional period. †Change in level of outcome in the period immediately following intervention initiation (excluding the 4-week implementation period) compared with the counterfactual. ‡Change in rate of respective outcomes per week during the integrated care period. §Change in incidence of outcome per week during the telehealth-integrated period when compared to the conventional period. ¶Data are % change in mean gestational age per 2-week period. ||Defined as the interval between diagnosis of pre-eclampsia and delivery; data are change in mean latency period per 2-week period (days). **Incidence calculated as the percentage of babies born at ≥40 weeks' gestation with birthweight <3rd percentile among all babies born at ≥32 weeks' gestation with birthweight <3rd percentile. ††Incidence calculated as the percentage of babies induced for suspected FGR at <39 weeks› gestation with birthweight ≥10th percentile among all babies born at >35 weeks' gestation with birthweight ≥10th percentile.

Table 3: **Interrupted time-series analysis of maternal and neonatal outcomes for low-risk and high-risk care models**

preterm birth, with no significant differences in rates (table 2) or change over time (table 3; appendix p 5) observed for either care model.

Combined analysis of care models (n=26 004) revealed no significant difference in stillbirth rate (7·8 per 1000 births *vs* 8·1 per 1000 births; p=0·81) or weekly incidence (0·002% weekly change [95% CI –0·01 to 0·02], p=0·81) during the integrated versus the conventional period (tables 2, 3; appendix p 5). A reduction in stillbirth following telehealth implementation in high-risk models was evident (15·1 per 1000 births [1·51%] *vs* 10·3 per 1000 births [1·03%], difference –0·48 percentage points [95% CI –1·12 to 0·16]), largely driven by decreased pregnancy terminations during the integrated period (5·6 per 1000 births [0·56%] *vs* 1·8 per 1000 births [0·18%], –0·38 percentage points [–0·71 to –0·06]; table 2).

Discussion

In an Australian public health service, telehealth replaced 45·94% of in-person antenatal consultations over a 12-month period without adversely affecting perinatal outcomes. This study, the largest study of the use of telehealth for antenatal care to date globally, showed no significant differences in the detection of pre-eclampsia and FGR, missed FGR, or rates of perinatal mortality but a significant increase in the number of women diagnosed with gestational diabetes. Moreover, the outcomes achieved at the 3-month evaluation[5] were maintained a year after implementation.

There were theoretical concerns from health-care providers that a shift to hybrid antenatal care could delay the diagnosis of pre-eclampsia, particularly because delays could contribute to disease progression and poorer outcomes. Reassuringly, gestational age at birth and rate of severe pre-eclamptic complications were not significantly changed by telehealth integration. A long-standing trend in high-risk models towards later pre-eclampsia diagnosis was noted, but the interrupted time-series analysis showed that this was unchanged by telehealth introduction. Although it could suggest diagnosis at more advanced disease states, declining rates of severe complications indicate that the management of pre-eclampsia continues

to improve over time. The good outcomes observed could reflect the application of evidence suggesting that home blood pressure monitoring is safe in pregnancy care and can reduce unnecessary medical intervention.[5,15] Our results also suggest that the use of a remote-to-hospital blood pressure monitoring protocol—which instructed women to either use a personal blood pressure machine (with instructions on how to use it) or visit their general practitioner or pharmacist to measure their blood pressure on the same day as their telehealth appointment, and supported with instructions on when to contact their antenatal care provider based on the blood pressure reading—achieves similar outcomes to models that provide blood pressure monitors to each patient.[5,16] Such infrastructure was not feasible in our study due to cost limitations in a publicly funded service, and time constraints attributable to the emerging pandemic.

Undetected FGR is an antecedent of stillbirth. Australian guidelines recommend measurement of symphyseal-fundal height from 24 weeks' gestation to screen for aberrant fetal growth.[7] Self-measured symphyseal-fundal height was introduced as an adjunct to integrated care as literature suggests similar performance to clinician-measured symphyseal-fundal height.[17] However, there is insufficient evidence to inform on the best application of self-measured symphyseal-fundal height,[18] making this study the first to use the measure in a large population. Lack of difference in FGR below the 3rd birthweight percentile suggests that introduction of self-measured symphyseal-fundal height to support detection of inadequate growth from home was an acceptable addition to measures currently used. However, compliance, correlation with clinical measurements, and how self-measurement of symphyseal-fundal height assisted in the identification of FGR remain to be evaluated. It is also unknown whether the frequency of ultrasound assessment increased during the integrated period. Such an increase might have contributed to improved identification of FGR, but could also have implications for cost-effectiveness of telehealth-integrated care. Our findings suggest that changes in practice to minimise FGR that preceded telehealth implementation were successfully maintained over the study period. There were concerns that reduced in-person appointments might lead to increased early-term induction of labour to prevent adverse outcomes in cases of suspected FGR. However, a significant reduction in the proportion of individuals induced for suspected FGR was seen in low-risk models, without corresponding increases in the incidence of FGR below the 3rd birthweight percentile, NICU admissions, or stillbirths. Additionally, in low-risk care models, we observed a reduction in the incidence of unnecessary early-term induction of labour for suspected FGR in an appropriately grown baby, indicating that such concerns were not warranted. Our findings suggest that most babies with FGR were appropriately detected and managed in the integrated period, while greater numbers of babies without FGR safely progressed to later gestation. The factors influencing this finding remain uncertain. The pandemic did not substantially affect induction-of-labour rates in high-income countries globally, or in Australia.[19,20] Therefore, it remains to be determined whether telehealth-integrated care in low-risk pregnancies led to improved escalation of care when FGR was suspected, and thus improved these outcomes.

Screening for gestational diabetes aligned with national guidelines and remained consistent throughout the study.[14] Thus, the increasing incidence in our population probably reflects pandemic-related changes,[21] with proportionate increases observed in other studies for birthweight[22] and BMI.[23] An increase in the incidence of gestational diabetes was also observed before the COVID-19 pandemic among women randomly allocated to receive telehealth care in the OB Nest trial,[5] suggesting that key differences might exist between virtual and in-person management that require further investigation. Contrastingly, the proportion of individuals who required insulin therapy was unchanged by telehealth implementation, similar to literature showing that virtual management of gestational diabetes is equivalent to in-person care.[4] However, our interrupted time-series analysis showed increasing weekly rates of babies born with macrosomia to a mother with gestational diabetes in low-risk models and a significant increase in birthweight overall, particularly in high risk multiparous women, in whom the rates of gestational diabetes were highest. Although this trend could suggest that some individuals did not achieve optimal glycaemic control, it requires further evaluation as increased rates of babies born with macrosomia were observed Victoria-wide during lockdown.[23]

Preterm birth remained unchanged throughout the study, with continual decline in high-risk models, probably enabled by practice-related changes such as maternal immunisation[24] that preceded telehealth implementation. While our findings are at odds with previously detailed reductions in preterm birth with pandemic-related lockdowns,[21] importantly, our study includes pre-pandemic trends and periods with reduced population lockdown.

Weekly NICU admission rates declined significantly in the integrated period, probably representing a true reduction as patients referred from other locations for tertiary care were excluded. Declining admissions could reflect reductions in unnecessary induction of labour and early-term iatrogenic harm, resulting in healthier, well grown fetuses. Similar reductions in NICU admission were reported in England and Wales,[25] although it remains unclear whether this was related to changing referral pathways or whether telehealth was widely used. Although this change correlates with a population lockdown, a potential confounder, the trend has continued after cessation of lockdown. The decline in NICU admission requires further exploration, but

provides reassurance that integrated care can produce beneficial perinatal outcomes.

Importantly, no significant differences in stillbirth rates were noted—a finding at odds with Victorian[26] and international data.[27] This discrepancy could suggest that our study remains underpowered to analyse stillbirth, given that a non-significant increase of 1·1 stillbirths per 1000 births was observed for low-risk models. Disruptions to health-care services caused by the pandemic, including ultrasound and pregnancy termination services,[28] might have resulted in more missed congenital anomalies or affected pregnancies continuing beyond 20 weeks' gestation. This supposition is supported by an increase in undiagnosed congenital anomalies observed Victoria-wide during 2020 compared with 2018.[24] Further assessment of perinatal demise secondary to congenital anomalies could provide more clarity. Although stillbirth is a possible consequence of COVID-19,[29] the low prevalence of maternal infection in our cohort makes this an unlikely confounder. UK data have similarly shown a significant increase in stillbirth after excluding terminations of pregnancy, none of which occurred in women diagnosed with COVID-19.[27] Further evaluation is needed to assess whether this increase in stillbirth represents unintended consequences of pandemic-associated health-care changes. The potential impact of domestic violence, an established cause of stillbirth, also cannot be excluded. Pandemic-related stresses and movement restrictions have caused an escalation of domestic violence in Australia.[30] Previous literature has raised concerns regarding virtual screening for and management of domestic violence, and particularly with limitations of reviewing women at home, where perpetrators might reside. However, a Cochrane review[31] showed that detection of domestic violence did not significantly differ between in-person and written or computer-based screening. Validated computer-based domestic violence screening tools might be useful adjuncts to in-person screening when delivering integrated care, and could also provide access to virtual resources and online support.

Encouragingly, maternal parity did not alter these findings, with no significant differences observed in outcomes relating to pre-eclampsia, FGR, perinatal morbidity, or stillbirth. This finding is particularly reassuring for nulliparous individuals, who, due to their relative unfamiliarity with pregnancy, might be less able to recognise complications and deviations from normal, as well as being at unknown risk for some pregnancy complications such as pre-eclampsia and FGR. In addition, no differences were observed for low-risk or high-risk care models, suggesting that telehealth-integrated antenatal care is reasonable even for nulliparous individuals in high-risk care models.

Telehealth could improve accessibility to health care[32] and reduce non-attendance rates, particularly for people at high risk[33] and those in non-metropolitan areas. In the current study, we observed higher overall non-attendance in the integrated period, driven by increases in both missed telehealth and missed in-person appointments, which could reflect avoidance of in-person appointments due to fear of exposure to SARS-CoV-2, as well as reduced ability to afford transportation costs. Additionally, working from home with increased child minding and home-schooling responsibilities, which disproportionately affected women,[34] might have affected telehealth attendance. Indeed, multiparous individuals had significantly higher non-attendance rates across all consultation modes, but more so for telehealth than for in-person appointments, supporting this premise. Non-attendance rates were lowest during the second lockdown, corresponding to a period when most appointments were virtually delivered. This finding could suggest that the flexibility of remote consultation facilitates greater access to care in the context of societal upheaval, and that diversity in consultation modes might have provided some benefit in engaging people who otherwise missed in-person appointments. However, the population characteristics associated with non-attendance being younger maternal age, smoking, socioeconomic disadvantage, multiparity, and non-English speaking, were consistent regardless of consultation mode missed. These findings are consistent with characteristics observed internationally before the pandemic, and reflect the ongoing challenges in optimising care engagement, health literacy, and care access, which require ongoing efforts to address.[35–37] Such efforts are particularly important because reduced antenatal attendance is associated with poorer pregnancy outcomes.[35]

No telehealth-integrated programme has previously been implemented across all pregnancy models within a large service. Rapid increases in virtual appointments during the implementation period demonstrate the capability of telehealth to scale up in response to disasters in which infrastructure remains intact,[38] conferring advantages in the development of resilient antenatal services.[39] Following implementation, telehealth provided 52·6% of consultations during Melbourne's prolonged lockdown; however, a shift towards more in-person visits was observed as restrictions lifted. This pattern could reflect adjustments made to the telehealth-integrated schedules following our consumer evaluation, indicating a preference for more in-person appointments among nulliparous individuals (unpublished). Stabilised use of telehealth post lockdown, forming 37% of consultations in low-risk and 23% in high-risk care models, might indicate sustainable levels of use post pandemic.

To our knowledge, this is the largest evaluation of telehealth-integrated care across a clinically diverse, heterogeneous population, and has several strengths. First, previous literature has evaluated telehealth in small populations of predominantly White women.[5] By contrast, over 60% of individuals analysed in our study were non-Australian born, and 13·4% of those receiving integrated

care required an interpreter, making findings more generalisable globally. Around 18·7% of those included in our study were in the lowest SEIFA-IRSAD decile, indicating significant socioeconomic disadvantage. Given the growing concerns around the suitability of telehealth for people with social disadvantage, our study is the largest to evaluate the impact of telehealth-integrated antenatal care in this vulnerable group and provides important initial evidence that a hybrid model does not increase adverse outcomes. Indeed, while the lowest SEIFA-IRSAD decile was associated with higher rates of non-attendance, rates of non-attendance were significantly less with telehealth than in-person appointments, suggesting variety in consultation modes might further support improved care engagement and clinical outcomes.

Second, previous studies have used significant infrastructure to support the delivery of virtual antenatal care. By contrast, the low-cost remote monitoring protocol used in this study and its implementation within a publicly funded health service increase reproducibility of this model across a range of health-care settings, representing a further strength of the study.

A final strength of the study is that only ten pregnant individuals who received antenatal care and gave birth at Monash Health throughout the integrated period tested positive for COVID-19 during the study period, meaning that the disease itself is unlikely to have confounded our evaluation. This is important because COVID-19 in pregnancy is associated with poorer perinatal outcomes.[40]

The study is also subject to several limitations. First, telehealth was urgently implemented in response to the COVID-19 pandemic and a period of population-wide changes, including lockdown measures. These changes might have influenced telehealth uptake, engagement, and pregnancy outcomes, confounding the results. This is suggested by the small but significant differences in maternal characteristics consistently observed in the integrated period compared with the conventional period. We cannot measure and exclude the influence of these confounders with certainty, particularly as many extraneous variables remain undefined. It is, therefore, difficult to conclude whether outcomes occurred solely due to integrated care. Ongoing evaluation as societal disruptions stabilise will provide more clarity about the direct effects of telehealth on pregnancy outcomes.

An additional limitation is the lack of concurrent ultrasound use data. Ultrasound use is important in pregnancies complicated by pre-eclampsia and gestational diabetes to assess fetal growth, as well as in the screening and detection of FGR. Australian pregnancy care guidelines recommend a minimum first trimester dating scan and mid-trimester morphology scan, with additional second and third trimester scans performed as clinically required.[7] The impact of the COVID-19 pandemic and telehealth implementation on ultrasound use, particularly in the third trimester, remains to be determined. Broad changes to the use of obstetric ultrasound during the pandemic occurred.[41] In addition, clinicians might have recommended additional scans due to reduced in-person visits. Additional scans might have improved the detection of FGR, but are unlikely to have reduced induction-of-labour rates, given previous evidence.[42] Still, the extent to which ultrasound use contributed to the detection of pregnancy complications when in-person appointments were less frequent is unknown. Further evaluation of concurrent ultrasound use will assist in understanding implementation requirements and the true costs of this hybrid model. Lastly, we were unable to report on maternal ethnicity as it is not collected in the routine data systems and instead have reported on maternal country of birth.

In summary, telehealth can replace over 45% of in-person consultations without compromising pregnancy outcomes in singleton pregnancies. This hybrid schedule is suitable for all pregnancy care models and for those who are nulliparous or multiparous. Its use might be associated with fewer interventions, such as induction of labour for suspected FGR, without compromising perinatal morbidity. These findings support the ongoing use of telehealth in providing personalised, agile, antenatal care.

Contributors

KRP and RH conceived the study. KRP, DLR, and MD-T developed the study methodology. KT and MR collected the data. KT did the analysis with supervision from MD-T, KRP, and RH. MD-T validated the data and analysis. KT, DLR, BWM, and KRP interpreted the findings. KT and KRP wrote the manuscript with all authors involved in reviewing and editing the final manuscript. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication. KT, MD-T, and KRP accessed and verified the data.

Declaration of interests

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Data sharing

On request, de-identified individual participant data collected during the study period will be made available with approval from the Monash Health Human Research Ethics Committee (research@monashhealth.org.au).

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