A cost-minimisation population-based analysis of telehealth-integrated antenatal care

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Summary

Background In response to the COVID-19 pandemic, Victoria's largest maternity service provider implemented a telehealth-integrated antenatal care (ANC) schedule for high- and low-risk pregnancies. The program has been maintained since March 2020. Given ever-increasing healthcare costs, economic evaluation is crucial to ensure value and guide ongoing use.

Methods The aim of the study was to perform a cost-minimisation analysis of telehealth integrated ANC compared to conventional in-person ANC, from the hospital and patient perspectives. We hypothesised that the costs associated with telehealth integrated ANC would be less than in-person ANC. We generated propensity score matched pre- and post-telehealth cohorts from women with a singleton pregnancy who received ANC and birthed at Monash Health from 1 Jan 2018–22 Mar 2020 (pre-telehealth), and 20 Apr 2020–31 Dec 2021 (post-telehealth). Data were extracted from electronic medical and finance records. We assigned costs for all Monash Health outpatient, inpatient, and emergency department episodes to calculate mean cost per birth. Patient travel costs were estimated based on distance residing from hospital.

Findings Matched pre- and post-telehealth cohorts of n = 13,534 each were created. There were no significant differences in stillbirth, pre-eclampsia, severe maternal morbidity, or death. There was a AU$133 (0.98%, 95% CI [–0.17%, 2.16%]) increase in cost per birth in the post-telehealth cohort. This was driven by increased hospital costs (AU$340 or 2.64% increase, [1.44%, 3.86%]), due to a 4.78% increase in antenatal inpatient episodes and 3.51% increase in outpatient appointments post-telehealth. Increased care complexity was noted in the post-telehealth period with increased rates of gestational diabetes, caesarean birth, and specialty-led care (p-values all <0.0001). In contrast, patient costs of accessing healthcare fell significantly from AU$562 pre-telehealth to AU$355 post-telehealth (difference -AU$207 (–36.81%, [–37.46%, –36.16%]).

Interpretation Telehealth supported the provision of a greater volume of antenatal care to more complex pregnancies, while maintaining safety and quality of care, for only a minimal cost increase to health funders and substantial cost savings to patients. This finding provides reassurance regarding the financial viability of telehealth-integrated antenatal care.

Funding None.

Keywords: Telemedicine; Prenatal care; Pregnancy; Health economics

Introduction

Prior to the coronavirus disease 2019 (COVID-19) pandemic, telehealth use in antenatal care (ANC) was limited to specific patient groups and interventions.[1] Like other areas of healthcare, the pandemic led to the rapid uptake of telehealth more broadly to support the provision of essential ANC.[2] While there is evidence for clinically effective obstetric telehealth interventions, few studies evaluated cost impacts, and even fewer incorporated economic evaluations of routine antenatal telehealth appointments.[3]

One of the largest telehealth-integrated ANC programs occurred within the largest maternity service in

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Research in context

Evidence before this study

We searched Ovid MEDLINE from database inception to 22 May 2024, using the search terms "telehealth" OR "telemedicine" OR "digital health"; AND "pregnancy" OR "antenatal" OR "prenatal" OR "perinatal" OR "obstetric"; AND "economic" OR "cost". There was evidence for telehealth's clinical efficacy in targeted interventions in pregnancy, and an increase in the use of telehealth for antenatal care since the COVID-19 pandemic. Few studies evaluated the cost impact of these pregnancy interventions, however, and even fewer incorporated economic evaluations of routine antenatal telehealth appointments.

Since the 1990s, telehealth has been proposed to decrease the cost of healthcare delivery, but economic evaluations of telehealth are scarce and conflicting. Our implementation of telehealth-integrated antenatal care demonstrated comparable clinical outcomes when evaluated at 3- and 12-months. Therefore, as per World Health Organization recommendations, economic evaluation is crucial for informing ongoing delivery.

Added value of this study

This study was, to our knowledge, the first cost analysis of broadly implemented telehealth-integrated antenatal care. It demonstrates that telehealth can lead to substantial cost savings for patients, and be effectively implemented across a diverse population from various socio-economic and cultural backgrounds, utilising all models of antenatal care. It shows that costs to the health service are slightly increased in inpatient and outpatient settings due to greater volume of care episodes, but given greater pregnancy complexity, this cost increase may not be seen in the absence of COVID-19. The cost of technology for patients and the hospital were not barriers to successful implementation. Our study demonstrates that telehealth enabled the health service to provide safe and high-quality care for a greater volume and complexity of pregnancies, for only a minimal cost increase.

Implications of all the available evidence

Telehealth-integrated antenatal care can provide cost savings to patients, and is economically viable and sustainable for hospitals. However, the full impact of telehealth on costs to all involved stakeholders is still unclear. Further research into antenatal telehealth would help us better understand the economic impacts on a societal level, incorporating more comprehensive valuations of benefits and costs to patients and other stakeholders. Our findings highlight that while cost analyses are crucial for evaluating new interventions, hospital data collection may not be well set up to facilitate robust economic evaluation. Ideally, prospectively designed data collection of costs during the implementation of any new digital health innovations should occur to support rigorous cost analyses consistent with international standards for quality.

Victoria, Australia. This program ensured ongoing regular antenatal contacts by replacing a proportion of in-person appointments with telehealth appointments for women in both low- and high-risk pregnancy care models. Importantly, our previous evaluations of program clinical quality and safety indicated no change in clinical outcomes with up to 53% of in-person consultations converted to telehealth compared to traditional in-person delivered ANC.[4,5]

With telehealth-integrated ANC now maintained as the standard of care, supporting health service resilience and responsiveness to the COVID-19 variant waves that followed the initial wildtype virus, the World Health Organization (WHO) emphasises the importance of economic evaluation to ensure value for money when implementing digital health interventions.[6] Given the rapidly escalating cost of healthcare globally, in part driven by rising maternity care costs, the long-term sustainability of health expenditure is a key concern.[7]

Despite suggestions since the mid-1990s that telehealth could lead to cost savings, economic evaluations of telehealth have been scarce and conflicting.[8] There is an even greater dearth of evidence looking at the cost impacts of telehealth in ANC,[2,9] and to our knowledge, there have been minimal cost evaluations of telehealth integration into routine ANC programs for both low- and high-risk pregnancies. A greater understanding of the cost impacts of telehealth-integrated ANC is essential to guide its ongoing use in the provision of high-value, sustainable maternity care.

Hypothesis and aims

The aim of the study was to perform a cost-minimisation analysis of telehealth integrated ANC compared to conventional in-person ANC at Monash Health. We hypothesised that the costs associated with telehealth integrated ANC would be less than in-person ANC.

Methods

Study design, ethics, and reporting

Given the established equality in health outcomes of telehealth ANC and standard ANC,[5] we conducted a cost-minimisation analysis to identify the least-cost option. Cost-minimisation analysis compares the costs of two or more interventions without considering health outcomes. It is the appropriate economic evaluation when clinical efficacy has been established.[10] We compared the mean cost per birth before and after telehealth-integrated ANC implementation at Monash Health. This project received Monash Health Human

Research Ethics Committee approval (RES-22-0000-251Q) to utilise existing routinely collected healthcare data, which was analysed in a deidentified manner, ensuring privacy and confidentiality. As such, individual participant consent was not required. All results were reported according to the CHEERS 2022 checklist, STROBE and RECORD guidelines.[11,12]

Study setting and population

Monash Health consists of one tertiary referral and two secondary hospitals. The study population was all women with a singleton pregnancy who received ANC and birthed at Monash Health between 1 Jan 2018–31 Dec 2021. Women were excluded if they had no antenatal attendance or reduced antenatal attendance (first appointment at 28 weeks' gestation or later), as they would have minimal telehealth-integrated ANC. We defined a pre-telehealth population (births from 1 Jan 2018–22 Mar 2020), and post-telehealth population (20 Apr 2020–31 Dec 2021), allowing for a one-month implementation period (23 Mar 2020–19 Apr 2020). The telehealth-integrated ANC program has been described in detail previously.[4,5] The high-risk model of care included those requiring obstetric specialty-led care, based on medical comorbidities or obstetric complications. All other models of care were considered low-risk.

Data collection

Patient demographic and medical data, including maternal medical history, pregnancy, and birth outcomes, were extracted from electronic medical records (Cerner (North Kansas City, Missouri, United States) and Birthing Outcomes System (Melbourne Clinical and Translational Sciences, Melbourne, Victoria, Australia)). Maternal postcode data was obtained as a proxy for socio-economic status using the Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD).[13]

Data were extracted from routine hospital cost data collected on all Monash Health outpatient occasions of care (including all telehealth and in-person ANC appointments), but also all inpatient and emergency department (ED) occasions of care, from date of conception to six weeks postpartum for mothers, and from birth until 28 days of life for babies. This encompasses the pregnancy, puerperal, and neonatal periods in the time horizon of our economic evaluation. Most variables had minimal missing data (<0.4%), except for body mass index (BMI) with 59.9% missing in the post-telehealth cohort, analgesia in labour (16%), interpreter use (1.5%), and neonatal intensive care (NICU) or special care nursery (SCN) admission (0.9%).

Outcomes

The primary outcome was the difference in mean cost per birth between pre- and post-telehealth cohorts. Secondary outcomes included differences in health service use and clinical outcomes between the pre- and post-telehealth cohorts.

Statistical analysis

All data files were received and cleaned in Excel (Microsoft Corporation, Redmond, Washington, United States), then imported into SAS 9.4 (SAS Institute, Cary, North Carolina, United States) for analysis. Descriptive statistics were performed to compare baseline demographic characteristics, ANC service utilisation, and clinical outcomes between pre- and post-telehealth groups. Continuous variables were tested for normality using Kolmogorov–Smirnov, then independent samples T-test or Mann–Whitney U were used for parametric and non-parametric variables respectively. Interval and ordinal variables were compared using Mann–Whitney U, and categorical variables were compared using Pearson's chi-squared, or Fisher's exact test for values less than five. A p-value < 0.05 was considered statistically significant. Unless otherwise specified, continuous data were reported as mean and standard deviation (SD), while discrete data were reported as number and percentage of the group. Relative Risk (RR) and 95% Confidence Intervals (CI) were also reported. For cost comparisons, we reported the numeric difference, cost ratio (% difference), and its 95% CI.

Propensity score matching (PSM) was utilised to estimate the average treatment effect (in our analysis, the average effect of antenatal telehealth on health service utilisation and costs) on the treated units (in our analysis, women who received antenatal telehealth). We used PSM to account for demographic and maternal comorbidity differences between pre- and post-telehealth populations. We did not control for clinical outcomes that may have been influenced by telehealth-integrated ANC. A logistic regression model was used to calculate each woman's propensity score, as follows:

$$y = -0.9191 + 0.0196x_1 - 0.1516x_2 - 0.1524x_3 - 0.3401x_4 - 0.1365x_5 - 0.0980x_6 + 0.1095x_7 - 0.1421x_8 - 0.0244x_9 - 0.3209x_{10} + 0.1430x_{11} - 0.8101x_{12} + 0.0141x_{13} + 0.3692x_{14} + 0.2670x_{15} - 0.00503x_{16} + 0.0881x_{17} + 0.0291x_{18} + 0.2815x_{19} + 0.0329x_{20} + 0.4318x_{21}$$

Where, x_1 = maternal age, x_2 = mother quit smoking during pregnancy, x_3 = smoking status, x_4 = alcohol or drug use, x_5 = socioeconomic quintile 2, x_6 = socioeconomic quintile 3, x_7 = socioeconomic quintile 4, x_8 = socioeconomic quintile 5, x_9 = mother's refugee status, x_{10} = mother has a partner, x_{11} = mother identified as Aboriginal or Torres Strait Islander, x_{12} = mother's identification as Aboriginal or Torres Strait Islander is unknown, x_{13} = mother born in Australia, x_{14} = mother speaks language other than English, x_{15} = interpreter required, x_{16} = parity, x_{17} = mother gave birth at Casey hospital, x_{18} = mother gave birth at Dandenong hospital, x_{19} = mother had anxiety, x_{20} = mother had depression, x_{21} = mother had neurological conditions. A greedy matching technique was then used to match women 1:1 within a caliper of 0.2 times the SD of the (pooled) logit of the propensity score to generate pairs of women who were otherwise similar except for their pre- and post-telehealth grouping.[14] The matching produced two equal-sized pre- and post-telehealth cohorts for economic analysis.

We used a health service and patient perspective to quantify the cost of services accessed in each PSM cohort. External care episodes were not included, as this data was not accessible. Each Monash Health inpatient, outpatient, or ED episode within the study's time horizon was assigned a cost. Inpatient and ED episodes were mapped to costs using the Australian Refined Diagnosis Related Group (AR-DRG) codes and Australasian Triage Scale (ATS) categories respectively. Round 23 of the Independent Health and Aged Care Pricing Authority (IHACPA) National Hospital Cost Data Collection (NHCDC),[15] from financial year (FY) 2018–2019 was used to standardise inpatient and ED episode cost assignments. For outpatient episodes, the Weighted Ambulatory Service Event (WASE) cost for each episode was obtained directly from Monash Health. The cost of all services accessed were summed to calculate a mean cost per birth for each PSM cohort.

Patient costs were calculated from the average distance between patients' residences and hospital clinics. Average travel cost was then measured through multiplying the average number of in-person appointments by the cents per kilometre cost from the Australian Taxation Office.[16] Average travel time per appointment was used to estimate the cost of lost productivity using the 2020–2021 median hourly earnings in Australia, according to the Australian Bureau of Statistics.[17] We conducted a separate univariate sensitivity analysis to account for doubled and halved travel costs, given known variation in travel time, distance, and income within our patient population. All costs were reported in 2021 Australian dollars (AU$) unless otherwise specified. All costs from previous FYs were inflated according to the Reserve Bank of Australia's inflation calculator, and costs were not discounted as the time horizon of the economic analysis was less than a year. No currency conversions were required, as all costs were in Australian dollars.

While the program set-up costs were considered sunk costs in the primary analysis, we conducted a sensitivity analysis to test different assumptions of ongoing operational costs. Most of the telehealth technology was pre-existing, but additional costs included the purchase of webcams and soundbars, plus staff to set up the program. Set-up costs for patients were also considered sunk costs, assuming pre-existing access to either phones or internet, scales for patient weight and tools for self-measuring symphyseal-fundal height. Blood pressure (BP) monitoring devices were available for patients to borrow, but not fetal heart rate (FHR) monitoring equipment. The infrastructure costs to the health service were estimated to be AU$3 000, but we tested assumptions of AU$5,000, AU$10,000, and AU$20,000 per year of set-up and maintenance costs.

Role of the funding source

There was no funding for this study.

Results

There were 36,506 total births during the study period. After exclusions, the pre-telehealth population had 18,628 births and the post-telehealth population 14,137 births (Fig. 1). Significant baseline population differences existed between these groups with the post-telehealth population slightly older (30.97 vs 30.61, $p < 0.0001$), more likely to be English-speaking (79.17% vs 74.35%, $p < 0.0001$) and born in Australia (41.08% vs 38.08%, $p < 0.0001$), less likely to require an interpreter (10.94% vs 11.91%, $p = 0.0069$), and less likely to be partnered (86.11% vs 89.03%, $p < 0.0001$) (Supplementary Table S1). They also had lower rates of alcohol and other drug use (2.32% vs 2.90%, $p = 0.0011$), and were more likely from a less deprived area ($p < 0.0001$). After PSM, the pre- and post-telehealth cohorts had 13,534 births each (Fig. 1) with demographics outlined in Table 1. The intention was to also control for BMI, but due to high rates of missing BMI data in the post-telehealth cohort (8469 women; 59.9%) it was not possible.

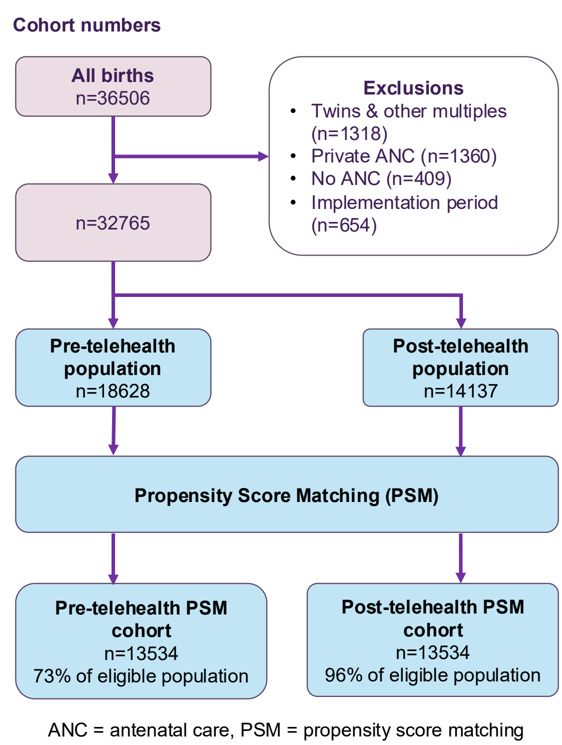

Fig. 1: Exclusions and final propensity score-matched cohort numbers.

Economic analysis

Telehealth-integrated care was associated with a non-significant AU$133 (0.98%, 95% CI [−0.17%, 2.16%]) cost increase in net average cost per birth to AU$13565 compared to AU$13432 pre-telehealth (Table 2). This was driven by post-telehealth increases in inpatient and outpatient costs (Table 2). A 4.78% ([2.65%, 6.95%]; p < 0.0001) increase in the average number of maternal antenatal inpatient episodes, but 9% decrease ([−16.12%, −1.27%]; p = 0.04) in neonatal episodes, contributed to an AU$177 per birth cost increase post-telehealth. While a 3.51% ([2.49%, 4.53%]; p < 0.0001) increase in post-telehealth antenatal outpatient appointments (0.42 additional appointments per woman) resulted in an additional AU$122 cost per birth, while increased postpartum appointments led to an AU$41 per birth cost increase. In comparison, a 17.29% ([−27.2%, −6.02%]; p = 0.0032) decrease in neonatal ED episodes was noted, but with no significant differences in maternal episodes of care, no significant cost differences overall occurred. The final average cost to health funders was AU$13210 per birth, an AU$340 increase (2.64%, [1.44%, 3.86%]; p < 0.0001) compared to the pre-telehealth cohort.

In contrast, post-telehealth average patient costs were AU$355 per birth, an AU$207 saving (−36.90%, [−37.62, −36.19%]; p < 0.0001) compared to the pre-telehealth cohort (Table 2). This was achieved through reduced travel costs and improved productivity, with AU$113 and AU$94 saved respectively.

Our univariate sensitivity analysis showed an increase of AU$0.55, AU$1.10, and AU$2.19 per birth respectively for estimates of AU$5000, AU$10000, and AU$20000 a year in set-up and maintenance costs (Supplementary Table S2). While the sensitivity analysis for travel costs showed that when travel costs were doubled, patients saved even more money with telehealth (Supplementary Table S3).

Service utilisation

Differences in ANC service utilisation is described in Table 3. Women in the post-telehealth cohort were more likely to have a timely first antenatal appointment (RR 1.13, 95% CI [1.12, 1.14]; p < 0.0001) and third trimester fetal growth scans (1.03, [1.01, 1.05]; p = 0.0006), but less likely to receive midwifery-led models of care (0.93, [0.90, 0.96]; p < 0.0001) and early/mid-trimester ultrasounds (0.90, [0.88, 0.91]; p < 0.0001). Supplementary Fig. S1 demonstrates the proportion of telehealth appointments over time stratified by model of care. Telehealth appointment rates fluctuated in response to COVID-19 waves and lockdowns.

Clinical outcomes

Significant clinical differences existed in the post-telehealth compared to the pre-telehealth PSM cohort (Table 4). These included an increased caesarean birth (31.45% vs 28.82%, RR 1.09, 95% CI [1.05, 1.13]; p < 0.0001) and neuraxial anaesthesia rate (38.43% vs 33.17%, RR 1.15, [1.11, 1.20]; p < 0.0001). While induction of labour rates did not significantly change, the indication for induction shifted from fetal indications (40.50% vs 44.93%, RR 0.90 [0.86, 0.94]; p < 0.0001) to maternal indications (56.58% vs 53.01%, RR 1.07, [1.03, 1.10]; p = 0.0002). Potentially influenced by an increase in gestational diabetes mellitus (GDM) rates (28.44% vs 23.15%, RR 1.23, [1.18, 1.28]; p < 0.0001) but decrease in fetal growth restriction (FGR) rates (6.76% vs 8.12%, RR 0.83, [0.77, 0.91]; p < 0.0001). There was no significant difference in gestation at birth, but a slight increase in median birth weight (3350 g vs 3330 g, p = 0.02). There was a non-significant increase in NICU admissions (3.57% vs 3.40%, RR 1.05, [0.93, 1.19]; p = 0.44), but a large decrease in SCN admissions (9.73% vs 13.29%, RR 0.73, [0.68, 0.78]; p < 0.0001). There were no significant differences in severe pre-eclampsia, maternal or fetal mortality.

Variable	Pre-telehealth cohort (n = 13,534) mean (SD) or n (%)	Post-telehealth cohort (n = 13,534) mean (SD) or n (%)
Maternal age (years)[a]	30.95 (5.13)	30.93 (5.09)
Socio-economic quintiles[a]		
1—Lowest SES quintile	3006 (22.21)	3001 (22.17)
2	598 (4.42)	627 (4.63)
3	5013 (37.04)	4953 (36.60)
4	3517 (25.99)	3564 (26.33)
5—Highest SES quintile	1396 (10.31)	1388 (10.26)
Refugee	380 (2.81)	419 (3.10)
Partnered[a]	11,861 (87.64)	11,809 (87.25)
Aboriginal and Torres Strait Islander status		
Neither	13,424 (99.19)	13,407 (99.06)
Either/both	107 (0.79)	124 (0.92)
Unknown/ refused to answer	3 (0.02)	3 (0.02)
Born in Australia[a]	5379 (39.74)	5390 (39.83)
Maternal language—english[a]	10,635 (78.58)	10,658 (78.75)
Interpreter use[a]	1493 (11.03)	1510 (11.16)
Parity	1.01 (1.17)	1.02 (1.17)
Comorbidities[a]		
Anxiety	955 (7.06)	973 (7.19)
Depression	752 (5.56)	793 (5.86)
Neurological	55 (0.41)	58 (0.43)

p-values all >0.05 with no statistically significant differences. SES = Socio-economic status. [a]Indicates statistically significant difference BEFORE matching.

Table 1: **Baseline characteristics after propensity score matching.**

Discussion

To our knowledge, this is one of the first cost-minimisation analyses of telehealth-integrated ANC across all pregnancy care models. Considering previously demonstrated clinical efficacy between telehealth-integrated and standard antenatal care,[4,5] here we have

	Pre-telehealth matched cohort (n = 13,534) mean (SD)	Post-telehealth matched cohort (n = 13,534) mean (SD)	Cost ratio % difference	Cost ratio 95% CI Lower Limit	Cost ratio 95% CI Upper Limit	p-value (MWU)	Difference (post-telehealth—pre-telehealth)
Inpatient episodes							
Maternal–antenatal							
Average count	1.32 (0.82)	1.39 (1.19)	4.78%	2.65%	6.95%	**<0.0001**	0.07
Average cost—AU$	$10,113 ($4968)	$10,336 ($5090)	2.20%	1.16%	3.27%	**<0.0001**	$223
Maternal–postpartum							
Average count	0.06 (0.27)	0.07 (0.34)	13.00%	1.25%	26.11%	0.1878	0.01
Average cost—AU$	$222 ($1356)	$244 ($1480)	9.97%	−21.16%	53.39%	0.2738	$22
Neonatal							
Average count	0.10 (0.34)	0.09 (0.32)	−9.00%	−16.12%	−1.27%	**0.0394**	−0.01
Average cost—AU$	$1036 ($5843)	$968 ($11,531)	−6.63%	−28.54%	21.99%	**0.0343**	−$69
Total inpatient costs—AU$	$11,371 ($8425)	$11,548 ($12,994)	1.55%	0.29%	2.84%	**0.0005**	$177
Emergency department episodes							
Maternal–antenatal							
Average count	0.15 (0.49)	0.16 (0.57)	3.95%	−3.70%	12.19%	0.6592	0.01
Average cost—AU$	$136 ($444)	$142 ($513)	4.68%	−14.55%	28.21%	0.7221	$6
Maternal–postpartum							
Average count	0.05 (0.23)	0.05 (0.24)	7.27%	−4.80%	20.86%	0.3452	0.00
Average cost—AU$	$44 ($230)	$47 ($238)	6.65%	−24.35%	50.37%	0.3433	$3
Neonatal							
Average count	0.04 (0.21)	0.03 (0.19)	−17.29%	−27.20%	−6.02%	**0.0032**	−0.01
Average cost—AU$	$53 ($270)	$44 ($244)	−17.60%	−43.71%	20.62%	0.0028	−$9
Total emergency department costs—AU$	$233 ($592)	$233 ($636)	−0.01%	−14.73%	17.25%	0.4231	$0
Outpatient episodes							
Maternal–antenatal							
Average count	11.83 (4.95)	12.25 (5.25)	3.51%	2.49%	4.53%	**<0.0001**	0.42
Telehealth	0.01 (0.11)	4.79 (3.72)	66687.43%	54602.80%	81449.88%	**<0.0001**	4.78
In-person	11.83 (4.94)	7.46 (3.51)	−36.90%	−37.56%	−36.24%	**<0.0001**	−4.37
Average cost—AU$	$1248 ($728)	$1371 ($636)	9.79%	8.23%	11.37%	**<0.0001**	$122
High-risk pregnancies							
Average count	13.76 (6.81)	14.82 (6.89)	7.76%	4.91%	10.68%	**<0.0001**	1.06
Telehealth	0.00 (0.06)	6.38 (4.94)	161514.67%	86752.82%	300630.62%	**<0.0001**	6.38
In-person	13.75 (6.81)	8.44 (4.37)	−38.63%	−40.32%	−36.90%	**<0.0001**	−5.31
Average cost—AU$	1568.61 (961.66)	1666.45 (842.63)	6.24%	2.57%	10.03%	**0.0007**	$98
Low-risk pregnancies							
Average count	11.39 (4.29)	11.61 (4.54)	1.94%	0.92%	2.97%	**0.0002**	0.22
Telehealth	0.01 (0.12)	4.39 (3.23)	55446.19%	44888.86%	68480.96%	**<0.0001**	4.38
In-person	11.38 (4.28)	7.22 (3.21)	−36.57%	−37.25%	−35.89%	**<0.0001**	−4.16
Average cost—AU$	1174.66 (640.58)	1297.37 (549.69)	10.45%	8.77%	12.14%	**<0.0001**	$123
Maternal–postpartum							
Average count	0.17 (0.47)	0.50 (0.91)	185.97%	170.26%	202.56%	**<0.0001**	0.33
Average cost—AU$	$17 ($50)	$58 ($111)	244.91%	205.29%	289.62%	**<0.0001**	$41
Total outpatient costs—AU$	$1265 ($730)	$1429 ($654)	12.93%	11.36%	14.52%	**<0.0001**	$164
Total costs to health service—AU$	$12,870 ($8757)	$13,210 ($13,226)	2.64%	1.44%	3.86%	**<0.0001**	$340
Patient costs							
Estimated travel costs per birth—AU$	$307 ($128)	$193 ($91)	−36.90%	−37.61%	−36.19%	**<0.0001**	−$113
Estimated cost of lost productivity from travel time per birth—AU$	$255 ($107)	$161 ($76)	−36.90%	−37.61%	−36.20%	**<0.0001**	−$94
Total costs to patients—AU$	$562 ($235)	$355 ($167)	−36.90%	−37.62%	−36.19%	**<0.0001**	−$207
Net cost (Patients and health service)—AU$	$13,432 ($8808)	$13,565 ($13,246)	0.98%	−0.17%	2.16%	**0.0089**	$133

All costs reported in 2021 Australian dollars and rounded to the nearest dollar. Bolded data points highlight statistical significance. MWU = Mann–Whitney U test.

Table 2: Cost per birth in each cohort.

shown that telehealth-integrated care led to substantial patient savings (AU$207 per birth) with a 2.6% (AU$340 per birth) health service cost increase. These cost shifts represent a small fraction of the AU$13564 net cost per birth, a cost in line with previous Australian estimates of AU$14278 per birth.[18] Furthermore, the slight health service cost increase is less than anticipated in the context of increased pregnancy complexity, with higher rates of GDM, specialist-led care, and caesarean birth; all outcomes associated with greater costs.

The largest contributors to increased health service costs post-telehealth were maternal inpatient admissions and outpatient appointments. Increased inpatient costs were likely impacted by the ongoing COVID-19 pandemic and delta wave that occurred over the post-telehealth period. In addition, increased rates of caesarean births in the post-telehealth cohort, associated with more expensive and prolonged inpatient episodes, likely contributed.[15] Similarly, increased outpatient costs may reflect additional appointments provided for women contracting COVID-19 in pregnancy. The shift of women to more specialist-led care in the post-telehealth cohort, likely influenced by increasing GDM rates, is also associated with more frequent and expensive specialist appointments. While a minimal 2.6% health service cost increase occurred, telehealth may have significantly reduced expected costs given the higher volume of more complex care, through improved efficiencies without additional health service investment in infrastructure or staffing.

Regarding set-up costs, Theiler et al.'s previous economic evaluation of telehealth ANC for low-risk pregnancies in the United States found a US$101 per birth increase in supply costs, attributed to extra home BP and FHR monitoring equipment. Conversely, estimated set-up costs in our sensitivity analysis led to a negligible cost increase of less than AU$3 per birth, however home BP and FHR monitoring equipment were not utilised. While the ability to provide home BP monitoring could further enhance care and reduce healthcare costs,[19,20] there is no evidence to suggest that home FHR monitoring can improve healthcare outcomes. Certainly, the excellent perinatal outcomes achieved through this model without complex home monitoring additions[5] provides reassuring evidence that telehealth-integrated ANC can be safely introduced and maintained at minimal cost.

Patient travel costs were the largest source of cost saving. These still likely underrepresent the true cost savings, as only transit time and distance was included, with parking costs, waiting time, additional lost productivity, and costs for accompanying partners or childcare not accounted for, as these were not routinely recorded data. Our findings were consistent with Snoswell et al.'s suggestion that most telehealth cost savings are likely to come from reduced travel.[21] These savings apply to patients in or out of a pandemic setting.

	Pre-telehealth cohort (n = 13,534) n (%) or median (range)	Post-telehealth cohort (n = 13,534) n (%) or median (range)	Relative risk RR (95% confidence interval)	p-value
Timely first antenatal appointment (≤12 weeks' gestation)	11,267 (83.25)	12,762 (94.30)	**1.13 (1.12–1.14)**	**<0.0001**
Model of care				
Midwife/ Caseload, Young Women (low risk)	4656 (34.40)	4316 (31.89)	**0.93 (0.90–0.96)**	**<0.0001**
Collaborative (low risk)	5195 (38.38)	5549 (41.00)	**1.07 (1.04–1.10)**	**<0.0001**
Shared care (low risk)	1151 (8.50)	987 (7.29)	**0.86 (0.79–0.93)**	**0.0002**
Specialty-led (high risk)	2532 (18.71)	2682 (19.82)	**1.06 (1.01–1.11)**	**0.0208**
Ultrasounds				
Received early scan (≤14 weeks' gestation)	12,663 (93.56)	11,763 (86.91)	**0.93 (0.92–0.94)**	**<0.0001**
Received mid-trimester scan (18–22 weeks' gestation)	11,163 (82.48)	10,508 (77.64)	**0.94 (0.93–0.95)**	**<0.0001**
Received third trimester scan (≥28 weeks' gestation)	8650 (63.91)	8918 (65.89)	**1.03 (1.01–1.05)**	**0.0006**
Number of scans[a]	5 (1–45)	5 (1–38)	–	**<0.0001**
Received appropriate scans (Early & Mid)	10,539 (77.87)	9445 (69.79)	**0.90 (0.88–0.91)**	**<0.0001**

Bolded data points highlight statistical significance. [a]Data relate only to those who received at least one third trimester scan.

Table 3: **Characteristics of antenatal care.**

This highlights the value of telehealth programs for future pandemic preparedness, but also for improving flexibility, convenience and accessibility, particularly in areas where travel is a significant barrier to accessing care.

Concerns exist about the disproportionate financial impact of telehealth on economically disadvantaged populations, due to the "digital divide" decreasing engagement with care.[22] However, our analysis demonstrated on the contrary that telehealth-integrated ANC increased the proportion of women receiving a timely first antenatal appointment, even after controlling for socio-economic status. Our findings indicated that access to internet or mobile phones was not a major barrier to receiving care for our population, in keeping with national data indicating that well over 90% of Australians of reproductive age have access to such technologies.[23] The stable clinical outcomes and costs with telehealth in a population with over 60% of patients born outside of Australia (Table 2) from 158 different countries and speaking 105 different languages, provides reassuring evidence that telehealth can be safely

	Pre-telehealth cohort (n = 13,534) n (%) or median (IQR)	Post-telehealth cohort (n = 13,534) n (%) or median (IQR)	Relative risk RR (95% confidence interval)	p-value
Birth type				
Vaginal	7465 (55.16)	7183 (53.07)	**0.96 (0.94–0.98)**	**0.0006**
Instrumental	2168 (16.02)	2095 (15.48)	0.97 (0.91–1.02)	0.2232
Caesarean	3901 (28.82)	4256 (31.45)	**1.09 (1.05–1.13)**	**<0.0001**
Induction of labour	5380 (39.75)	5504 (40.67)	1.02 (0.99–1.05)	0.1243
Indication for induction[a]				
Fetal indication	2417 (44.93)	2229 (40.50)	**0.90 (0.86–0.94)**	**<0.0001**
Maternal indication	2852 (53.01)	3114 (56.58)	**1.07 (1.03–1.10)**	**0.0002**
Maternal request	111 (2.06)	161 (2.93)	**1.42 (1.12–1.80)**	**0.0042**
Epidural or spinal anaesthesia[b]	3792 (33.17)	4379 (38.43)	**1.15 (1.11–1.20)**	**<0.0001**
5-min Apgar score <7	379 (2.80)	378 (2.80)	1.00 (0.87–1.15)	0.9706
Requiring neonatal resuscitation	1649 (12.18)	1536 (11.35)	**0.93 (0.87–1.00)**	**0.0331**
NICU/SCN admission				
NICU	456 (3.40)	479 (3.57)	1.05 (0.93–1.19)	0.4440
SCN	1783 (13.29)	1306 (9.73)	**0.73 (0.68–0.78)**	**<0.0001**
Gestation at birth (weeks)	39.1 (38.2–40.0)	39.1 (38.2–40.0)	–	0.4635
Birth weight (grams)	3330 (2990–3660)	3350 (3020–3670)	–	**0.0209**
Gestational diabetes	3133 (23.15)	3849 (28.44)	**1.23 (1.18–1.28)**	**<0.0001**
Pre-eclampsia (mild and severe)	449 (3.32)	424 (3.13)	0.94 (0.83–1.08)	0.3898
Fetal growth restriction	1099 (8.12)	915 (6.76)	0.83 (0.77–0.91)	**<0.0001**
Severe maternal morbidity (composite of below)	1304 (9.63)	1301 (9.61)	1.00 (0.93–1.07)	0.9507
Severe PPH (≥1000 mL or transfusion)	1143 (8.45)	1138 (8.41)	1.00 (0.92–1.08)	0.9129
Severe PET (including eclampsia, HELLP syndrome and severe pre-eclampsia)	96 (0.71)	90 (0.66)	0.94 (0.70–1.25)	0.6589
Severe maternal infection (including chorioamnionitis and maternal signs of sepsis)	48 (0.35)	41 (0.30)	0.85 (0.56–1.30)	0.4578
Uterine rupture	10 (0.07)	3 (0.02)	0.30 (0.08–1.09)	0.0674
Required high dependency care	165 (1.22)	118 (0.87)	**0.72 (0.57–0.90)**	**0.0052**
Mortality				
Maternal death	1 (0.01)	1 (0.01)	1.00 (0.06–15.99)	1.0000
Stillbirth	114 (0.84)	111 (0.82)	0.97 (0.75–1.26)	0.8408

Bolded data points highlight statistical significance. NICU = neonatal intensive care unit, SCN = special care nursery, PPH = postpartum haemorrhage, PET = pre-eclamptic toxaemia, HELLP = haemolysis, elevated liver enzymes and low platelets. [a]Denominator = inductions in each group. [b]More than 16% of data missing.

Table 4: **Clinical outcomes.**

and cost-effectively implemented in a culturally diverse setting.

Previous cost evaluations of telehealth-integrated ANC have solely assessed low-risk pregnancies.[24,25] Our findings of patient savings from transport costs were comparable to Barbour et al.'s savings of US$56 and 3 h of time per patient in 2017, especially after adjusting for inflation and currency conversion.[24] Theiler et al. found a US$120 increase in staff costs per patient due to a significant increase in nurse appointments from 5.5 to 22.3 per birth, accompanied by a decrease in obstetrician appointments from 9.4 to 6.3 per birth.[25] While our analysis did not quantify staff costs based on salary data, we similarly saw an increase in appointments per patient (albeit only an additional 0.42 appointments per patient) leading to slightly increased health service provider costs. While previous studies are informative, they were undertaken in the United States, a country with one of the highest global healthcare expenditures[26] and vastly different funding structure compared to Australia's universal government-funded public healthcare system. Indeed, our 2.6% increase in maternity costs over our four year study period, a period including the COVID-19 pandemic, appear minimal compared to the 48% increase in Australian maternity care costs between 2012 and 2018.[27]

Strengths and limitations

This study has several strengths. Firstly, we believe it is one of the first cost analysis of telehealth-integrated routine ANC across both high- and low-risk pregnancies. Additionally, we have demonstrated the cost-effectiveness and broad applicability of telehealth-integrated ANC in a large socio-economically and culturally diverse population. Secondly, the cost-minimisation methodology encompassing broader service utilisation, provides greater visibility of cost impacts across pregnancy and the postpartum period rather than just outpatient appointments. This ensures a more complete view of the impacts of adjustments in outpatient care on both ED and inpatient healthcare utilisation.

As a retrospective cost analysis however, several limitations exist. Firstly, some clinical variables had substantial missing data, particularly BMI. This may have influenced our cost analysis, as other studies indicated that maternal BMI rose during the pandemic, and increased BMI is associated with greater pregnancy complexity and costs.[28] Secondly, COVID-19 pandemic-related confounders may have impacted post-telehealth outcomes and service utilisation, for example, influencing the increased number of appointments per patient. However, these are likely to have further increased healthcare-related costs further indicating the likely program cost savings to health funders. Thirdly, the rapid implementation of telehealth for the COVID-19 pandemic meant no prospective surveys or data collection for economic analysis were implemented. The optimal economic evaluation would incorporate broader cost impacts to all stakeholders. While our analysis incorporated all inpatient, outpatient, and ED episodes of care at Monash Health, as well as estimating travel costs and time off work for patients, we were unable to include costs and benefits to external stakeholders, such as external health service utilisation (general practitioner visits, presentations to other EDs), costs to external employers (days off work), and individualised patient costs (satisfaction, travel, productivity, childcare, avoided infectious illnesses).[29] These would have required prospective surveys and data linkage to state-wide and national data collection, which would have also helped to quantify shifts in service utilisation during the pandemic, but require such systems to already be instituted given the unpredictable timing of a pandemic. This limits assessment of true program costs to all stakeholders, and highlights the importance of embedding economic evaluation into the implementation process for new interventions, as recommended by the WHO.[6] Our study highlights the fragmentation of routinely collected healthcare data in Australia, impairing the facilitation of cost analyses. Given the importance of economic evaluation for informing value-based healthcare; transparent and accessible financial data to facilitate safe, adaptable, and sustainable healthcare is needed. Ideally, data capture and reporting should be congruent with globally agreed frameworks, such as the CHEERS 2022 statement[11] to support international comparisons.

The retrospective nature of the study also limits our understanding of causal relationships between all these factors. We know background trends for GDM, caesarean births, and anaesthesia use are increasing over time in Australia.[30] These contribute to increased care costs over time, as are changing intervention and investigation rates, and potential unknown factors we were unable to control for.[31] More detailed data with exact cost breakdowns (e.g., for pathology/imaging) to support more complex multivariate statistical models looking at associations between different variables would help to further clarify the driver of the cost increases, but these were not available.

Future directions and implications

Our findings provide encouraging evidence for the value and ongoing efficacy of telehealth-integrated ANC. However, further research would be beneficial to provide a more comprehensive understanding of telehealth's cost impacts across non-pandemic settings, including costs and benefits to other funders, valuations of intangible outcomes like user experience, and impacts on different population groups. While not explicitly assessed in our study, it is reassuring to note that patient satisfaction with telehealth integrated ANC has been favourable pre- and post-pandemic, both in Australia and overseas.[25,32,33] However, we must continue to explore the impact of telehealth on patients from diverse backgrounds, as we strive to understand the distributional effects of telehealth integrated ANC and harness telehealth's potential to improve healthcare access.[22] Economic valuation of subjective telehealth-integrated ANC outcomes will be beneficial as we move towards less medicalised and more personalised pregnancy care. The value of ANC should not be determined purely by the clinical outcomes it produces, but also informed by patient experiences.[2]

This study contributes to the limited literature on the cost impacts of telehealth in ANC, reinforcing the integral role economic evaluation should play in the implementation of telehealth in all fields of healthcare. While each country has its own unique healthcare needs, health system structure, and funding complexities, our findings of cost savings for patients and stable costs for the healthcare system may still be informative more broadly. It may help inform future studies on the cost impact of telehealth and inform future policy on the use of telehealth in maternity care, to harness its potential to provide more equitable, resilient, and high-value maternity care for all.

Contributors

KRP developed the original concept for this project. Research design and methodology were developed by KRP, EJC, and YN. YN collected the data. Data were analysed by YN with supervision from KRP and EJC. KRP and EJC also accessed and verified the data. KRP, EJC, BWM, RJH, and YN interpreted the findings. YN, KRP, and EJC wrote the primary manuscript, with all other authors contributing feedback to review and editing. All authors had full access to all the data in the study and accept responsibility to submit for publication. KRP had the final responsibility for the decision to submit for publication.

Data sharing statement

De-identified data relating to this study is available on request from the Monash Health Human Research Ethics Committee (research@monashhealth.org.au).

Declaration of interests

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101239.

References

1 Goldstein KM, Gierisch JM, Zullig LL, et al. *Telehealth services designed for women: an evidence map*. Telehealth services designed for women: an evidence map. Washington (DC). 2017.
2 Atkinson J, Hastie R, Walker S, Lindquist A, Tong S. Telehealth in antenatal care: recent insights and advances. *BMC Med*. 2023;21(1):332.
3 DeNicola N, Grossman D, Marko K, et al. Telehealth interventions to improve obstetric and gynecologic health outcomes: a systematic review. *Obstet Gynecol*. 2020;135(2):371–382.
4 Palmer KR, Tanner M, Davies-Tuck M, et al. Widespread implementation of a low-cost telehealth service in the delivery of antenatal care during the COVID-19 pandemic: an interrupted time-series analysis. *Lancet*. 2021;398(10294):41–52.
5 Thirugnanasundralingam K, Davies-Tuck M, Rolnik DL, et al. Effect of telehealth-integrated antenatal care on pregnancy outcomes in Australia: an interrupted time-series analysis. *Lancet Digital Health*. 2023;5(11):e798–e811.
6 World Health Organization. *Monitoring and evaluating digital health interventions: a practical guide to conducting research and assessment*. Geneva: World Health Organization; 2016.
7 World Health Organization. *Global expenditure on health: public spending on the rise?*. 2021.
8 Snoswell CL, Chelberg G, De Guzman KR, et al. The clinical effectiveness of telehealth: a systematic review of meta-analyses from 2010 to 2019. *J Telemed Telecare*. 2021;29:669–684.
9 Wu KK, Lopez C, Nichols M. Virtual visits in prenatal care: an integrative review. *J Midwifery Wom Health*. 2022;67(1):39–52.
10 Drummond MF. *Methods for the economic evaluation of health care programmes*. United Kingdom. United Kingdom: Oxford University Press; 2015.
11 Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. *BMJ*. 2022;376:e067975.
12 Benchimol EI, Smeeth L, Guttmann A, et al. The REporting of studies conducted using observational routinely-collected health data (RECORD) statement. *PLoS Med*. 2015;12(10):e1001885.
13 Australian Bureau of Statistics. *2033.0.55.001 Socio-Economic Indexes for Australia (SEIFA), 2016 [data set]*; 2018. https://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa. Accessed October 3, 2022.
14 Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083–3107.
15 Independent Hospital Pricing Authority. *National hospital cost data collection report: public sector, round 23 financial year 2018-19*. Sydney: Independent Hospital Pricing Authority; 2021.
16 Australian Taxation Office. *Income and deductions for business - deductions for motor vehicle expenses - cents per kilometre method*; 2022. https://www.ato.gov.au/Business/Income-and-deductions-for-business/Deductions/Deductions-for-motor-vehicle-expenses/Cents-per-kilometre-method/. Accessed October 3, 2022.
17 Australian Bureau of Statistics. *Employee earnings*; 2021. https://www.abs.gov.au/statistics/labour/earnings-and-working-conditions/employee-earnings/aug-2021.
18 Callander E, Shand A, Ellwood D, Fox H, Nassar N. Financing maternity and early childhood healthcare in the Australian healthcare system: costs to funders in private and public hospitals over the first 1000 days. *Int J Health Policy Manag*. 2021;10(9):554–563.
19 Kalafat E, Leslie K, Bhide A, Thilaganathan B, Khalil A. Pregnancy outcomes following home blood pressure monitoring in gestational hypertension. *Pregnancy Hypertens*. 2019;18:14–20.
20 Xydopoulos G, Perry H, Sheehan E, Thilaganathan B, Fordham R, Khalil A. Home blood-pressure monitoring in a hypertensive pregnant population: cost-minimization study. *Ultrasound Obstet Gynecol*. 2019;53(4):496–502.
21 Snoswell CL, Taylor ML, Comans TA, Smith AC, Gray LC, Caffery LJ. Determining if telehealth can reduce health system costs: scoping review. *J Med Internet Res*. 2020;22(10):e17298.
22 Clare CA. Telehealth and the digital divide as a social determinant of health during the COVID-19 pandemic. *Netw Model Anal Health Inform Bioinform*. 2021;10(1):26.
23 Australian Bureau of Statistics. *Household use of information technology, Australia, 2016-2017 financial year [Internet]*. Canberra: Australian Bureau of Statistics; 2018.
24 Barbour KD, Nelson R, Esplin MS, Varner M, Clark EA. 873: a randomized trial of prenatal care using telemedicine for low-risk pregnancies: patient-related cost and time savings. *Am J Obstet Gynecol*. 2017;216(1):S499.
25 Theiler RN, Butler-Tobah Y, Hathcock MA, Famuyide A. OB Nest randomized controlled trial: a cost comparison of reduced visit compared to traditional prenatal care. *BMC Pregnancy Childbirth*. 2021;21(1):71.
26 Organisation for Economic Co-operation and Development. *Health spending (indicator)*. Paris: OECD; 2023.
27 Callander EJ, Enticott JC, Eklom B, Gamble J, Teede HJ. The value of maternity care in Queensland, 2012–18, based on an analysis of administrative data: a retrospective observational study. *Med J Aust*. 2023;219(11):535–541.
28 Rolnik DL, Matheson A, Liu Y, et al. Impact of COVID-19 pandemic restrictions on pregnancy duration and outcome in Melbourne, Australia. *Ultrasound Obstet Gynecol*. 2021;58(5):677–687.
29 Davalos ME, French MT, Burdick AE, Simmons SC. Economic evaluation of telemedicine: review of the literature and research guidelines for benefit-cost analysis. *Telemed J e-Health*. 2009;15(10):933–948.
30 Australian Institute of Health and Welfare. *National core maternity indicators*. Canberra: AIHW; 2022.
31 Woo VG, Lundeen T, Matula S, Milstein A. Achieving higher-value obstetrical care. *Am J Obstet Gynecol*. 2017;216(3):250.e1–250.e14.
32 Futterman I, Rosenfeld E, Toaff M, et al. Addressing disparities in prenatal care via telehealth during COVID-19: prenatal satisfaction survey in East Harlem. *Am J Perinatol*. 2021;38(1):88–92.
33 Isautier JM, Copp T, Ayre J, et al. People's experiences and satisfaction with telehealth during the COVID-19 pandemic in Australia: cross-sectional survey study. *J Med Internet Res*. 2020;22(12):e24531.