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Improving obstetric and perinatal outcomes with a remote patient monitoring program for hypertension in a large integrated care system

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A B S T R A C T

Objective: To determine the effect of a remote patient monitoring program for hypertension (RPM HTN) in patients diagnosed with hypertensive disorders of pregnancy.

Study Design: We used a matched retrospective cohort design to evaluate differences in obstetric and perinatal outcomes using data from electronic medical records. Patients enrolled in RPM HTN between November 1, 2019, and October 31, 2021, who delivered a pregnancy at ≥20 weeks gestation were compared to a cohort of patients matched by age, race, HTN and diabetes status, who delivered in the 48-month period before implementation of RPM HTN.

Results: 1030 patients were enrolled in RPM HTN and 937 were matched to historical controls. Five hundred and seventeen (50.2 %) were enrolled in the antepartum period and 513 (49.8 %) were enrolled postpartum. Patients in the RPM HTN cohort were more likely to have a post-hospital discharge blood pressure (BP) measured within the first 20 days after delivery (RR 1.56, 95 % CI: 1.47–1.65: $p < 0.01$) and were more likely to have that BP be normal (RR 1.43, 95 % CI: 1.31–1.55: $p = 0.05$). They were also more likely to be taking antihypertensives postpartum (RR 1.27, 95 % CI: 1.15–1.40; $p < 0.01$) and to be evaluated by an obstetric clinician within 20 days of delivery (RR 1.50, 95 % CI 1.42–1.58; $p < 0.01$).

Conclusions: A remote HTN monitoring program for 937 obstetric patients was associated with improved BP monitoring, better postpartum BP control, and improved linkages to clinician care after delivery, when compared to historical controls.

1. Introduction

The United States (U.S.) has the highest maternal mortality rate among high-income countries, with 32.9 deaths per 100,000 live births in 2021 [1]. Severe maternal morbidity has steadily increased over the last three decades as pregnant women have become older, more obese, and more likely to have pre-existing medical conditions [2,3]. The most common causes of preventable maternal death in the U.S. are severe hypertension, hemorrhage, and venous thromboembolism [4,5]. Hypertensive disorders of pregnancy (HDP), defined as pre-pregnancy chronic hypertension and pregnancy-associated hypertension (pre-eclampsia, eclampsia, gestational hypertension, and chronic hypertension with super-imposed preeclampsia), are a major cause of maternal morbidity and mortality, and have been steadily increasing, affecting about 15.9 % pregnancies in 2019, compared to 5.9 % of pregnancies in 2003 [3,6–8]. Maternal mortality rates in the U.S. are rising, and Black women have nearly three times higher mortality rates than White women [1]. Racial and sociodemographic disparities are present, with HDP prevalence highest among Black women (20.9 %), low-income women, and those living in the South [3,9].

Kaiser Permanente of Georgia (KPGA) is a large, multispecialty integrated health care system serving over 320,000 members in the Atlanta metropolitan area. Our patient population is 43 % Black, 30 % White, 5 % Asian, 4 % Hispanic and 18 % unknown/other [10]. Georgia has one of the highest maternal mortality rates — with an MMR of 28.8 (2018–2020) [11], and one of the highest hypertension mortality rates in the country [12]. We developed an innovative perinatal patient safety program (PPSP) in 2019 to improve our obstetric and perinatal outcomes and decrease maternal and perinatal morbidity and mortality by improving the quality of care for pregnant women [13].

We implemented a remote patient monitoring program for hypertension (RPM HTN) to improve care for obstetric patients within our PPSP. To our knowledge, a large-scale remote blood pressure (BP) monitoring program in obstetric patients diagnosed with HDP that

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follows patients from the antepartum through the postpartum period has not previously been reported in the U.S. This study describes the RPM HTN program's interventions and reports on outcomes in the first 24 months after implementation.

2. Methods

The KPGA PPSP developed a Cocoon Pregnancy Care Model that places the pregnant woman in the center of a protective layer of a care team and services to improve perinatal outcomes. The model included telehealth, remote monitoring, and integration of psychosocial support into routine prenatal care and has been described in detail here [13]. One of the services provided was RPM HTN for pregnant or postpartum women diagnosed with or considered to be at high risk for developing HDP.

We designed a matched retrospective cohort study to evaluate differences in obstetric and perinatal outcomes between patients enrolled in RPM HTN compared to a matched historical control cohort. Outcomes were extracted from the electronic medical record (EMR) for patients enrolled in RPM HTN in the first 24-month period of the program and were compared to a matched cohort of patients who delivered in the 48-month period before implementation of the RPM HTN intervention. One-to-one matching was done and those in the intervention program without historical matches were excluded from the analysis. This study was reviewed by our institution's Institutional Review Board (IRB) and designated as exempt from IRB review, as it was part of an ongoing quality improvement initiative and included only retrospective chart reviews.

Eligibility criteria for inclusion in the RPM HTN intervention cohort included all patients enrolled in RPM HTN who delivered a pregnancy at ≥20 weeks gestation between November 1, 2019, and October 31, 2021, and had either:

1) a history of chronic hypertension,
2) developed pregnancy-associated hypertension in the antepartum, intrapartum, or postpartum period, or
3) were at high risk for developing pregnancy-associated hypertension based on medical history, clinical symptoms, or medical exam (e.g., patients with a single elevated systolic or diastolic BP anytime during pregnancy).

Patients who were < age 18 years, did not have access to a smart phone, did not speak English, and who were not enrolled in the KPGA electronic messaging system (KP.org) were not eligible for inclusion.

Eligibility criteria for inclusion in the RPM HTN control cohort included all patients who delivered a pregnancy at ≥20 weeks gestation between November 1, 2015, and October 31, 2019, and had either:

1) a history of chronic hypertension, or
2) developed pregnancy-associated hypertension in the antepartum, intrapartum, or postpartum period.

Patients who were < age 18 years were excluded from the analysis. We did not exclude patients based on smart phone possession status as that information was unavailable. We also did not exclude based on ability to speak English or enrollment status in KP.org as telephone outreach or electronic messaging through the EMR were not used for HTN management in the period preceding implementation of RPM HTN.

The intervention cohort was matched to the control cohort on the following criteria:

1) age in years (<30,31–34, 35–39, 40 +),
2) race (Black, White, other),
3) any HDP, and
4) any diabetes.

The category of "other" race included Asian, Hispanic and unknown race. Matching was extended to the preceding 48 months to facilitate a suitable number of historical control matches.

We collected data retrospectively from the EMR. Data were collected on maternal demographics, medical conditions, and obstetric outcomes, and were maintained in a secure database. All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were expressed in absolute frequency. We compared associations for the matched cohorts using Fisher exact tests and results were expressed as relative risk (RR) and 95 % confidence interval (CI). We set statistical significance at $p < 0.05$.

Patients enrolled in RPM HTN received a Bluetooth-enabled BP monitor and cuff (Omron BP Monitor – HEM 9200 T/9210 T; OMRON Healthcare) that could transmit BPs real-time to KPGA's EMR via an application on their smartphone (KP Health Ally app). All enrolled patients already had access to a smartphone and mobile internet. Obstetric nurses assisted patients with using the app, educated them on how to check BPs twice daily, and provided education on BP parameters and preeclampsia warning signs. BPs in the EMR were monitored daily by Maternal-Child Health (MCH) nurses, nurse practitioners or certified nurse midwives. Patients had weekly telehealth visits with MCH nurses to review BPs, provide psychosocial support, and reinforce education messages. The RPM HTN program has been described in detail in a previous publication [13].

An alert system notified patients via text and clinicians via the EMR of severely elevated systolic BPs (SBP) ≥160 mm Hg and/or diastolic BPs (DBP) ≥105 mm Hg, SBP <90 mm Hg, a 7-day average SBP ≥145 mm Hg and/or DBP ≥95 mm Hg, or if no BPs were recorded in 3 days. Patients with mildly elevated BPs (SBP 140–159 mm Hg and/or DBP 90–104 mm Hg) without any symptoms were instructed to repeat their BP measurement in 15 min, and physicians were consulted to provide further recommendations. Patients with severely elevated BPs were scheduled for a same-day clinic visit or sent for hospital evaluation if after-hours or if they reported symptoms of preeclampsia. A stringent threshold of DBP ≥105 mm Hg was conservatively classified as severe HTN, to allow for potential delays in evaluation as patients were being monitored at home and would need additional time to present for clinical evaluation.

Patients received remote BP surveillance from enrollment in the antepartum period until hospital admission for delivery, and/or during the immediate postpartum period from hospital discharge until their final 6-week postpartum visit. All patients with HDPs were kept in the hospital for BP monitoring for a minimum of 48 h after delivery. Patients were initiated on antihypertensives if they received magnesium sulfate and/or had SBPs ≥140 mm Hg and/or DBPs ≥90 mm Hg two or more times, six hours after delivery. Antihypertensives were titrated as needed, and patients were discharged home if they had no severely elevated BPs in the preceding 24 h prior to discharge. Patients discharged home with elevated BPs received daily telehealth visits with a clinician who adjusted medications as needed until BPs normalized. Patients were readmitted to the hospital within 6 weeks of delivery if they had symptoms of severe preeclampsia or persistent severely elevated BPs.

Patients received telehealth or in-person postpartum follow-up within 1–2 days of discharge with an MCH nurse, and within 1 week after discharge plus every 1–3 weeks thereafter with a physician. At the 6-week postpartum visit, patients were unenrolled from RPM HTN and follow-up with a primary care physician was scheduled within 4 weeks. Prior to November 2019, the standard management for patients with an HDP did not include remote home BP monitoring. Patients were seen in clinics at a frequency guided by their clinicians and BPs were usually measured during clinic visits. On a case-by-case basis, some patients purchased their own home BP machine, and BP management was individualized by their care team.

For this study, the first postpartum BP measurements recorded from

hospital discharge to 20 days postpartum and the first BP recorded in the 21–56 days postpartum period were analyzed. BPs could be home BPs taken with the remote BP device or clinic BPs recorded in the EMR. When multiple BPs were recorded on a particular day, the first recorded BP was used. In this analysis, the first postpartum BP measurements for patients in the historical cohort were all clinic BPs, and those for patients in the RPM HTN cohort were predominantly home BPs.

3. Results

A total of 1227 KPGA patients had an HDP diagnosis and delivered between November 1, 2019, and October 31, 2021, and were potentially eligible for enrollment in RPM HTN. Of these, 1030 (83.9 %) were enrolled in RPM HTN and 197 (16.1 %) were not enrolled. On chart review, of the 197 patients with an HDP who were not enrolled, 90 (7.3 %) were eligible for inclusion but not included. Most of these patients were diagnosed with an HDP in the first few months of the intervention period when clinicians were not yet used to enrolling all eligible patients. Seventy-nine patients (6.4 %) did not actually have an HDP in the current pregnancy after chart review and were therefore not eligible for inclusion. The remaining 24 patients (1.9 %) had either incomplete enrollment, transferred their care outside of KPGA, declined enrollment, or were ineligible because they were < age 18, non-English speaking, or not enrolled in KP.org.

Five hundred and seventeen patients (50.2 %) were enrolled in the antepartum period, and 513 (49.8 %) were enrolled postpartum. 13.5 % of patients enrolled in the first trimester, 15.7 % in the second trimester, 21.0 % in the third trimester, 37.6 % from birth to 6 days postpartum, 10.4 % from 7 days to 13 days postpartum, and 1.7 % from 14 days to 56 days postpartum.

Of the 1030 patients in the RPM HTN program, 937 had suitable historical control matches and were included in the analysis. Patients in the RPM HTN cohort had a mean age of 31.5 years and a mean pre-pregnancy BMI of 32.8. The majority of patients were Black (60.6 %) and multiparous (50.6 % & 53.7 %) (Table 1). Patients in the RPM HTN cohort were more likely to have pregnancy-associated hypertension than patients in the historical cohort (81.2 % vs 75.4 %; $p < 0.01$), but patients in the RPM HTN cohort were less likely to have pre-gestational diabetes (4.0 % vs 6.3 %; $p = 0.02$).

The mean gestational age at delivery was similar in both cohorts (37.7 weeks vs 37.6 weeks; $p = 0.66$) and most patients delivered by cesarean section (51.1 % vs 52.8 %; $p = 0.46$) (Table 2). Patients in the RPM HTN cohort had a longer mean length of delivery hospital stay (3.1 days vs 2.7 days; $p < 0.01$) and were more likely to be readmitted within 30 days postpartum (RR 1.80, 95 % CI 1.41–2.31; $p < 0.01$). Intensive care unit (ICU) admission rates were similar (RR 1.22, 95 % CI 0.51–2.94; $p = 0.45$), but mean ICU length of stay was shorter for the RPM HTN cohort (1.4 days vs 2.3 days; $p = 0.04$). During the study period there was one maternal death in the historical cohort and no deaths in the RPM HTN cohort, but this was not statistically significant ($p = 0.50$).

Patients in the RPM HTN cohort were more likely to be diagnosed as

Table 1
Demographic characteristics of pregnant patients enrolled in the RPM HTN Cohort and patients included the Historical Control Cohort, Kaiser Permanente Georgia.

	RPM HTN Cohort N = 937	Historical Control Cohort N = 937	p value
Mean Age (±SD), (years)	31.5 (±5.5)	31.3 (±5.7)	0.64
Race n (%)			
Black	568 (60.6)	568 (60.6)	1.00
White	232 (24.8)	232 (24.8)	1.00
Hispanic/Latino	30 (3.2)	41 (4.4)	0.18
Asian	33 (3.5)	33 (3.5)	1.00
Other	74 (7.9)	63 (6.7)	0.33
Mean Body Mass Index (±SD)	32.8 (±8.3)	32.5 (±8.1)	0.59
Multiparous n (%)	474 (50.6)	503 (53.7)	0.18
Hypertensive Condition n (%)			
Hypertensive Disorder of Pregnancy	826 (88.2)	826 (88.2)	1.00
Pre-pregnancy Chronic Hypertension	265 (28.3)	255 (27.2)	0.61
Pregnancy-associated Hypertension	761 (81.2)	707 (75.4)	< 0.01
Diabetes n (%)			
Any Diabetes	198 (21.1)	198 (21.1)	1.00
Pregestational Diabetes	37 (4.0)	59 (6.3)	0.02
Gestational Diabetes	184 (19.6)	176 (18.8)	0.64

RPM HTN Cohort patients enrolled between November 1, 2019, and October 31, 2021. Historical Control Cohort included patients seen in the 48-month period before RPM HTN implementation.

Table 2
Obstetric & perinatal outcomes of pregnant patients enrolled in the RPM HTN Cohort and patients included the Historical Control Cohort, Kaiser Permanente Georgia.

	RPM HTN Cohort N = 937	Historical Cohort N = 937	RR (95 % CI)	p value
Obstetric Outcomes				
Mean Gestational Age at Delivery (±SD), (weeks)	37.7 (±2.7)	37.6 (±2.9)	–	0.66
Preterm delivery (<37 weeks), n (%)	212 (22.6)	240 (25.6)	0.88 (0.75 – 1.04)	0.13
Cesarean Section, n (%)	479 (51.1)	495 (52.8)	0.97 (0.89 – 1.06)	0.46
Maternal Death, n (%)	0 (0)	1 (0.1)	0.33 (0.01 – 8.17)	0.50
Mean Length of Hospital Stay, (days)	3.1	2.7	–	< 0.01
% Postpartum Readmission within 30 days, n (%)	157 (16.8)	87 (9.3)	1.80 (1.41 – 2.31)	< 0.01
ICU Admission During Pregnancy to 6 weeks Postpartum				
Any ICU Admission n (%)	11 (1.2)	9 (1.0)	1.22 (0.51 – 2.94)	0.45
Admission for Hemorrhage/ Hysterectomy n (%)	5 (0.53)	3 (0.32)	1.67 (0.40 – 6.95)	0.48
Admission for Hypertensive Complication n (%)	2 (0.21)	3 (0.32)	0.67 (0.11 – 3.98)	0.66
Admission for COVID-19n (%)	2 (0.21)	0 (0)	5.00 (0.24 – 104.01)	0.30
Admission for Other Diagnosis n (%)	2 (0.21)	3 (0.32)	0.67 (0.11 – 3.98)	0.66
Mean ICU LOS (±SD), (days)	1.4 (±0.8)	2.3 (±1.1)	–	0.04
Perinatal Outcomes				
Fetal Growth Restriction, n (%)	46 (4.9)	24 (2.6)	1.92 (1.18 – 3.11)	< 0.01
Placental Abruption, n (%)	18 (1.9)	7 (0.8)	2.57 (1.08 – 6.13)	0.03
Fetal Demise, n (%)	12 (1.3)	16 (1.7)	0.75 (0.36 – 1.58)	0.56
Neonatal Demise, n (%)	2 (0.2)	5 (0.5)	0.40 (0.08 – 2.06)	0.10
NICU Admission, n (%)	3 (0.3)	1 (0.1)	3.00 (0.31 – 28.79)	0.34
Mean NICU LOS (±SD), (days)	9.7 (±4.0)	14.0 (NC)	–	–

RPM HTN Cohort patients enrolled between November 1, 2019, and October 31, 2021. Historical Control Cohort included patients seen in the 48-month period before RPM HTN implementation.

having a fetus with growth restriction (FGR) (RR 1.92, 95 % CI: 1.18–3.11; p < 0.01) and they were more likely to be diagnosed with a placental abruption (RR 2.57, 95 % CI: 1.08–6.13; p = 0.03) (Table 2). There were no significant differences in the rates of fetal demise (RR 0.75, 95 % CI: 0.36–1.58; p = 0.56), and neonatal demise (RR 0.40, 95 % CI: 0.08–2.06; p = 0.10).

Patients in the RPM HTN cohort were more likely to have a post-hospital discharge BP measured in the first 20 days after delivery (RR 1.56, 95 % CI: 1.47–1.65; p < 0.01), and have that BP be normal (RR 1.43, 95 % CI: 1.31–1.55; p < 0.01). (Table 3). In addition, patients in the RPM HTN cohort were more likely to be taking any antihypertensives postpartum (RR 1.27, 95 % CI: 1.15–1.40; p < 0.01), and to be taking multiple antihypertensives (RR 1.41, 95 % CI: 1.13–1.77; p < 0.01). Finally, patients in the RPM HTN cohort were more likely to be evaluated by an obstetric clinician within the first 20 days of delivery (RR 1.50, 95 % CI 1.42–1.58; p < 0.01), in the period between 21–56 days of delivery (RR 1.06, 95 % CI: 1.03–1.10; p < 0.01), and to be evaluated by an adult medicine clinician between 1 and 3 months after delivery (RR 1.97, 95 % CI 1.73–2.24) (Table 3).

Table 3
Postpartum blood pressure surveillance, management and care linkage outcomes for pregnant patients enrolled in the RPM HTN Cohort and patients included the Historical Control Cohort, Kaiser Permanente Georgia.

	RPM HTN N = 937	Historical Cohort N = 937	RR (95 % CI)	p value
Blood Pressure Surveillance, Management & Outcomes				
Post-hospital discharge BP assessed within 20 days after delivery, n (%)	854 (91.1)	548 (58.5)	1.56 (1.47 – 1.65)	< 0.01
1st post-hospital discharge BP within 20 days after delivery normal, n (%)	610 (65.1)	427 (45.6)	1.43 (1.31 – 1.55)	< 0.01
1st post-hospital discharge BP within 20 days after delivery below severe range, n (%)	920 (98.2)	920 (98.2)	1.00 (0.99 – 1.01)	1.00
BP 21–56 days after delivery assessed, n (%)	814 (86.9)	790 (84.3)	1.03 (0.99 – 1.07)	0.11
1st BP 21–56 days after delivery normal, n (%)	746 (79.6)	711 (75.9)	1.05 (1.00 – 1.10)	0.05
1st BP within 21–56 days after delivery below severe range, n (%)	934 (99.7)	928 (99.0)	1.01 (1.00 – 1.01)	0.08
Postpartum antihypertensive medications	486 (51.9)	383 (40.9)	1.27 (1.15 – 1.40)	< 0.01
Any antihypertensive, n (%)	158 (16.9)	246 (26.2)	1.41 (1.13 – 1.77)	< 0.01
Multiple antihypertensive medications, n (%)	315 (33.6)	172 (18.3)	1.28 (1.11 – 1.47)	< 0.01
Beta Blocker, n (%)	274 (29.2)	27 (2.9)	1.59 (1.35 – 1.88)	1.00
Calcium Channel Blocker, n (%)	27 (2.9)	59 (6.3)	1.00 (0.59 – 1.69)	< 0.02
Diuretic, n (%)	34 (3.6)		0.62 (0.41 – 0.94)	
Other antihypertensive medication, n (%)				
Postpartum Surveillance and Care Linkage				
OB clinician evaluation within 20 days after delivery, n (%)	887 (94.7)	591 (63.1)	1.50 (1.42 – 1.58)	< 0.01
OB clinician evaluation 21–56 days after delivery, n (%)	852 (90.9)	803 (85.7)	1.06 (1.03 – 1.10)	< 0.01
Adult medicine evaluation 1–3 months after delivery, n (%)	462 (49.3)	235 (25.1)	1.97 (1.73 – 2.24)	< 0.01

RPM HTN Cohort patients enrolled between November 1, 2019, and October 31, 2021. Historical Control Cohort included patients seen in the 48-month period before RPM HTN implementation.

4. Discussion

This is the largest remote HTN monitoring program in pregnancy reported to date in the U.S., with 937 patients receiving remote BP monitoring daily from HDP diagnosis in the antepartum or postpartum period until 6 weeks postpartum. Previous studies have limited interventions to mostly the postpartum period [14–21], and a recent systematic review of postpartum home BP monitoring included 13 studies and concluded that home BP monitoring improved BP ascertainment postpartum and decreased racial disparities, but did not find sufficient evidence to prove reductions in severe maternal morbidity and mortality [21]. Our study examined patients from antepartum until their 6-week postpartum visit and found that patients in the RPM HTN cohort were more likely to have their BPs monitored and recorded, more likely to be started on antihypertensives, more likely to have their BPs controlled with 3 weeks and 8 weeks postpartum, and more likely to be linked to care with their obstetric and primary care clinician after delivery.

Our study found that patients in the RPM HTN cohort had a shorter mean ICU length of stay but had a longer length of hospital stay for delivery and a higher rate of readmissions compared to a historical cohort (16.8 % vs 9.3 %). Our high readmission rates might reflect the fact that our program had a robust ability to identify and respond to abnormal BP values – we reviewed daily electronic transmissions of BPs and had high levels of surveillance – program evaluation data showed that by early 2022, nearly all patients in RPM HTN (96 % – 98 %), were transmitting BP values to the EMR daily [13].

The fact that most deliveries were at term is notable as closer BP monitoring did not lead to an increased rate of preterm deliveries. Enhanced BP monitoring might have allowed for early intervention and delivery when indicated, but it also allowed for continued safe outpatient management of patients who did not meet criteria for delivery. We expected that patients in the RPM HTN cohort would have longer lengths of stay during their hospital admission as our new protocols required starting and titrating antihypertensives to effect better BP control prior to hospital discharge. Our enhanced BP surveillance postpartum likely led to better identification of patients with severe BPs and more readmissions to improve BP control. Identifying patients with HDP, managing, and controlling their BPs, and initiating early deliveries when indicated, are important pathways to preventing maternal and neonatal morbidity and mortality. Therefore, the improvements seen with the RPM HTN intervention are reassuring.

Patients in RPM HTN were more likely than patients in the control cohort to be diagnosed with FGR or placental abruption. Pregnancy-associated hypertension has been increasing in the U.S. over the past few decades and is known to be associated with complications like FGR and placental abruption [8]. The increases in diagnosis of FGR and placental abruption in patients in the RPM HTN cohort was likely secondary to this increasing incidence, coupled with heightened awareness and training about HDPs, and improved ultrasound surveillance for patients diagnosed with HDPs that accompanied introduction of the RPM HTN program. This increasing incidence and heightened awareness likely also accounted for the higher diagnosis of pregnancy-associated hypertension in the RPM HTN cohort.

We found no significant differences in the mode of delivery. Fifty-one percent of patients in the RPM HTN cohort and 52.8 % of patients in the

historical cohort had cesarean sections. This is similar to previous reports documenting higher rates of cesarean section (35 % to 66 %) in patients with hypertensive disorders [6,9]. The relatively high cesarean section rate observed in our cohorts may be explained by cohort characteristics such as high prevalence of obesity and diabetes and the fact that patients with HDPs are more likely to be induced and/or to have complications leading to cesarean section like placental abruption.

Previous analyses of our KPGA dataset showed that in 2021, 21.1 % of our obstetric patients had an HDP, and that Black women had a much higher incidence (54.6 %) compared to White women (24.4 %), Asian women (3.2 %), and Hispanic women (2.5 %) [13]. Our study, in a large U.S. cohort with majority Black women and a high incidence of HDPs, showed improved monitoring of BPs and improvements in BP control in the postpartum period with RPM HTN. Optimized management of HDPs in Black women is necessary given the racial disparities observed in the prevalence and complications from HDPs – Black women have a higher incidence of HDPs and have a greater risk of the most severe complications [3,6]. They are also 2.6 times more likely to die of preeclampsia and twice as likely to have a fetal demise when compared to White women. [22] Self-monitoring and telehealth are part of the recommended strategies for identifying and monitoring women with HDPs [3,5], and are emerging as an important tool in reducing disparities – programs are feasible, safe and acceptable, allow for earlier detection of hypertension, and can potentially allow for better control of hypertension in pregnancy [15,17–19,23–29].

This intervention was a quality improvement program that was modified as needed to improve outcomes, causing variations in care over the reporting period – the COVID pandemic, for example, caused us to transition some postpartum clinic visits to telehealth visits. These variations caused differences in how we monitored patients over time but also allowed us to realize that we could safely conduct some postpartum and BP follow-up visits via telehealth. Intervention cohort patients received comprehensive services as part of the new Cocoon Pregnancy Care Model, which could have led to improved outcomes noted and therefore confounded results. Our historical control cohort also extended over a 48-month period during which variations secondary to practice changes and population changes over time could not be ruled out.

Our study was limited in power to evaluate impact on rare outcomes like maternal deaths, neonatal deaths, and neonatal ICU admissions, and a longer period of monitoring will likely be required to better understand whether telemonitoring programs for hypertension can improve maternal and neonatal morbidity and mortality. Our study was also limited because it wasn't designed to measure cost-effectiveness. We acknowledge that there will be increased costs due to the increases in readmissions, lengths of stay, and more outpatient visits, and future work is needed around evaluating costs and decreasing readmissions.

5. Conclusions

Our RPM HTN program was one of the elements of our Cocoon Pregnancy Care Model. It was relatively easy to implement because of KPGA's integrated medical system and EMR, the presence of other elements of Cocoon Pregnancy Care like our MCH nurses, our 24/7 call center that was linked with clinicians in clinics and the hospitals, and our relative ease of connecting patients with primary care clinicians for follow-up. The program can however be adapted and replicated in different clinical settings, including in settings with less comprehensive resources as long as the core elements of patient education, surveillance, outreach and follow-up are put in place. Technology is improving and becoming more widely available — Bluetooth-enabled BP monitoring devices are now available commercially with apps to record and transmit values. Clinicians can create programs to monitor patients closely and designate staff in their offices to help identify and respond to abnormal BP values and get patients connected with care quickly.

The cost of introducing RPM HTN will vary in different clinical settings but can be made affordable by incorporating some of the costs into pre-existing services. The major expenses for our RPM HTN program included purchases of the Omron BP devices and the annual salaries for four new dedicated MCH nurses who provided outreach in addition to other responsibilities. We utilized our pre-existing staff including an NP and CNM who reviewed charts and provided clinical outreach to patients with abnormal BPs, and we absorbed additional appointments generated by the program without addition of new clinical staff. Patient communications were via the EMR and through the call center which were already pre-existing. Programs looking to incorporate RPM HTN should budget for the costs of buying BP devices and software to integrate them into their EMRs, hiring one or more dedicated nurses to provide surveillance and outreach for the program, and planning for additional telehealth or in-person visits in response to abnormal BP values. Pre-existing staff and structures can also be leveraged to operationalize the program.

We plan to monitor the impact of this program on maternal morbidity long term by continuing to track multiple variables and outcomes through our obstetric database. We will continue to track enrollments in the program and protocol adherence for severe hypertension and hypotension alerts, the number of patients on antihypertensives, the number of patients that achieve blood pressure control on antihypertensives, hospital admissions, readmissions, and lengths of stay, and inductions and deliveries due to hypertension alerts. We will also continue to monitor hospital data on multiple outcomes including severe maternal morbidity, severe preeclampsia, gestational hypertension, HELLP syndrome, stillbirth, FGR, abruption, ICU admissions, neonatal death and maternal death.

This report adds to the body of knowledge showing that telemonitoring programs for HDPs should be an important part of care, especially for patients at high-risk of developing hypertensive conditions or complications of HDPs. Our novel program to remotely monitor and manage BPs in the antepartum and postpartum period shows that close monitoring and management during and after pregnancy is feasible and can lead to improved standardized management of hypertension in pregnancy, better postpartum BP control, and improved linkages to care for postpartum management of hypertension.

Declaration of interests.

Fatu Forna is Executive Director of a non-profit organization called The Mama-Pikin Foundation in Sierra Leone, West Africa; serves as a member of the Scientific and Technical Advisory Group for the World Health Organization: HRP (the UNDP/UNFPA/UNICEF/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction); serves on the Jada Global Access Committee; and serves as a consultant to the Concept Foundation.

Ericka Gibson, Philidah Seda, Annette Miles, Grace Sobers, Felipe Lobelo, Armand Mbanya, Belkis Pimentel, Serena Leung, and Kate Koplan have nothing to report.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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