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Prospective Cohort Study of Remote Patient Monitoring with and without Care Coordination for Hypertension in Primary Care

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Abstract

Background Out-of-office blood pressure (BP) measurements contribute valuable information for guiding clinical management of hypertension. Measurements from home devices can be directly transmitted to patients' electronic health record for use in remote monitoring programs.

Objective This study aimed to compare in primary care practice care coordinator-assisted implementation of remote patient monitoring (RPM) for hypertension to RPM implementation alone and to usual care.

Methods This was a pragmatic observational cohort study. Patients aged 65 to 85 years with Medicare insurance from two populations were included: those with uncontrolled hypertension and a general hypertension group seeing primary care physicians (PCPs) within one health system. Exposures were clinic-level availability of RPM plus care coordination, RPM alone, or usual care. At two clinics (13 PCPs), nurse care coordinators with PCP approval offered RPM to patients with uncontrolled office BP and assisted with initiation. At two clinics (39 PCPs), RPM was at PCPs' discretion. Twenty clinics continued usual care. Main measures were controlling high BP (<140/90 mm Hg), last office systolic blood pressure (SBP), and proportion with antihypertensive medication intensification.

Results Among the Medicare cohorts with uncontrolled hypertension, 16.7% (39/234) of patients from the care coordination clinics were prescribed RPM versus <1% (4/600) at

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noncare coordination sites. RPM-enrolled care coordination group patients had higher baseline SBP than the noncare coordination group (148.8 vs. 140.0 mm Hg). After 6 months, in the uncontrolled hypertension cohorts the prevalences of controlling high BP were 32.5% (RPM with care coordination), 30.7 % (RPM alone), and 27.1% (usual care); multivariable adjusted odds ratios (95% confidence interval) were 1.63 (1.12–2.39; $p = 0.011$) and 1.29 (0.98–1.69; $p = 0.068$) compared with usual care, respectively.

Conclusion Care coordination facilitated RPM enrollment among poorly controlled hypertension patients and may improve hypertension control in primary care among Medicare patients.

Background and Significance

Only 44% of U.S. adults with hypertension are controlled, and the level of control has declined in recent years.[1] Meta-analyses have shown that self-measurement of out-of-office blood pressure (BP) combined with telemonitoring interventions improve BP control.[2–4] Out-of-office measurement has been widely endorsed as a means to improve diagnosis management of hypertension.[5–7]

In 2019 the U.S. Medicare began coverage for remote physiological monitoring or remote patient monitoring (RPM) services that can be used to support the remote management of BP.[8] RPM has been applied in a variety of contexts.[9–11] However, the optimal strategy for implementing RPM for hypertension into routine practice is not fully understood. Specifically, we hypothesized that including additional clinical team members beyond patients' regular primary care clinicians to support and coordinate RPM uptake and proactively attempt to enroll uncontrolled hypertension patients would facilitate meaningful differences in the adoption of RPM for hypertension at the clinic level and in hypertension control.

Objectives

We conducted a three-arm pragmatic pilot cohort study in hypertensive Medicare patients at primary care practices, making available an RPM system for BP with and without the support of nurse care coordination. We compared short-term hypertension control, systolic blood pressure (SBP) achieved, and antihypertensive medication intensification at two clinics with RPM available to primary care clinicians with care coordination support, two clinics with RPM without care coordination, and 20 clinics receiving usual care. We also compared the degree of RPM uptake, usage, and persistence as well as possible implementation burdens in the two intervention groups.

Methods

We compared hypertension outcomes separately in poorly controlled and general hypertension cohorts between pilot practices and nonparticipating primary care practices in the same medical group within Northwestern Medicine, a large health system in the Chicago Illinois region. Four practices (two in Chicago and two in its northern suburbs) were approached based on convenience; one from each region was included in each of the two intervention groups. Patients were followed from February 15, 2021 through August 14, 2021. The system uses the Epic (Epic Systems Corp., Verona, Wisconsin, United States) electronic health record (EHR), from which all study data, including data used for identifying the comparison cohorts and outcome data, were abstracted. To improve comparability between patients at intervention clinics and control clinics, we only used BP data collected at primary care locations.

This study was approved by the Northwestern University Institutional Review Board. All data used were obtained in the course of routine medical care with a waiver of informed consent. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement recommendations (►**Supplementary Material: STROBE Statement—: Checklist of items that should be included in reports of cohort studies**, available in the online version.[12]

Interventions/Exposures

Remote Patient Monitoring Implementation in Practices without Care Coordination: Remote Patient Monitoring Only

We had previously integrated Omron VitalSight RPM into the EHR to automatically transmit BP and pulse data to patients' records.[13] Primary care physicians (PCPs) at the two RPM-only clinics received communication by email and at practice meetings explaining RPM procedures, ordering, use, and financial implications. We used passive decision support (an Epic "Best Practice Advisory") at the point of care to notify physicians when patients met study criteria for RPM. It remained at the discretion of the clinician whether to offer RPM. Omron Healthcare was notified of orders electronically and sent patients a Bluetooth-enabled automated BP monitor, cuff, cellular data transmitter, and optional scale if selected by the ordering clinician.

Remote Patient Monitoring Implementation in Practices with Care Coordination

Clinicians in the two care coordination group clinics received the same supports provided to the RPM-only group. In

addition, they received care coordination support, which is more described in the ►Supplementary Material (Description of Care Coordination Approach; available in the online version). In short, we sent PCPs messages with lists of patients whose last two office BPs were ≥ 140/90 mm Hg and asked who should be offered RPM. Nurse care coordinators (T.C. and J.C.) communicated with patients via phone and patient portal and used an EHR registry and care management tools for identification, tracking, automatic monitoring of clinical status, and charting for RPM patients. Activities included providing education about how and when to perform home BP monitoring, contacting patients without at least 12 readings (from at least three different days), reviewing charts when mean BP was ≥130/80 mm Hg, and, when appropriate, reviewing medication adherence, measurement technique, and messaging the patients' PCP.

Participants

Patients Prescribed Remote Patient Monitoring

We collected EHR data for all patients from the four pilot clinics who were prescribed RPM for BP during the study period.

Hypertension Cohorts

At study baseline, we identified cohorts of patients from 2 clinics where RPM was offered with care coordination, 2 clinics with RPM only, and 20 clinics not offered RPM. All physicians and their eligible patients from the pilot sites were enrolled in the cohorts. Two cohorts of "usual care" control patients were selected from the remaining 20 Northwestern Medical Group primary care sites. These patients contributed EHR data but had no new procedures implemented. Once identified, these patient cohorts were prospectively followed for 6 months (February 15, 2021–August 14, 2021).

Two patient populations were of interest: patients with uncontrolled hypertension and the broader hypertensive population. Uncontrolled hypertension cohorts included patients whose two most recent BPs from primary care (within the preceding 2 years) were elevated (either ≥140 mm Hg systolic or ≥90 mm Hg diastolic), and hypertension was diagnosed in the year preceding the study. The general hypertension population included patients with diagnosed hypertension plus those without diagnosed hypertension with BP ≥ 140/90 mm Hg at their most recent office visit in the prior 2 years.

The cohorts were held fixed for the study duration. At the start date, all patients were required to be aged 65–85 years, have Medicare or Medicare Advantage insurance, and have had at least one office or telehealth visit at an eligible primary care site in the preceding year. Exclusion criteria were persistent or permanent atrial fibrillation, stage 4 or more severe chronic kidney disease, or dementia. Overall participant selection and assignment are shown in ►Fig. 1.

Study Measurements

We abstracted demographic characteristics, diagnoses, and vital signs from the EHR. We measured the total number of patients prescribed RPM, and among them, we measured whether they used the device, time to uptake (days between prescription and first reading), intensity of use (mean readings per 30 d), and duration of use (time from first reading to a reading with no subsequent reading for 30 d). To examine

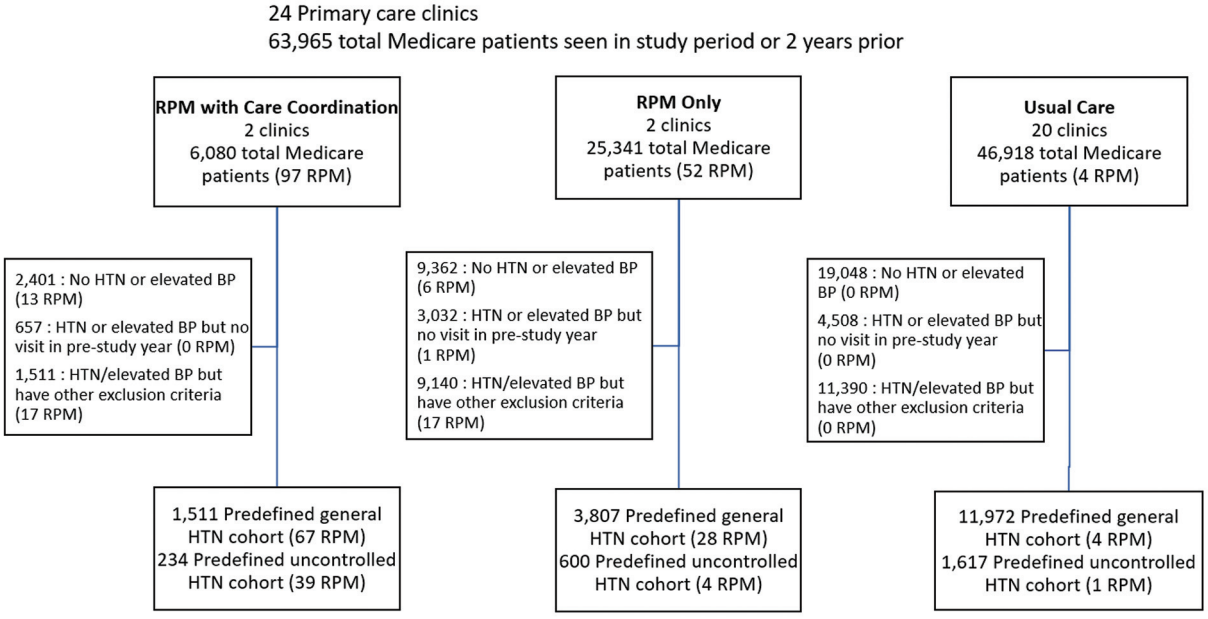

Fig. 1 Participant flow of Medicare patients in the 2 primary care practices with RPM and care coordination, 2 practices with RPM only, and 20 usual care practices. Hypertension cohorts were defined a priori. Primary care clinicians could prescribe RPM to any Medicare patient including those not included in the predefined cohorts and could prescribe it for diagnoses other than hypertension (e.g., heart failure). Four patients from usual care clinics were prescribed RPM from an endocrinology practice that was not part of this study. BP, blood pressure; HTN, hypertension; RPM, remote patient monitoring.

health care utilization, we measured office visits, patient portal messages, and telephone encounters at primary care clinics. In the care coordination group, we measured the number of patient portal messages and telephone calls sent by the care coordinators to patients prescribed RPM. We examined the frequency of Current Procedural Terminology codes associated with remote monitoring to quantify the extent to which RPM services were billed.

The primary effectiveness outcome, measured at 3 and 6 months after baseline, was the controlling high BP performance measure as defined by the 2020 National Quality Forum Measure 0018 (NQF0018): the lowest BP reading on the most recent day BP was obtained was <140/90 mm Hg and was within the prior 12 months.[14,15] Patients could fail NQF0018 if either criteria were not met. Patients without a corresponding BP measurement were considered to not meet the measure. Of note, this measure, which is used in public reporting quality programs, uses the lowest systolic and diastolic BPs obtained on the day with the most recent BP measurement and includes office BPs and BPs obtained via RPM.

Secondary outcomes included most recent primary care in-office SBP and antihypertensive medication intensification. If an individual had multiple in-office measurements from the most recent BP measurement day, we used their average. Patients with no BP measured in the prior year at 3 and 6 months were excluded from SBP analysis due to missingness. Antihypertensive medication intensification was determined from the EHR medication list and was a binary outcome that was considered present if the number of antihypertensive drug classes added or increased minus the number of antihypertensive medication classes discontinued or decreased was greater than zero. To evaluate the influence that the presence of remote readings had on controlling high BP, we compared a version of this metric that used office BPs exclusively (►**Supplementary Tables S1** and **S2**, available in the online version). For the two intervention groups, we also compared BPs obtained exclusively by home readings (►**Supplementary Table S3**, available in the online version).

We solicited feedback from pilot-practice physicians after the study using an emailed survey. Survey methods, results, and qualitative feedback about the care coordination process from the care coordinators (J.C. and T.C.) are provided (►**Supplement Clinician User Experience Survey** and **Qualitative Advice for RPM Implementation from Ambulatory Care Coordinators**, available in the online version).

Statistical Analysis

We used means and proportions to describe demographic characteristics, health care usage, and clinical presentation of patients enrolled in RPM at pilot practices. In a subgroup of RPM users who had submitted at least 12 remote readings, we visualized patient-specific trajectories of SBP from remote readings. We used linear regression to overlay an average of the patient-specific trajectories separately in the care coordination group and the RPM-only group.

At the end of the 6-month follow-up, we calculated averages and proportions as appropriate for continuous and binary outcomes for the RPM-eligible and usual care cohorts for the outcomes at 3 and 6 months. Generalized linear models were used to estimate differences in means of continuous variables (identity link) and differences in log-odds for categorical variables (logit link); a type-I error rate of 5% was prespecified. All models were adjusted for age, gender, ethnicity/race, number of office visits in prior year, and SBP at baseline.

Results

Remote Patient Monitoring Uptake and Blood Pressure Outcomes among Patients Prescribed Remote Patient Monitoring

Twenty-six clinicians from the four intervention practices ordered an RPM device for 149 patients during the study period. Characteristics were similar by age and gender and differed somewhat by race and ethnicity (►**Table 1**). RPM-prescribed patients in the care coordination group had less heart failure (3.1 vs.19.2%) at baseline. Baseline SBP was higher among RPM-prescribed patients in the care coordination group than the RPM-only group (mean [standard deviation] 148.8 [15.5] vs. 140.0 [20.1] mm Hg), and the rate of controlling high BP at baseline was lower (18.6 vs. 44.2%). Patients prescribed RPM in the care coordination group were more likely than those in the RPM-only group to initiate RPM (83.5 vs. 67.3%, $p = 0.02$) and more likely to transmit at least 12 BP readings (79.4 vs. 63.5%, $p = 0.04$). A higher proportion of PCPs in the care coordination group than the RPM-only group prescribed RPM at least once (84.6 vs. 38.5%, $p = 0.009$) and the median number of patients with RPM ordered differed (median [interquartile range]: 5 [4, 11] vs. 0 [0, 2], $p < 0.001$).

At 6 months, among RPM-prescribed patients, 72.2% of the care coordination group and 69.2% of the RPM-only group met the controlling high BP measure ($p = 0.71$). Changes in antihypertensive medication intensification were common and did not differ by group (►**Table 1**).

The average remotely measured SBP trajectories among RPM users with at least 12 readings trended downward over time in both groups (►**Supplementary Fig. S1**, available in the online version). Usage among patients who initiated RPM were similar in the two groups (►**Table 1**).

Hypertensive Cohorts

The uncontrolled hypertension cohorts consisted of 234 patients in the care coordination group, 600 in the RPM-only group, and 1,617 in the usual care group (►**Table 2**). Mean office BPs over the 2 years preceding the study were similar, 154.3/79.1, 153.0/80.4, and 152.1/79.8 mm Hg, respectively. RPM ordering and initiation were greater in the care coordination group than in the RPM-only group at 3 and 6 months (►**Table 3**). By 6 months, 16.2% ($n = 38/234$) of the care coordination cohort and 0.5% ($n = 3/600$) of the RPM-only cohorts had initiated RPM ($p < 0.0001$).

Blood Pressure Outcomes: Uncontrolled Hypertensive Cohorts

►**Table 3** includes primary and secondary outcome comparisons at 3 and 6 months in the uncontrolled hypertensive

Table 1 Characteristics of patients prescribed remote patient monitoring at pilot practices and blood pressure outcomes: February 15, 2021 to August 14, 2021

	RPM clinics with care coordination	RPM clinics without care coordination	*p*-Value
Patients, No.	97	52	
Clinics, No.	2	2	
Primary care physicians, No.	13	39	
RPM-prescribed patients per physician, median (IQR)	5 (4, 11)	0 (0, 2)	0.0002
Physicians with any RPM-prescribed patients, %	84.6	38.5	0.009
Characteristics of patients			
Age, mean, y (SD)	74.0 (6.3)	72.2 (9.8)	0.34
Female, No. (%)	67 (69.1)	33 (63.5)	0.49
Site, No. (%)			
Site A	N/A	35 (67.3)	
Site B	N/A	17 (32.7)	
Site C	80 (82.5)	N/A	
Site D	17 (17.5)	N/A	
Ethnic/race, No. (%)			0.019
Hispanic	1 (1.0)	7 (13.5)	
Non-Hispanic Black	31 (32.0)	14 (26.9)	
Non-Hispanic White	57 (58.8)	28 (53.9)	
Other/unknown	8 (8.3)	3 (5.8)	
Primary language: English, No. (%)	95 (97.9)	49 (94.2)	0.34
Baseline clinical characteristics			
Chronic conditions, No. (%)			
Atrial fibrillation	5 (5.2)	6 (11.5)	0.19
Chronic kidney disease	9 (9.3)	7 (13.5)	0.43
Coronary heart disease	11 (11.3)	11 (21.2)	0.11
Diabetes mellitus	24 (24.7)	16 (30.8)	0.43
Heart failure	3 (3.1)	10 (19.2)	0.002
Hypertension	94 (96.9)	47 (90.4)	0.13
Most recent in-office SBP[a] in year prior to study start, mean (SD), mm Hg	148.8 (15.5)	140.0 (20.1)	0.005
Most recent in-office DBP[a] in year prior to study start, mean (SD), mm Hg	76.4 (8.1)	77.2 (10.8)	0.80
Controlling high blood pressure: most recent BP[b] <140/90 mm Hg in year prior to study start, No. (%)	18 (18.6)	23 (44.2)	0.0008
Clinical outcomes after 6 months			
Controlling high blood pressure: most recent BP[b] <140/90 mm Hg (office or RPM), No. (%)	70 (72.2)	36 (69.2)	0.71
Controlling high blood pressure: most recent BP[b] <140/90 mm Hg (office only), No. (%)	51 (52.6)	31 (59.6)	0.41
Patients with BP measured (office only), No.	94	49	
Most recent SBP[c] (office only), mean (SD), mm Hg	140.9 (17.1)	140.6 (20.9)	0.53
Most recent DBP[c] (office only), mean (SD), mm Hg	74.2 (9.0)	76.9 (11.6)	0.38
Patients with BP measured (office or RPM), No.	97	51	
Most recent SBP[c] (office or RPM), mean (SD), mm Hg	132.5 (19.5)	134.5 (23.1)	0.93

Table 1 (*Continued*)

	RPM clinics with care coordination	RPM clinics without care coordination	*p*-Value
Most recent DBP[c] (office or RPM), mean (SD), mm Hg	75.9 (12.1)	78.3 (10.9)	0.10
Antihypertensive medication intensification change, No. (%)			0.94
No change	52 (53.6)	27 (51.9)	
Any decrease	14 (14.4)	7 (13.5)	
Any increase	31 (32.0)	18 (34.6)	
Antihypertensive medication intensification increased, No. (%)	31 (32.0)	18 (34.6)	0.74
RPM usage			
Patients with any remote BP transmitted, No. (%)	81 (83.5)	35 (67.3)	0.02
Patients with at least 12 remote BP transmitted, No. (%)	77 (79.4)	33 (63.5)	0.04
Time to initial use (d), median (IQR)	8 (5, 14.5)	6 (4, 11)	0.27
Number of remote BP transmitted per month (intensity), median (IQR)	46.9 (30.0, 60.9)	43.3 (23.1, 58.7)	0.44
Time to discontinuation (d), median (IQR)	106 (65, 128)	91 (45, 132)	0.65

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; IQR, interquartile range; N/A, not available; RPM, remote pulse monitoring; SBP, systolic blood pressure; SD, standard deviation.
[a]When multiple blood pressure measurements were available in a time window, their average was used.
[b]When multiple blood pressure measurements were available on the same day, the lowest SBP and lowest DBP were used according to the measure specifications. "Most recent" was defined as the most recent within 1 year of the measurement date.
[c]When multiple blood pressure measurements were available on the same day, their average was used.

cohorts. The proportion with controlled high BP was greater in the care coordination group compared with usual care at 3 months, adjusted odds ratio (aOR): 1.64 (95% confidence interval [CI]: 1.11–2.42, $p = 0.01$) and at 6 months, aOR: 1.63 (CI: 1.12–2.39, $p = 0.01$) but not for the RPM-only cohort compared with usual care, aOR: 1.18 (0.88–1.56, $p = 0.27$) and aOR: 1.29 (0.98–1.69, $p = 0.068$), respectively. There was a small difference in most recent office SBP at 6 months between the RPM-only group and the usual care group, adjusted mean (95% CI): 144.9 (143.3–146.5) versus 146.6 (145.4–147.8) mm Hg ($p = 0.048$); office SBP in the care coordination cohort did not significantly differ from usual care. Few patients had antihypertensive medication intensification in the first 3 months ($N = 272/2,451$; 11%). By 6 months, 21.4% of the care coordination cohort, 15.8% of the RPM-only cohort, and 16.9% of the usual care cohort had antihypertensive medication increased (adjusted *p*-values 0.04 and 0.03 care coordination with RPM vs. usual care and vs. RPM only, respectively).

Results for the general hypertensive cohorts are in ►**Supplementary Tables S4** and **S5** (available in the online version).

Additional Results

In both sets of cohorts, controlling high BP assessed using office BPs alone did not differ significantly across groups at 3 or 6 months (►**Supplementary Tables S1** and **S2**, available in the online version). Comparisons of health care utilization (►**Supplementary Tables S6**, **S7**, and **S8**; available in the online version), remotely measured BPs (►**Supplementary Tables S3**, **S9**, **S10**, available in the online version), and the results of the physician survey and qualitative observations from the nurse care coordinators are provided in the ►**Supplementary Content** (available in the online version).

Discussion

We introduced RPM for BP for Medicare patients in two practices with nurse care coordinator support and two practices without care coordination. In care coordination practices, RPM uptake was spread over a higher proportion of PCPs than in noncare coordination practices. Patients prescribed RPM in the care coordination practices had higher average baseline SBP and were more likely to use RPM once prescribed compared with patients prescribed RPM in noncare coordination practices. Patients prescribed RPM from the noncare coordination practices were more likely to have heart failure. Compared with baseline, after 6 months among patients prescribed RPM, 54% more patients from the care coordination practices and 25% more patients from the RPM-only practices met the controlling high BP measure. Changes in the intensity of antihypertensive medication treatment were common among RPM-prescribed patients with about a third receiving medication intensification and 14% receiving a reduction. In a priori–selected uncontrolled hypertension cohorts, at 3 and 6 months, patients from RPM with care coordination practices had an increased odds of controlled high BP compared with usual care practices. Given the low rates of prescribing RPM in noncare coordination practices, it is not surprising that similar differences were not observed for RPM only.

We suspect the reasons for the low RPM uptake we observed particularly among the RPM practices that did not have care coordination are multifactorial. In our survey,

Table 2 Baseline characteristics for uncontrolled hypertension cohorts as of February 15, 2021

	RPM clinics with care coordination	RPM clinics without care coordination	Usual care
Patients, No.	234	600	1,617
Practices, No.	2	2	20
Age mean, y (SD)	73.1 (5.0)	74.4 (5.6)	73.8 (5.3)
Female, No. (%)	153 (65.4)	422 (70.3)	958 (59.3)
Ethnic/race, No. (%)			
Hispanic	6 (2.6)	35 (5.8)	91 (5.6)
Non-Hispanic Black	44 (18.8)	217 (36.2)	232 (14.3)
Non-Hispanic White	161 (68.8)	286 (47.7)	1,116 (69.0)
Other/unknown	23 (9.8)	62 (10.3)	178 (11.0)
Site, No. (%)			
Site A	N/A	526 (87.7)	N/A
Site B	N/A	74 (12.3)	N/A
Site C	118 (50.4)	N/A	N/A
Site D	116 (49.6)	N/A	N/A
Primary language, No. (%)			
English	229 (97.9)	576 (96.0)	1,484 (91.8)
Spanish	4 (1.7)	16 (2.7)	36 (2.2)
Other	1 (0.4)	8 (1.3)	97 (6.0)
Chronic conditions, No. (%)			
Atrial fibrillation (paroxysmal)	18 (7.7)	51 (8.5)	118 (7.3)
Chronic kidney disease	22 (9.4)	58 (9.7)	137 (8.5)
Coronary heart disease	26 (11.1)	95 (15.8)	268 (16.6)
Diabetes mellitus	68 (29.1)	187 (31.2)	429 (26.5)
Heart failure	7 (3.0)	34 (5.7)	70 (4.3)
Average SBP (SD) February 16, 2020 to February 15, 2021, mm Hg	154.3 (12.7)	153.0 (11.2)	152.1 (11.9)
Average DBP (SD) February 16, 2020 to February 15, 2021, mm Hg	79.1 (8.6)	80.4 (9.0)	79.8 (9.1)
Blood pressure measurements February 16, 2020 to February 15, 2021, No. (%)			
1	118 (50.4)	253 (42.2)	685 (42.4)
2	70 (29.9)	184 (30.7)	505 (31.2)
3 or more	46 (19.7)	163 (27.2)	427 (26.4)
In-person/telehealth visits February 16, 2020 to February 15, 2021, No. (%)			
1	83 (35.5)	178 (29.7)	479 (29.6)
2	67 (28.6)	148 (24.7)	469 (29.0)
3–4	66 (28.2)	176 (29.3)	470 (29.1)
5 or more	18 (7.7)	98 (16.3)	199 (12.3)

Abbreviations: DBP, diastolic blood pressure; N/A, not available; RPM, remote pulse monitoring; SBP, systolic blood pressure; SD, standard deviation.

physicians identified uncertainties about patients' out-of-pocket cost and feeling that RPM was not needed for patients who were already home monitoring as significant reasons for not prescribing RPM. For practices without care coordination, time constraints, lack of dedicated staff, unfamiliarity with the ordering process, and concerns about the amount of time required to manage patients doing RPM were factors described by PCPs. We did not survey patients to identify patient reasons for not initiating RPM or for discontinuing it. Authors describing another hypertension remote monitoring

Table 3 Blood pressure outcomes at 3 and 6 months, uncontrolled hypertension cohorts

	RPM clinics with care coordination ($n = 234$)	RPM clinics without care coordination ($n = 600$)	Usual care ($n = 1,617$)	*p*-Value RPM with CC vs. usual care	*p*-Value, RPM only vs. usual care	*p*-Value RPM with CC vs. RPM only
3-mo outcomes						
RPM prescribed, No. (%)	37 (15.8)	4 (0.7)	0 (0)			<0.0001
RPM initiated, No. (%)	34 (14.5)	3 (0.5)	0 (0)			<0.0001
Number of remote BP transmitted per month (intensity), median (IQR)	74.5 (50, 98.5)	55.3 (30, 100)	N/A			0.51
Patients with office SBP measured, No.	223	559	1,564			
Most recent office SBP[a]	149.7 (147.5, 151.8)	148.4 (147.0, 149.8)	149.5 (148.5, 150.5)	0.90	0.16	0.31
Controlling high blood pressure (last SBP <140 systolic and DBP <90[b], No. (%)	51 (21.8)	113 (18.8)	268 (16.6)			
Adjusted odds ratio of controlling high blood pressure (95% CI)	1.64 (1.11, 2.42)	1.18 (0.88, 1.56)	Ref.	0.01	0.27	0.13
Antihypertensive medication intensification change, No. (%)				0.41	0.69	0.32
No change	191 (81.6)	495 (82.4)	1,333 (82.4)			
Any decrease	11 (4.7)	43 (7.2)	107 (6.6)			
Any increase	32 (13.6)	63 (10.5)	177 (11.0)			
Antihypertensive medication intensification increased, No. (%)	32 (13.6)	63 (10.5)	177 (11.0)	0.12	0.79	0.12
6-mo outcomes						
RPM prescribed, No. (%)	39 (16.7)	4 (0.7)	1 (0.06)			<0.0001
RPM initiated, No. (%)	38 (16.2)	3 (0.5)	0 (0)			<0.0001
Number of remote BP transmitted per month (intensity), median (IQR)	47.6 (30, 75.6)	36.5 (4.8, 100)	N/A			0.60
Patients with office SBP measured, No.	222	536	1,487			
Most recent office SBP[a]	147.3 (144.9, 149.6)	144.9 (143.3, 146.5)	146.6 (145.4, 147.8)	0.59	0.048	0.08
Controlling high blood pressure (last SBP <140 systolic and DBP <90)[b], No. (%)	76 (32.5)	184 (30.7)	438 (27.1)			
Adjusted odds ratio of controlling high blood pressure (95% CI)	1.63 (1.12, 2.39)	1.29 (0.98, 1.69)	Ref.	0.011	0.068	0.26
Antihypertensive medication intensification change, No. (%)				0.08	0.94	0.13
No change	163 (69.7)	440 (73.3)	1,204 (74.5)			

(*Continued*)

Table 3 (*Continued*)

	RPM clinics with care coordination ($n = 234$)	RPM clinics without care coordination ($n = 600$)	Usual care ($n = 1,617$)	*p*-Value RPM with CC vs. usual care	*p*-Value, RPM only vs. usual care	*p*-Value RPM with CC vs. RPM only
Any decrease	21 (9.0)	65 (10.8)	140 (8.7)			
Any increase	50 (21.4)	95 (15.8)	273 (16.9)			
Antihypertensive medication intensification increased, No. (%)	50 (21.4)	95 (15.8)	273 (16.9)	0.04	0.60	0.03

Abbreviations: BP, blood pressure; CC, care coordination; CI, confidence interval; DBP, diastolic blood pressure; IQR, interquartile range; N/A, not available; Ref., reference; RPM, remote pulse monitoring; SBP, systolic blood pressure; SD, standard deviation.

[a]Predicted SBP from the model adjusted for age, gender, race, no. of office visits at baseline, and average SBP at baseline. When multiple blood pressure measurements were available on the same day, the average was used.

[b]When multiple blood pressure measurements were available on the same day, the lowest SBP and the lowest DBP were used according to the measure specifications.

program surveyed patients who dropped out before completing the program goals and found the belief that BP was controlled, a lack of willingness to increase medication, the desire to work directly with their physician rather than a care team, and perceived inconvenience to be reasons for participant withdrawal.[16]

The fact that we observed improvements in our measure of controlling high BP that includes the use of remotely obtained BP values but did not see comparable reductions in office SBP or an alternative measure of controlling high BP using solely office BPs speaks to the importance of using out-of-office BPs in the management of hypertension. The downward trajectories of SBP over time as measured by home BP readings suggest that differences in the assessment of hypertension control observed between measures using RPM and office readings versus office readings alone are not merely due to hypertensive individuals having higher readings in the office than at home.

These findings, particularly those from the care coordination group are consistent with prior literature showing overall positive effects of out-of-office BP when combined with telemonitoring interventions.[2–4] It is notable that compared with usual care cohorts, controlling high BP was better in the care coordination group even though the care coordination approach tested here was not a particularly high intensity cointervention. Several other prior successful remote BP monitoring interventions involved more extensive clinical contact.[17–20] The low uptake among the RPM-only group and the differences we observed between groups highlights the major role care coordination played in proactively engaging patients who had uncontrolled office BP.

Strengths and Limitations

A major study strength was the use of EHR data to enable a prospective cohort design and follow these cohorts for 6 months. The main limitation was that randomization was not feasible. The intervention practices were selected a priori, so patients and physicians at intervention practices could be different from those elsewhere in the medical group. Controlling for differences in important baseline variables should alleviate much of this bias, but residual unmeasured confounding is possible. Second, we observed fairly low uptake of RPM, and only small percentages of the intervention cohorts received RPM. Greater RPM uptake would have allowed us to better judge the effects of RPM in these patient populations. What this does provide, however, is a real-world evaluation of effectiveness. Third, since patients could be prescribed RPM at any time during the study and since the 6-month follow-up was fairly short, the duration of use varied, and was brief in some cases. Longer follow-up may have shown different findings. Fourth, we did not survey patients, so cannot say what factors were barriers or facilitators to initial RPM prescription and its use once prescribed. Fifth, the generalizability of these findings to other settings and in particular to populations with greater numbers of non-English speakers is not known. Lastly, in this study, registered nurses performed care coordination, and

the findings may have differed if coordinators with a different level of training had been involved.

Conclusion

In an observational comparative effectiveness study, RPM for hypertension supported by nurse care coordinators led to enrollment of a higher proportion of eligible hypertensive Medicare patients compared with RPM enrollment delivered only at the discretion of patients' PCPs and was directed at patients with higher baseline BPs. BP control in the uncontrolled hypertension cohort from the care coordinator–supported practices was greater at 3 and 6 months compared with a control cohort.

Clinical Relevance Statement

Within primary care practices, proactive outreach and care coordination to support RPM for hypertension can be used to substantially increase RPM enrollment directed at Medicare patients with uncontrolled hypertension. In the example described here, this led to measurable differences in the rate of controlling high BP.

Multiple-Choice Questions

1. In this study comparing the introduction of RPM for BP into primary care practice for Medicare patients with and without nurse care coordination, which of the following differences occurred between RPM-prescribed patients?
   a. Among patients who used the BP monitor, the number of uses per month was lower and time to stopping monitoring was sooner in practices that did not have care coordination support.
   b. Among patients prescribed RPM, patients in the practices with care coordination were more likely to successfully start to self-monitor than were RPM-prescribed patients from practices without care coordination.
   c. Patients prescribed RPM from practices without care coordination had higher baseline BPs than RPM-prescribed patients from care coordination practices.
   d. Among patients prescribed RPM, patients in the practices with care coordination were more likely to have their antihypertensive medical regimens increased than were RPM-prescribed patients from practices without care coordination.

   Correct Answer: The correct answer is option b. Among patients prescribed RPM from clinics with care coordination, a greater proportion started transmitting remote BP values and they were more likely to transmit 12 or more values. Among RPM users, there were not significant differences in the uses per month or duration of use. RPM-prescribed patients from the care coordination practices had higher baseline SBP than the patients from the practices without care coordination, but the proportion with their antihypertensive medication regimen intensified did not differ.

2. In the cohorts followed here of Medicare patients with uncontrolled hypertension from practices that had RPM with care coordination introduced, RPM introduced without care coordination, or did not have RPM introduced (usual care), which of the following was true at 6 months?
   a. Controlling high BP (<140/90 mm Hg) was more likely in practices that had RPM introduced with care coordination compared with usual care, but there was no difference in most recent office BP.
   b. There were no differences in controlling high blood pressure between any of the groups at 6 months.
   c. Controlling high blood pressure (<140/90 mm Hg) was more likely in practices that had RPM introduced with care coordination compared with usual care and most recent office BP was lower.
   d. Controlling high blood pressure (<140/90 mm Hg) was more likely both in practices that had RPM introduced with care coordination and without care coordination compared with usual care.

   Correct Answer: The correct answer is option a. The adjusted odds of meeting the performance measure controlling high blood pressure was greater in the care coordination practices. This measure uses the BP from the most recent day on which BP was obtained both from in the office and RPM. Few patients in the cohort from the practices without care coordination adopted RPM and the BP outcomes did not differ.

Note

These findings of this stdy were presented in part and in abstract form at the American College of Cardiology (ACC.22) National Meeting in Washington, DC, on April 2, 2022,

Protection of Human and Animal Subjects

This study was approved by the Northwestern University Institutional Review Board. All data used were obtained in the course of routine medical care with a waiver of informed consent.

Registration

This study is registered with ClinicalTrials.gov (identifier: NCT04764318).

Role of the Funder

The Northwestern University investigators were solely responsible for the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation and approval of the manuscript; and decision to submit the manuscript for publication. All analyses were conducted by the Northwestern University employees. Employees from Omron Healthcare Co. Ltd participated and provided input into study meetings and reviewed the manuscript. The Northwestern University investigators retained the right to publish and what content to publish independent of the funder.

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Conflict of Interest

The Northwestern University and the Northwestern Medicine investigators (L.C.P., L.A., Y.P., J.Y.L., S.D.P., J.C., T.C., K. P.) reported receiving grant funding from Omron Healthcare Co. Ltd during the conduct of the study. S.D.P. reported receiving an honorarium for speaking from Omron Healthcare Co. Ltd. J.L. reported receiving salary and reimbursement for travel from Omron Healthcare Co. Ltd. H.S. reported receiving salary and reimbursement for travel from Omron Healthcare Co. Ltd. An employee from Downshift Consulting (C.J.D.) participated and provided input into study meetings and revision of the manuscript. No other disclosures were reported. S.D.P. reported other from Omron Healthcare Co. Ltd, during the conduct of the study; personal fees and other from Omron Healthcare Co. Ltd, personal fees from RAND Corporation, personal fees from the National Committee for Quality Assurance, outside the submitted work; and S.D.P. has served as Chair of the Cardiovascular Measurement Advisory Panel for the National Committee for Quality Assurance.

References

1 Muntner P, Hardy ST, Fine LJ, et al. Trends in blood pressure control among US adults with hypertension, 1999-2000 to 2017-2018. JAMA 2020;324(12):1190–1200
2 Omboni S, Gazzola T, Carabelli G, Parati G. Clinical usefulness and cost effectiveness of home blood pressure telemonitoring: meta-analysis of randomized controlled studies. J Hypertens 2013;31 (03):455–467, discussion 467–468
3 Duan Y, Xie Z, Dong F, et al. Effectiveness of home blood pressure telemonitoring: a systematic review and meta-analysis of randomised controlled studies. J Hum Hypertens 2017;31(07): 427–437
4 Tucker KL, Sheppard JP, Stevens R, et al. Self-monitoring of blood pressure in hypertension: a systematic review and individual patient data meta-analysis. PLoS Med 2017;14(09):e1002389
5 Shimbo D, Artinian NT, Basile JN, et al; American Heart Association and the American Medical Association. Self-measured blood pressure monitoring at home: a joint policy statement from the American Heart Association and American Medical Association. Circulation 2020;142(04):e42–e63
6 Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation 2018;138(17): e426–e483
7 Williams B, Mancia G, Spiering W, et al; List of authors/Task Force members. 2018 Practice Guidelines for the management of arterial hypertension of the European Society of Hypertension and the European Society of Cardiology: ESH/ESC Task Force for the Management of Arterial Hypertension. J Hypertens 2018;36 (12):2284–2309
8 Gordon WJ, Henderson D, DeSharone A, et al. Remote patient monitoring program for hospital discharged COVID-19 patients. Appl Clin Inform 2020;11(05):792–801
9 Chi WN, Reamer C, Gordon R, et al. Continuous remote patient monitoring: evaluation of the heart failure cascade soft launch. Appl Clin Inform 2021;12(05):1161–1173
10 Lara B, Kottler J, Olsen A, Best A, Conkright J, Larimer K. Home monitoring programs for patients testing positive for SARS-CoV-2: an integrative literature review. Appl Clin Inform 2022;13(01): 203–217
11 Centers for Medicare and Medicaid Services Federal Register/Vol. 84, No. 221/Friday, November 15, 2019/Rules and Regulations. 42 CFR Parts 403, 409, 410, 411, 414, 415, 416, 418, 424, 425, 489, and 498 [CMS–1715–F and IFC].
12 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JPSTROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg 2014; 12(12):1495–1499
13 Petito LC, Anthony L, Peprah YA, et al. Remote physiologic monitoring for hypertension in primary care: a prospective pragmatic pilot study in electronic health records using propensity score matching. JAMIA Open 2023;6(01):ooac111
14 Centers for Medicare and Medicaid Services Quality Payment program. Accessed January 25, 2022 at https://qpp.cms.gov/docs/QPP_quality_measure_specifications/CQM-Measures/2020_Measure_236_MIPSCQM.pdf
15 National Committee for Quality Assurance Controlling high blood pressure. Accessed January 25, 2022 at https://www.ncqa.org/hedis/measures/controlling-high-blood-pressure/
16 Blood AJ, Cannon CP, Gordon WJ, et al. Results of a remotely delivered hypertension and lipid program in more than 10000 patients across a Diverse Health Care Network. JAMA Cardiol 2023;8(01):12–21 Erratum in: JAMA Cardiol 2022 Nov 30
17 Margolis KL, Asche SE, Bergdall AR, et al. Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control: a cluster randomized clinical trial. JAMA 2013; 310(01):46–56
18 Margolis KL, Asche SE, Dehmer SP, et al. Long-term outcomes of the effects of home blood pressure telemonitoring and pharmacist management on blood pressure among adults with uncontrolled hypertension: follow-up of a cluster randomized clinical trial. JAMA Netw Open 2018;1(05):e181617
19 Green BB, Cook AJ, Ralston JD, et al. Effectiveness of home blood pressure monitoring, web communication, and pharmacist care on hypertension control: a randomized controlled trial. JAMA 2008;299(24):2857–2867
20 Green BB, Anderson ML, Ralston JD, Catz SL, Cook AJ. Blood pressure 1 year after completion of web-based pharmacist care. JAMA Intern Med 2013;173(13):1250–1252