ORIGINAL RESEARCH

Success in the Achieving CARdiovascular Excellence in Colorado (A CARE) Home Blood Pressure Monitoring Program: A Report from the Shared Networks of Colorado Ambulatory Practices and Partners (SNOCAP)

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Background: **Blood pressure (BP) control among primary care patients with hypertension is suboptimal. Home BP monitoring (HBPM) has been shown to be effective but is underused.**

Methods: **This study was a quasi-experimental evaluation of the impact of the A CARE HBPM program on hypertension control. Nonpregnant adults with hypertension or cardiovascular disease risk factors were given validated home BP monitors and reported monthly average home BP readings by Internet or phone. Patients and providers received feedback. Change in average home and office BP and the percentage of patients achieving target BP were assessed based on patient HBPM reports and a chart audit of office BPs.**

Results: **A total of 3578 patients were enrolled at 26 urban and rural primary care practices. Of these, 36% of participants submitted ≥2 HBPM reports. These active participants submitted a mean of 13.5 average HBPM reports, with a mean of 19.3 BP readings per report. The mean difference in home BP between initial and final HBPM reports for active participants was −6.5/−4.4 mmHg ($P < .001$) and −6.7/−4.7 mmHg ($P < .001$) for those with diabetes. The percentage of active participants at or below target BP increased from 34.5% to 53.3% ($P < .001$) and increased 24.6% to 40.0% ($P < .001$) for those with diabetes. The mean difference in office BP over 1 year between participants and nonparticipants was −5.4/−2.7 mmHg ($P < .001$ for systolic BP, $P = .01$ for diastolic BP) for all participants and −8.5/−1.5 mmHg ($P = .014$ for systolic BP, $P = .405$ for diastolic BP) for those with diabetes.**

Conclusions: **An HBPM program with patient and provider feedback can be successfully implemented in a range of primary care practices and can play a significant role in BP control and decreased cardiovascular disease risk in patients with hypertension. (J Am Board Fam Med 2015;28:548–555.)**

Keywords: **Community-Based Participatory Research, Hypertension, Practice-based Research, Quality Improvement**

Elevated blood pressure is a major risk factor for stoke, kidney disease, and cardiovascular disease. Yet only half of people with hypertension (HTN) in the United States achieve adequate blood pressure control.[1] In 2008, an American Heart Association scientific statement called for the routine use of home blood pressure monitoring (HBPM) in

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patients with HTN.[2] However, HBPM is underused in primary care.[3,4]

Home blood pressure measurement is a better predictor of cardiovascular disease outcomes[2,5] and target organ damage[5,6] than blood pressure measured in a physician's office. HBPM is an evidence-based strategy that has been shown to lower blood pressure,[2,7–11] improve medication adherence,[2,12,13] and promote lifestyle changes to improve blood pressure control.[2] The best evidence for the efficacy of HBPM comes from trials using HBPM in conjunction with additional support, usually nurse- or pharmacist-led follow-up of patients with uncontrolled blood pressure.[8,11] Whether the major impact of these trials came from HBPM, intensive pharmacist- or nurse-led follow-up, lifestyle and adherence counseling by pharmacists or nurses, or a combination of these is unclear.

The Achieving Cardiovascular Excellence in Colorado (A CARE) program was a quality improvement initiative to help primary care practices use HBPM to improve blood pressure control, particularly in rural and urban underserved populations. The A CARE program was designed for primary care practices of varying sizes, including small practices and community health centers. The program aimed to provide participating patients with self-management tools to support HBPM and a reporting system that could be easily integrated into routine practice so patients could share home blood pressure information with their providers, who could, in turn, make clinical and lifestyle management decisions to improve blood pressure control between regular office visits.

Because intensive disease management and follow-up from pharmacists is not generally available in primary care practices, this project describes the impact of the A CARE HBPM program, embedded in the primary care practice setting, on participants' blood pressure.

Methods

A CARE was a quality improvement intervention that used HBPM to improve blood pressure control. A chart audit of randomly selected patients with HTN was conducted to compare blood pressure control among A CARE participants with nonparticipants. The evaluation protocol and chart audit instrument were approved by the Colorado Multiple Institutional Review Board at the University of Colorado Anschutz Medical Campus.

Implementation

Twenty-six practices implemented the A CARE program. Practices were members of the Shared Networks of Colorado Practices and Partnerships (SNOCAP), a statewide affiliation of practice-based research networks. Practices were primarily in rural or underserved urban areas. Nonpregnant adults aged 18 years and older were eligible. Since this was a quality improvement program, patients and practices were not randomized. Providers selected participants based on patient needs, although they were encouraged to enroll patients with elevated office blood pressure readings, established HTN, or other cardiovascular disease risk factors.

Practice and Patient Training

Staff and providers at participating practices attended a continuing medical education program that included training in HTN control, the importance of HBPM, and home blood pressure measurement technique. Before starting the program, participating patients were asked to watch a training video that reviewed both HBPM technique and the system for reporting HBPM results to their provider. Trained practice staff evaluated patient HBPM cuff use while the patient was in the office and answered patients' questions. Enrolled patients received a copy of the video for review at home and a patient education booklet that reinforced the information presented in the video.

Home Blood Pressure Monitoring

Participating patients were given a home blood pressure monitor. The home blood pressure monitors used in A CARE (Prevention [Mark of Fitness] models WS-80 and DS 1902; Nissei/Japan Precision Instruments, Inc., Gunma, Japan) were validated for accuracy by the German Hypertension Society using standard international criteria.[14] The DS 1902 monitor was validated with a one-size cuff that fits arm sizes of 9 to 17 inches (22 to 43 cm), which is equivalent to the standard regular and large adult cuff sizes used in offices. Patients with arm size >16.5 inches (office extra-large or thigh cuff) received the WS-80 wrist cuff. Training for patients emphasized the importance of arm position when using this cuff, especially for patients who received the wrist cuff. Participants were asked to measure their blood pressure once a day, varying the time of day of measurement. The monitors automatically recorded each reading and included a

feature that could average up to 30 blood pressure readings. Patients enrolled by registering with the A CARE reporting system. Registration information included demographic information, cuff type, and diagnosis of diabetes.

Reporting

Participants were asked to report once a month their average home blood pressure and the number of readings taken using the A CARE secure website, interactive telephony, or mail-based reporting systems. Monthly reminders to report HBPM results were sent via E-mail or telephone. Patients received immediate feedback about whether their reported average home BP was at goal, how the blood pressure compared with the previous report, and a graph of all reports over time. Information was stored in the secure, Health Insurance Portability and Accountability Act–compliant A CARE reporting system database. For most patients, the home blood pressure goal was an average of <135/85 mmHg. For patients with self-reported diabetes, the home blood pressure goal was <130/80 mmHg. These goals were based on the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, which was the standard of care at the time of the program. Providers received a weekly faxed report that included the average home blood pressures for their patients who had reported during the past 7 days and a list of patients in the practice who were enrolled in the program but had not reported in the past 90 days.

Evaluation

For this quality improvement, quasi-experimental program, a before-and-after methodology was used to evaluate the effect of HBPM on blood pressure control. Two data sources were used for this evaluation: (1) chart audit of office blood pressure measurements and (2) home blood pressure reports.

A retrospective chart audit was conducted to collect office blood pressure data at 20 clinics that had participated in A CARE for at least 1 year. Eligibility criteria included being an adult aged 18 years or older, a diagnosis of HTN (as indicated by a billing code 401.x), at least 1 office visit in the year preceding the clinic's A CARE start date, and diagnosis of HTN at an office visit the year before the clinic state date. Patients in the A CARE program must have been enrolled for at least 4 months before the audit. A total of 20 randomly selected A CARE patients and 20 nonparticipating patients were audited in each clinic, for a total of 40 charts. In clinics with fewer than 20 patients enrolled in A CARE, all participant charts were audited. Equal numbers were audited in each group to maximize power. A minimum of 200 controls were included to provide a stable estimate.

To further evaluate the effect of HBPM on clinic blood pressure control, the change in home blood pressure levels and the proportion of participants at target were assessed using the A CARE HPBM database. Initial blood pressure reports were compared with the most recent report for all patients who had reported at least twice.

The main outcomes of chart audit and HBPM data analyses were mean change in blood pressure and change in the proportion of patients at target blood pressure.

The chart audit analysis compared blood pressure at the final visit before the clinic started the program compared with blood pressure at the final visit at the end of the project. HBPM analysis compared the initial home blood pressure report to the most recent report for all patients who had reported at least twice. Target office blood pressure is defined as ≤140 *and* ≤90. For diabetes, the target is ≤130 *and* ≤80. Target home blood pressure is ≤135/85 mmHg. For diabetes, the target home blood pressure level is ≤130/80 mmHg.

Statistical Analysis

Descriptive statistics were computed to describe baseline patient and practice characteristics. Patient and practice characteristics were used as covariates in the analyses if they were associated with the outcome in bivariate analyses (at $P < .20$) or if they were determined to be clinically important. χ^2 And *t* tests were used to determine whether there were differences between HBPM participants and nonparticipants. General linear mixed-effects models (SAS Proc Mixed; SAS Institute, Inc., Cary, NC), adjusted for clustering of patients within practices using a practice random effect, were used to compare change in systolic and diastolic blood pressure for participants and nonparticipants. For the dichotomous outcome of blood pressure at target before and after the intervention, generalized linear mixed models (SAS Proc GLIMMIX; SAS Institute, Inc.) were used. All hypothesis tests were 2-sided with $\alpha = 0.05$ or *P* values reported. Statis-

Table 1. Demographic Characteristics of Achieving CARdiovascular Excellence in Colorado (A CARE) Participants

	All Participants (n = 3578)	Participants With Diabetes (n = 853)
Age (years)	Mean 60.3 years	Mean 63.8 years
18–34	136 (3.8)	7 (0.8)
35–49	618 (17.3)	104 (12.2)
50–64	1501 (42.0)	358 (41.9)
≥65	1319 (36.9)	385 (45.1)
Missing	4 (0.1)	
Female sex, n (%)	1996 (55.8)	465 (54.5)
Race, n (%)		
White	1877 (52.5)	371 (43.4)
African American	133 (3.7)	19 (2.2)
Asian/Pacific Islander/Native American/Alaska Native	80 (2.3)	26 (3.0)
Other or unspecified	1487 (41.56)	438 (51.3)
Hispanic ethnicity	1534 (42.9)	446 (52.2)
Diabetes, n (%)	853 (23.8)	853 (100)

tical analysis was conducted using SAS software version 9.4 (SAS Institute, Inc.).

Results

A CARE enrolled a total of 3578 participants from January 2007 to June 2010. Demographic characteristics of these patients are shown in Table 1. Of these patients, 24% had self-identified diabetes mellitus. Approximately 10% of patients used the wrist cuff.

Home Blood Pressure Monitoring

Active participants in A CARE were those who submitted at least 2 home blood pressure reports; 36% of A CARE participants were active participants (see Table 2). Over an average of 368 days of participation, active participants submitted a mean of 13.5 average home blood pressure reports, with a mean of 19.3 readings per report. The average time between submitted reports was 56.9 days. Initial home blood pressure (systolic/diastolic) for active participants was

Table 2. Home Blood Pressure Monitoring Results (Participants Submitting ≥2 Reports)

	All Participants (n = 1289)	Participants With Diabetes (n = 273)
Reports submitted, mean (range)	13.5 (2–199)	12.0 (2–70)
Readings per report, mean (range)	19.3 (0–60)	20.3 (0–60)
Time between reports (mean days)	56.9	59.7
Months in the program (mean)	14.3	14.6
Blood pressure (mmHg)		
Average initial home SBP	137.6	139.1
Average initial home DBP	83.0	80.7
Average final home SBP	131.2	132.4
Average final home SBP	78.7	76.0
Difference in SBP/DBP between initial and final HBPM report	−6.5/−4.4†	−6.7/−4.7†
Percentage of BP < target*		
Initial	34.5	24.6
Final	53.3	40.0
Change in percentage at target from initial to final HBPM report	18.8†	15.4†

*Target = home blood pressure (BP) <130/80 mmHg with diabetes; home BP <135/85 for all other patients.
†$P < .001$.
DBP, diastolic blood pressure; HBPM, home blood pressure monitoring; SBP, systolic blood pressure.

Table 3. Demographic Characteristics of Patients in the Chart Audit (n = 732)

	A CARE Participants (n = 378)	Nonparticipants (n = 352)	A CARE Participants With Diabetes (n = 113)	Nonparticipants With Diabetes (n = 97)
Mean age, years	60.0	58.7	61.5	61.1
Female sex, n (%)	235 (62.2)	204 (58.0)	70 (62.0)	56 (57.7)
Race, n (%)				
White	157 (41.5)	127 (36.1)	31 (27.4)	31 (32.0)
Black	7 (1.9)	11 (3.1)	2 (2.1)	2 (1.8)
Asian/Pacific Islander	4 (1.06)	1 (0.3)	0 (0)	0 (0)
Other	3 (0.8)	0 (0)	0 (0)	0 (0)
Unknown*	207 (54.8)	213 (60.5)	80 (70.8)	64 (66.0)
Hispanic ethnicity, n (%)†	171 (45.2)	120 (34.1)	69 (61.1)	43 (44.3)
Diabetes, n (%)	113 (29.9)	97 (27.6)	—	—

*Race/ethnicity data were not found in the medical record.
†Statistically significant difference ($P < .05$) between patients in A CARE and non participants.
A CARE, Achieving Cardiovascular Excellence in Colorado.

137.6/83.0 mmHg. This decreased to 131.2/78.7 mmHg on the final home blood pressure report, for a mean difference of −6.5/−4.4 mmHg ($P < .001$). The percentage of these patients achieving target blood pressures increased from 34.5% initially to 53.3% on the final home blood pressure report ($P < .001$). For participants with diabetes, the mean difference in home blood pressure was −6.7/−4.7 mmHg ($P < .001$), and the percentage of patients at target increased from 24.6% initially to 40.0% ($P < .001$).

Chart Audit

A chart audit compared office blood pressures of 378 randomly selected patients who had participated in A CARE for at least 4 months with office blood pressures of 352 randomly selected control nonparticipants. There was no significant difference in age or diabetes status between the 2 groups. The A CARE participant group had a larger percentage of Hispanic patients than the group of nonparticipants (see Table 3).

For A CARE participants, mean office blood pressure decreased 6.3/4.1 mmHg, from 141.5/84.4 to 135.1/80.4 mmHg ($P < .001$). The change in mean systolic and diastolic blood pressure in the office for nonparticipants was not significant (see Table 4). The mean difference between the A CARE patients and nonparticipants was −5.4/−2.7 mmHg ($P < .001$ for systolic blood pressure; $P = .01$ for diastolic blood pressure). For A CARE pa-

Table 4. Change in Mean Office Systolic and Diastolic Blood Pressure in Chart Audit Patients

	A CARE Participants (n = 378)	Nonparticipants (n = 352)	A CARE Participants With Diabetes (n = 113)	Nonparticipants With Diabetes (n = 97)
SBP				
Initial	141.5	133.3	142.3	131.6
Final	135.1	132.5	137.0	133.7
Mean difference*	−6.3 ($P < .001$)	−0.9 ($P = .54$)	−5.9 ($P = .0175$)	+2.6 ($P = .335$)
DBP				
Initial	84.4	80.9	83.0	79.5
Final	80.4	79.5	79.3	77.4
Mean difference†	−4.1 ($P < .001$)	−1.42 ($P = .128$)	−3.60 ($P = 0.0082$)	−2.1 ($P = .1245$)

*Intervention vs comparison group: $P = .0003$ for total, $P = .0137$ for patients with diabetes.
†Intervention vs comparison group: $P = .0101$ for total, $P = .4050$ for patients with diabetes.
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Table 5. Percentage of Patients at Target Blood Pressure at First versus Last Office Visit

	All Participants		Patients With Diabetes	
	A CARE (n = 378)	Control (n = 352)	A CARE (n = 106)	Control (n = 91)
At target first office BP	30.8	49.4	11.7	28.3
At target last office BP	48.3	58.7	22.3	38.6
Difference	17.5*	9.3*	10.6†	10.3†

*Achieving Cardiovascular Excellence in Colorado (A CARE), $P < .0001$; comparison, $P = .0.0072$.
†ACARE, $P = .0381$; comparison, $P = .0917$.
Intervention vs comparison group on change in at-target blood pressure (BP): all participants, $P = .0782$; patients with diabetes, $P = .9671$.

tients with diabetes, mean office blood pressure decreased from 142.3/8.0 to 137.0/79.3 mmHg (see Tables 4 and 5). There was no significant change in mean office blood pressure for nonparticipants with diabetes. Among patients with diabetes, the mean difference between the groups was −8.5/−1.5 ($P = .014$ for systolic blood pressure; $P = .405$ for diastolic blood pressure).

There was a 56.8% increase in the percentage of patients with an at-target office blood pressure in the A CARE program, compared with a 18.8% increase in the control group ($P = .078$; see Table 5).

Discussion

Participants in the A CARE HBPM program had a significant decrease in average home blood pressure over an average of 12 months of participation in the program (−6.5/−4.4 mmHg). A similar decrease occurred in patients with diabetes (−6.7/−4.7 mmHg). These results represent a major positive impact on the target population's risk for cardiovascular events. A population-wide 5-mmHg decrease in systolic blood pressure would be expected to decrease stroke mortality by 14%, coronary heart disease mortality by 9%, and overall mortality by 7%.[15]

Since it was not possible to compare home blood pressure readings among A CARE participants with home blood pressure readings among control patients, it was not possible to rule out a temporal trend toward improved blood pressure control among all patients, whether they participated in HBPM or not. As a partial attempt to determine the temporal trend in blood pressure control, we conducted a chart audit comparing office blood pressure measurements among A CARE participants with those of nonparticipants. A CARE participants had a significantly greater decrease in office blood pressure readings over approximately 1 year than nonparticipants. There was an even greater improvement in office blood pressure measurements for participants with diabetes, a group in which it is often difficult to achieve blood pressure control.

Multiple factors have kept HBPM from being widely adopted, despite recommendations for use by all patients with HTN. These include the cost of home blood pressure monitors, which are generally not covered by insurance; a lack of provider recommendations for HBPM; lack of provider trust in HBPM accuracy, and the absence of systems that allow patients to report HBPM results to providers.

A CARE provided home blood pressure monitors to the participants at no cost and successfully increased the number of underserved patients with a low socioeconomic status using HBPM. Participating providers knew that the home blood pressure monitors they gave to patients had been validated for accuracy and that patients had been trained in their use. This allowed them to feel comfortable using HBPM results in managing their patients with HTN. Indeed, 84% of providers participating in A CARE who were surveyed noted that they preferentially relied on HBPM data for managing patients with HTN (unpublished survey data). The availability of the A CARE HBPM Internet and telephone reporting systems also helped facilitate the use of HBPM in managing patients with HTN.

We did not systematically collect data concerning any side effects or issues patients had with the HBPM program, but some providers noted that there are a small number of patients who develop significant anxiety concerning their HBPM results. These patients may tend to check their home blood

pressure more frequently than recommended. This was, however, a relatively rare occurrence among participants.

Participants in A CARE were more likely to have uncontrolled blood pressure at enrollment into that study than nonparticipants seen during a similar time frame. This suggests that HBPM programs with report-sharing systems, such as A CARE, provide a useful and effective resource for providers to use with patients with uncontrolled HTN.

When the A CARE study began, it was not clear whether HBPM alone improved blood pressure control. Since that time, additional meta-analyses and clinical studies have shown that HBPM does improve blood pressure control, although the degree of improvement varies. The majority of studies that showed improved blood pressure control using pharmacist-led follow-up of elevated blood pressure readings. This is possible in large health systems where clinical pharmacists are available but may not be practical in the average primary care practice or smaller rural community. The A CARE program was successfully implemented in a range of primary care practice settings, over half of which were small, rural practices with 1 to 3 practitioners. Patient satisfaction with the HBPM program was high. Since many patients with HTN are seen in these smaller practices, HBPM programs such as A CARE could play an important part in improving blood pressure control.

Limitations

The A CARE study assessed improvements in blood pressure control but did not specifically evaluate the impact of HBPM on cardiovascular disease outcomes such as myocardial infarction, stroke, or kidney disease. The A CARE study did not specifically address the cost-effectiveness of HBPM; however, multiple other studies have shown that HBPM is cost-effective.[16–18]

This study enrolled patients chosen by primary care physicians and was not a randomized controlled trial. The HBPM program is one possible explanation for the improved blood pressures in the A CARE group; however, it is not possible to rule out some other difference between the groups that could account for this improvement. For example, there is a possibility that providers introduced bias into the sample frame, choosing patients who were more likely to comply with any intensive treatment program. However, this study was conducted in 26 practices and included several thousand patients. The findings are robust and in the appropriate direction. Even if bias was introduced, the program proved beneficial for participating patients. One-third of participants submitted multiple home blood pressure reports; thus comparing initial and follow-up blood pressure reports for all A CARE participants was not possible. Individual practices included intervention and control patients. Providers who enrolled some patients in the ACARE program may have become more diligent in their management of HTN among all their patients. While the improvement in blood pressure measurement and the percentage of patients in good control was higher among participating patients, a provider- or practice-level impact in overall HTN management may account for the overall higher rate of patients with good blood pressure control. Implementing HBPM in an office may improve overall HTN management in the office.

Conclusion

The HBPM program A CARE was successfully implemented into a variety of primary care practice settings, including small and rural practices. Patients benefitted from HBPM and are at lower risk of major cardiovascular events. HBPM may be an important component of cardiovascular risk reduction for primary care practices throughout rural and urban underserved communities.

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