

Hypertension Management Using Mobile Technology and Home Blood Pressure Monitoring: Results of a Randomized Trial in Two Low/Middle-Income Countries

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Abstract

Objective: Hypertension and other noncommunicable diseases represent a growing threat to low/middle-income countries (LMICs). Mobile health technologies may improve noncommunicable disease outcomes, but LMICs lack resources to provide these services. We evaluated the efficacy of a cloud computing model using automated self-management calls plus home blood pressure (BP) monitoring as a strategy for improving systolic BPs (SBPs) and other outcomes of hypertensive patients in two LMICs. **Subjects and Methods:** This was a randomized trial with a 6-week follow-up. Participants with high SBPs (≥ 140 mm Hg if nondiabetic and ≥ 130 mm Hg if diabetic) were enrolled from clinics in Honduras and Mexico. Intervention patients received weekly automated monitoring and behavior change telephone calls sent from a server in the United States, plus a home BP monitor. At baseline, control patients received BP results, hypertension information, and usual healthcare. The primary outcome, SBP, was examined for all patients in addition to a preplanned subgroup with low literacy or high hypertension information needs. Secondary outcomes included perceived health status and medication-related problems. **Results:** Of the 200 patients recruited, 181 (90%) completed follow-up, and 117 of 181 had low literacy or high hypertension information needs. The median annual income was \$2,900 USD, and average educational attainment was 6.5 years. At follow-up intervention patients' SBPs decreased 4.2 mm Hg relative

to controls (95% confidence interval $-9.1, 0.7$; $p=0.09$). In the subgroup with high information needs, intervention patients' average SBPs decreased 8.8 mm Hg ($-14.2, -3.4$, $p=0.002$). Compared with controls, intervention patients at follow-up reported fewer depressive symptoms ($p=0.004$), fewer medication problems ($p<0.0001$), better general health ($p<0.0001$), and greater satisfaction with care ($p\leq 0.004$). **Conclusions:** Automated telephone care management plus home BP monitors can improve outcomes for hypertensive patients in LMICs. A cloud computing model within regional telecommunication centers could make these services available in areas with limited infrastructure for patient-focused informatics support.

Key words: cardiology/cardiovascular disease, telehealth, telemedicine

Introduction

HYPERTENSION IN LOW/MIDDLE-INCOME COUNTRIES

More than one in four adults worldwide has hypertension,¹ and by 2025, the prevalence will increase 60%, totaling more than 1.5 billion people. Two-thirds of hypertensive people live in low/middle-income countries (LMICs) (i.e., countries identified by the World Bank as having an annual per capita gross national income of less than \$12,275 USD [and less than \$1,005 USD for low-income countries]).¹ In Latin America, more than 100 million adults are hypertensive, and rates among men are among the highest in the world.¹ Hypertension is a leading cause of the global epidemic of cardiovascular diseases.^{2,3}

TELEHEALTH AND MOBILE HEALTH IN CHRONIC DISEASE MANAGEMENT

Telehealthcare management is a widely accepted strategy for improving outcomes of people with noncommunicable diseases (NCDs). For hypertensive patients, home blood pressure (BP) monitoring is particularly effective when linked with telehealth follow-up.⁴ Even in low-resource countries, most adults have access to a telephone,⁵ and studies in Latin America indicate that nurse telemanagement can improve NCD outcomes.^{6,7} Unfortunately, frequent telehealth education and monitoring by clinicians are labor intensive and rarely available in LMICs.

Mobile health (m-health) services seek to increase access to between-visit support by augmenting clinician contact with

automated services delivered via smart phones,⁸ short message service (text messaging),⁹⁻¹² and automated calls.¹³⁻¹⁷ Automated telephone management and behavior-change calls can improve self-care and health outcomes among NCD patients and may be more cost-effective than in-person visits or calls with “live” clinicians.¹⁴⁻¹⁷ However, rigorous studies of m-health services in LMICs are rare.

CLOUD COMPUTING FOR M-HEALTH SUPPORT IN LMICS

Most countries lack the resources to launch and maintain an m-health service. Cloud computing models could make m-health services more available through regional centers with the capacity to support the technologic infrastructure. We tested the feasibility of delivering weekly automated telephone NCD management calls using a cloud computing approach.¹⁸ Calls were deployed from a server in the United States to diabetes patients in Honduras. Despite patients’ limited literacy and incomes, most had cell phones, most who were approached enrolled, and most completed their automated calls. At follow-up, patients reported high levels of intervention satisfaction and improvements to self-care. Hemoglobin A1c levels decreased significantly, and patients reported improvements in health status. Because the study did not include a control group, health benefits potentially attributable to the intervention could not be differentiated from secular trends or other potential biases.

PURPOSE OF THE STUDY

Here, we report the results of a randomized trial of automated telephone monitoring and behavior-change calls plus home BP monitoring among hypertensive patients in Honduras and Mexico. The computing infrastructure was maintained on a U.S. server, and weekly hypertensive support calls were delivered to participants’ telephones using voice over Internet protocol. The study’s primary outcome was systolic BP (SBP), with one preplanned subgroup analysis: patients with low literacy or high BP management information needs. Secondary outcomes included patients’ perceived general health, depressive symptoms, medication-related problems, and satisfaction with care.

Subjects and Methods

SITES AND SAMPLING

The study was approved by the University of Michigan Human Subjects Committee, as well as committees in Honduras and Mexico. Patients between 18 and 80 years of age were eligible if they had access and were able to use either a cell phone or landline telephone and had an SBP suggesting hypertension (i.e., SBP ≥ 130 mm Hg if diabetic or ≥ 140 mm Hg if nondiabetic).¹⁹

Patients living in rural and semirural areas of Cortés, Honduras were identified from four private and two public clinics. Clinical staff made initial patient contacts. Patients living in and around Real del Monte, Mexico, were recruited through a large primary care practice, a diabetes specialty clinic, and community outreach. In both countries, patients had limited health insurance. Seven of the eight participating clinics were staffed by primary care physicians as well as

nurses; the remaining clinic in Honduras was staffed only by a nurse practitioner.

RANDOMIZATION, MASKING, AND USUAL CARE

After completing informed consent, participants were randomized to the intervention or usual care group based on a computer-generated series of numbers that ensured balance between experimental groups within each country. Given the nature of the intervention, it was not possible to blind patients or their clinicians to their experimental assignment. At baseline, all patients received written information about hypertension produced and translated into Spanish by the American Heart Association. Patients with SBPs ≥ 160 mm Hg and < 180 mm Hg were given a letter directed to their primary care provider alerting that clinician about the patient’s high BP reading. Those patients were instructed to bring the letter to their next clinical encounter, and, when possible, research associates delivered the letter to the patient’s clinician directly. Patients with SBP values ≥ 180 mm Hg were immediately brought to the attention of a clinician. At the 6-week follow-up, control patients received a home BP monitor, and both control and intervention patients were offered the option to initiate or continue automated phone calls for 3 months.

INTERVENTION

The intervention was designed to address both provider and patient barriers to hypertension management.^{20,21} Intervention patients were given an electronic home BP monitor and written step-by-step instructions for checking their BP at home. Research associates also demonstrated use of the monitor during enrollment to ensure that low-literacy patients understood the procedure. Patients were instructed to measure their BP at least several times per week and keep a written record of the results. Intervention patients were told that they would receive a series of weekly automated monitoring and behavior-change calls. Whenever possible, an automated phone call was placed during enrollment to familiarize the patient with the call content and how to respond using their touchtone phone.

The telecommunications infrastructure for the automated calls was maintained on a U.S. server and interfaced with local telephone systems via session initiation protocol lines and voice over Internet protocol technology. Automated calls used a tree-structured algorithm to gather information about the patient’s BP, BP self-monitoring, medication adherence, and diet and to provide tailored advice based on the patient’s responses. Call scripts were translated into Spanish by a professional firm and reviewed by native Spanish-speaking clinicians in Honduras and Mexico. The final call script was professionally recorded by a native speaker.

The automated calling system was designed to have three mechanisms of action: (1) During the calls patients were reminded to check their BP regularly and were asked about recent systolic values above and below the normal range, medication adherence, and intake of salty foods. Based on their reports, patients received additional self-care information during the call and prompts to seek medical

attention or medication refills to address unacceptably high or low BP. (2) Structured e-mail alerts for health workers were generated automatically when patients reported that at least half the time in the prior week they had an SBP ≥ 140 mm Hg (nondiabetic patients), ≥ 130 mm Hg (diabetic patients), or ≤ 100 mm Hg (all patients). Alerts also were generated if the patient reported rarely or never taking his or her BP medication or less than a 2-week supply. (3) Patients had the option of enrolling with a family member or friend, who received a brief automated telephone update regarding the patient's self-reported health status each week, including information about the patient's hypertension self-care and how that caregiver could help the patient self-manage more effectively.

MEASUREMENTS

Primary outcome. Trained research associates measured BP at baseline and the 6-week follow-up visit using an electronic BP monitor after the patient was seated for at least 5 minutes. Pressures were taken in both arms, with a repeat measurement in the arm with the highest initial SBP. The final of the three readings was used in analyses. Diastolic BPs are presented here but were not a focus of the study because they have limited effect on cardiovascular risk.²²

Secondary outcomes. Surveys were professionally translated into Spanish. Patients reported their perceived general health (excellent, very good, good, fair, or poor), and depressive symptoms were measured using a validated Spanish version of the 10-item Center for Epidemiological Studies-Depression Scale ($\alpha = 0.79$ in this dataset).²³ Medication-related problems were measured using a 7-item index with yes/no responses (see Table 2 for the specific items). Medication adherence was measured using the Morisky scale,²⁴ but the scale was translated *de novo* and was found to be not reliable ($\alpha < 0.61$). Patients also reported their overall satisfaction with their healthcare and with health services related to their hypertension. For each satisfaction measure, we created a three-level ordinal variable indicating patient reports not receiving any ongoing care, patient reports receiving care but dissatisfied with the quality, or patient satisfied with the quality of his or her (hypertension or overall) care.

Other patient characteristics. Patients' height and weight were measured at baseline and used to calculate body mass index. Patients reported their age and years of education. Monthly family income from all sources was self-reported and converted to an annual income in U.S. dollars using the monetary exchange rate at the end of August 2011. Patients' health literacy was measured using validated items.²⁵

Intervention process. At follow-up, intervention patients were asked about their frequency of home BP monitoring, their responses to high SBPs, their experience responding to the automated calls, the perceived impact of the intervention on health and self-care, and intervention satisfaction. The automated telephone system captured information on all attempted calls, and these data were used to calculate the percentage of weeks in which patients completed assessments.

ANALYSIS

Initial analyses examined differences in baseline characteristics between intervention and control groups. Intervention effects were evaluated with regression models using end point values as dependent variables, experimental group as the predictor of interest, and baseline scores as covariates. Effects on SBP and depressive symptom scores were evaluated using ordinary least square regression models. The number of medication-related problems also was normally distributed and analyzed using ordinary least square regression. Effects on Likert-type variables (e.g., perceived general health and satisfaction with care) were analyzed using logistic regression models for ordinal dependent variables. Despite randomization, intervention and control patients differed at baseline in the percentage reporting use of antihypertensive medication. This variable was included as an additional control for confounding in multivariate models.

The intervention focused mainly on providing information and self-management education to patients. As such, we hypothesized *a priori* that the service would have a particularly strong impact on SBP in the subgroup of patients with low literacy or high information needs. This group was defined as patients who reported at baseline that they could not read, "most" or "all of the time" asked for help with filling out health-related forms, "most" or "all of the time" had problems learning about their health problems because of difficulty understanding written information, had never been told they had hypertension or had not spoken with a clinician about their BP in more than 6 months, or were confused about their medication regimen.

Results

RECRUITMENT AND BASELINE CHARACTERISTICS

In total, 416 patients were screened (Fig. 1), and 203 were excluded because they had SBPs below the cutoff ($n = 186$), had no telephone ($n = 13$), or were over 80 years of age ($n = 4$). Thirteen patients refused participation or did not complete the baseline survey. The remaining 200 patients were enrolled (100 in Mexico and 100 in Honduras). Compared with participants in Mexico, enrollees in Honduras on average had fewer years of education (7.4 years versus 5.5 years, $p = 0.004$) and were younger (59.2 years versus 56.1 years, marginally significant at $p = 0.05$). In total, 181 enrollees (91%) returned for follow-up at 6 weeks (83 from Honduras and 98 from Mexico). Those who returned were similar to those who did not return with respect to gender, age, education, and body mass index. Patients who completed follow-up had higher baseline SBPs than patients lost to follow-up (mean, 154 mm Hg versus 144 mm Hg, $p = 0.05$) and were more likely to have diabetes (47% versus 16%, marginally significant at $p = 0.05$).

Baseline characteristics were similar for intervention and control patients in the analytic sample (Tables 1 and 2). Participants had an average of 6.5 years of formal education and a median annual household income of \$2,900 USD. On average, participants had a baseline SBP of 154 mm Hg and a diastolic BP of 90 mm Hg. As noted in Subjects and Methods, more intervention than control patients

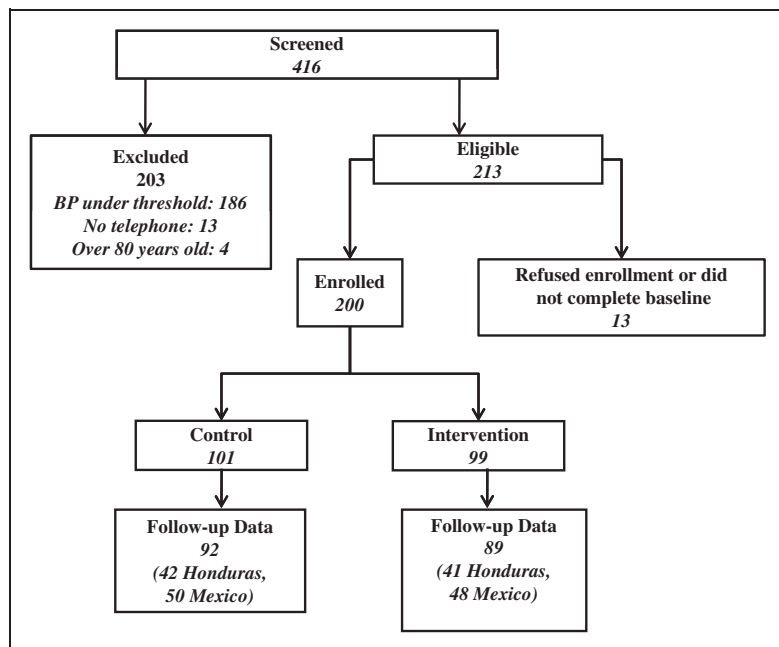


Fig. 1. Recruitment diagram. BP, blood pressure.

reported taking antihypertensive medication at baseline (89% versus 77%, $p=0.04$), and baseline medication use was included as a covariate in analysis of intervention effects.

One hundred seventeen patients (65% of the overall sample) had low literacy or high hypertension information needs and were included in the preplanned subgroup analysis. These patients had similar average baseline SBPs as patients with lesser information needs ($p=0.63$). Within that subgroup, baseline BPs and other clinical and demographic characteristics were similar between the intervention and control groups.

INTERVENTION PROCESS

Intervention patients completed 379 automated calls during 565 patient-call weeks, yielding an average call completion rate of 67%. At follow-up, intervention patients reported a variety of responses to information provided during the calls, including taking medication more regularly (70%), dietary changes (70%), and talking with their doctor about hypertension (61%). Twenty percent of intervention patients reported receiving a call from a doctor as a result of an alert generated from their automated calls.

Ninety-four percent of intervention patients reported using their home BP monitors at least several times per week. If their BP was high, 5% reported that they told their doctor during their next scheduled visit, and 8% reported getting in touch with a doctor before that visit. Other behaviors reported for high home BP readings included “taking more care” with medications (21%) and making a dietary change (14%).

More than 88% of patients reported that the automated calling system was easy to learn and use, and 93% reported that the automated calls included useful information for managing their hypertension (Table 3). Overall, 94% of intervention patients reported being very satisfied with the intervention, and 76% reported that the program was “excellent.”

EFFECTS ON BP

In the overall sample (Fig. 2 and Table 2), intervention patients at follow-up had SBPs that were 4.2 mm Hg lower on average than control patients (95% confidence interval [CI] $-9.1, 0.7$; $p=0.09$). In the subgroup with low literacy or high information needs, intervention patients had an average 8.8 mm Hg reduction in SBP relative to controls (95% CI $-14.2, -3.4$; $p=0.002$). According to the Joint National Committee guidelines for BP control, 57% of intervention patients had controlled BP at follow-up compared with 38% of the comparison group ($p=0.006$).¹⁹ In the

Table 1. Baseline Characteristics of Intervention and Control Patients

	INTERVENTION (N=89)	CONTROL (N=92)	TOTAL (N=181)	P VALUE
Sociodemographics				
Female	66.3	68.4	67.4	0.75
Age (years)	58.0±1.3	57.1±1.1	57.6±0.8	0.58
Years of education	6.1±0.5	6.8±0.6	6.5±0.4	0.40
Number in household	3.9±0.2	4.4±0.3	4.2±0.2	0.11
Median annual income (\$USD)	\$2,800	\$3,000	\$2,900	0.30
Low literacy/high information need ^a	61.4	68.1	64.8	0.27
Clinical characteristics				
Blood pressure medication	88.8	77.2	82.9	0.04
Body mass index (kg/m ²)	31.7±0.7	29.6±0.8	30.7±0.5	0.06
History of myocardial infarction ^b	17.1	17.0	17.1	0.92
Other prior CVD ^b	12.2	13.0	12.6	0.84
Diabetes ^b	43.8	38.5	41.1	0.47

Data are either percentages or mean±SE values.

^aCould not read, “most” or “all of the time” asked for help with filling out health-related forms, “most” or “all of the time” had problems learning about their health problems because of difficulty understanding written information, had never been told they had hypertension or had not spoken with a clinician about their blood pressure in more than 6 months, or were confused about their medication regimen.

^bSelf-report.

CVD, cardiovascular disease.

HYPERTENSION MANAGEMENT VIA M-HEALTH IN DEVELOPING COUNTRIES

Table 2. Outcome Values at Baseline and Follow-Up and Effects of Intervention

SBP RESULTS	BASELINE			FOLLOW-UP			DIF	95% CI	P VALUE
	INTERVENTION	CONTROL	P VALUE	INTERVENTION	CONTROL	P VALUE			
SBP (mm Hg) for all patients	153.2±2.1	150.0±2.1	0.29	142.5±2.3	143.6±2.4	0.74	-4.2	-9.1, 0.7	0.09
SBP (mm Hg) for subgroups									
Low literacy/high information needs	154.0±2.8	150.5±2.7	0.37	138.3±2.7	144.1±2.8	0.13	-8.8	-14.2, -3.4	0.002
Other patients	151.9±3.4	148.7±3.1	0.50	148.9±4.1	142.3±4.7	0.29	2.7	-6.9, 12.4	0.57
OTHER OUTCOMES (ALL PATIENTS)									
Depressive symptoms ^a	11.1±0.7	10.7±0.7	0.62	8.3±0.65	10.6±0.62	0.01	-2.5	-4.1, -0.8	0.004
Number of medication problems ^b	3.9±0.2	3.7±0.2	0.44	2.8±0.2	3.6±0.2	0.01	-1.1	-1.7, -0.5	<0.0001
Overall health ^c	1.9±0.07	2.0±0.07	0.41	2.5±0.09	2.1±0.08	0.0009	4.1 ^d	2.2, 7.8	<0.0001
Satisfaction with HTN care ^e	1.7±0.06	1.5±0.08	0.06	1.8±0.06	1.4±0.09	0.06	2.9 ^d	1.4, 6.1	0.004
Overall satisfaction with care ^f	1.7±0.06	1.7±0.07	0.52	1.8±0.06	1.4±0.08	0.0003	3.8 ^d	1.8, 7.9	<0.0001
Time since discussing HTN ^g	3.2±0.10	3.2±0.10	0.89	3.7±0.08	3.4±0.11	0.06	2.0 ^d	1.0, 4.0	0.06

Data in the Intervention and Control columns are mean±SE values.

^a10-item Center for Epidemiological Studies-Depression Scale.

^bPatients responded yes or no as to whether each of the following issues was a barrier to taking their medication exactly as prescribed by their doctor: (a) the medication's price; (b) difficulties aside from price in acquiring medication; (c) experiencing serious medication side effects; (d) being confused by the complexity of the regimen; (e) not being sure that the medication is important to get better; (f) being worried about the fact of having to take so much medicine; and (g) at times being worried about the long-term effects of the medication.

^c1=poor, 2=fair, 3=good, 4=very good, and 5=excellent.

^dAdjusted odds ratios estimated using ordinal logistic regression. Data represent the adjusted odds of being at a given level among intervention patients relative to control patients.

^eHow satisfied or dissatisfied are you with your healthcare related to your blood pressure? 0=not receiving care for blood pressure control; 1=receiving care but dissatisfied; 2=satisfied.

^fHow satisfied are you with your healthcare in general? 0=not receiving care, 1=receiving care but dissatisfied, 2=satisfied.

^gWhen was the last time that a doctor asked you about taking medicine for your high blood pressure? 1=never, 2=more than 6 months ago, 3=1-6 months ago, 4=during the last month.

Dif, difference between intervention and control groups at follow-up, controlling for baseline values; HTN, hypertension; SBP, systolic blood pressure.

overall intervention group, average diastolic BPs were 3.2 mm Hg lower at follow-up than in the control group (95% CI -6.8, 0.4; $p=0.08$) and 4.1 mm Hg lower in the subgroup with low literacy or high information needs (95% CI -8.8, 0.6; $p=0.09$).

EFFECTS ON OTHER OUTCOMES (TABLE 2)

Compared with controls, intervention patients at follow-up had lower Center for Epidemiological Studies-Depression Scale de-

pression scores (-2.5; 95% CI -4.1, -0.8; $p=0.004$) and fewer medication-related problems (-1.1; 95% CI -1.7, -0.5; $p<0.0001$), such as uncertainty as to whether their medication is important, worry about the long-term effects of their medication, or confusion by the complexity of the regimen. Intervention patients reported better overall health at follow-up, as well as greater overall satisfaction with care and satisfaction with care specifically related to their hypertension (each $p\leq 0.004$).

Table 3. Intervention Satisfaction

	PERCENTAGE
User-friendliness of the intervention	
Was easy to learn and use	88.5
Understood the feedback about health	94.9
Had problems receiving calls	29.9
Had problems responding during calls	16.9
Had problems taking blood pressures	7.8
IVR provided useful suggestions for HTN	93.5
IVR questions sometimes hard to understand	16.9
Had problems understanding the IVR voice	9.1
The language was what I'm familiar with	83.2
The calls were too long	2.6
The calls provided enough useful information	93.5
Overall, how would you rate the program?	
Excellent	75.9
Good	23.0
How much did the program meet your needs?	
Almost all needs were met	52.9
The majority of needs were met	31.0
Would you recommend this program to a friend?	
Yes	100.0
How satisfied were you with the amount of help?	
Very satisfied	89.5
Mostly satisfied	10.5
Did this program help you manage your HTN?	
Yes, a great deal	91.9
Yes, some	8.1
In general, how satisfied were you with the program?	
Very satisfied	94.2
Somewhat satisfied	5.8
HTN, hypertension; IVR, interactive voice response or "automated calls."	

Discussion

SUMMARY OF FINDINGS

In the overall sample, we observed a nonstatistically significant ($p=0.09$) 4.2 mm Hg relative decrease in SBP among intervention patients, as well as significant improvements in: depressive symptoms, medication-related problems, perceived health status, and treatment satisfaction. In the subgroup of patients with low literacy

or high information needs, we observed an 8.8 mm Hg reduction in average SBP with a significantly greater proportion of intervention than control patients having BPs in the acceptable range. This average reduction in SBP is slightly greater than that achieved in The Indian Polycap study (-7.4 mm Hg),²⁶ and a change of this magnitude has been linked with important reductions in cardiovascular events, including mortality.²⁷

Results of the subgroup analysis of patients with low literacy or high information needs are encouraging but should be considered as informing future studies, rather than definitive. Nevertheless, these patients represented 65% of all patients completing the study, and it is reasonable that this information-based intervention would have a greater impact on patients who reported a greater need for hypertension-related knowledge and education.

STUDY LIMITATIONS

This study had a relatively short follow-up period, and subsequent studies should seek to replicate these findings with larger samples and follow-up more consistent with published hypertension trials (i.e., 6–12 months). Prior care management studies suggest that some health behavior changes may be harder to maintain over a longer period^{28,29}; however, patients using this intervention over a longer time span may have a greater chance of overcoming clinical inertia²¹ and other barriers to finding a regimen that meaningfully reduces their SBP.

This intervention had two components—automated self-care support telephone calls and home BP monitoring—and we cannot tease out the relative benefit of each. A recent meta-analysis demonstrated that home BP monitoring can be useful but is only minimally effective unless telephone follow-up is in place to prompt improvements in adherence and care management.⁴ At follow-up, intervention patients reported both using the BP monitor and that they made changes to their clinical interactions and self-management as a result of the automated calls. Therefore, we believe that both components of the intervention contributed to patients' improved BP control. Home BP monitors are typically unavailable in LMICs, and even the battery cost could be a significant deterrent to some patients' use. Although the current study suggests that investment in monitors and the interactive voice response infrastructure may prevent costly cardiovascular complications downstream, future studies should explicitly test this hypothesis and explore creative ways for sharing a limited number of BP monitors across multiple members of the community.

Finally, the current intervention included relatively little collaborative work with patients' clinical teams. Although efforts were made to provide clinicians with timely feedback about their patients' status based on the interactive voice response reports, there was no effort to educate providers regarding hypertension management guidelines or strategies for improving patients' BP through medication adjustment or behavioral counseling. Intervention effects may be greater if the service is tailored and implemented using a broader-based approach for health system change, such as

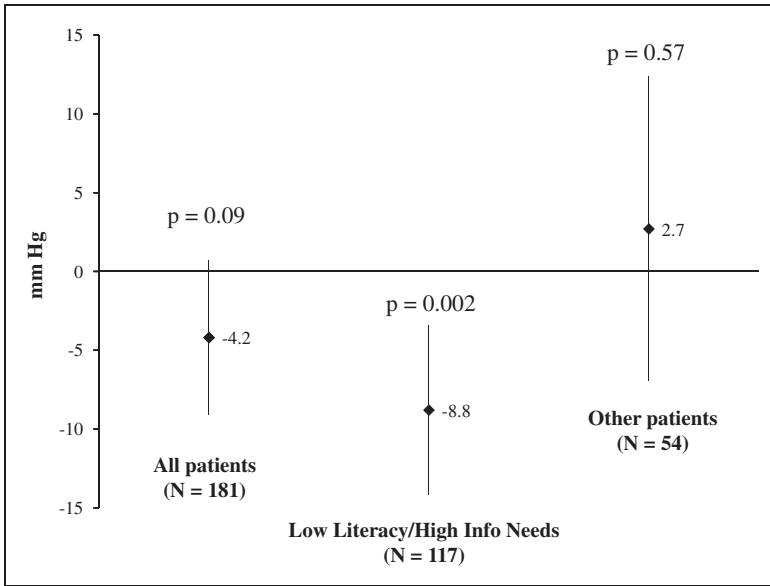


Fig. 2. Intervention effects on systolic blood pressure.

healthcare collaboratives.³⁰ Moreover, large numbers of hypertensive patients in LMICs go undiagnosed and have weak connections to primary care. Future studies should seek to identify ways to extend hypertensive management to this broader community in ways that cost-effectively leverage communication technologies for educating both patients and their clinical teams regarding approaches to achieving BP control.

RESEARCH IN CONTEXT

Hypertension and other NCDs are increasing rapidly in LMICs with no indication that healthcare systems will have resources to meet these demands. This model of telehealth would allow hypertensive patients to self-monitor their BPs, receive feedback and self-care prompting via automated calls, and potentially prevent serious and costly cardiovascular complications. Other m-health technologies such as short messaging service (or text messaging) may also assist patients in LMICs⁹⁻¹² but are more difficult for individuals with limited vision, dexterity, or literacy, all of which may be more common in less-developed countries.^{31,32} Text messaging self-care supports are less interactive than the multiple exchanges possible during an automated call, and the current intervention could augment or complement models based on short messaging service.

The telecommunication infrastructure tested in the current study is perhaps almost as important as the intervention’s impact on patients’ health outcomes. Like all cloud computing approaches, this model could make between-visit support for chronic disease management available to small practices that lack the human resources, hardware, and software to provide such services directly. By spreading fixed costs over a large number of users, cloud computing approaches such as this one can ensure data security and respond to changing community needs with maintenance costs shared by large numbers of healthcare providers. Future implementation studies should seek to identify scal-

able and economically sustainable models for transferring this technology out of academic medical centers to governmental or nongovernmental organizations that can maintain the infrastructure and adapt the content to meet local needs.

Conclusions

This study demonstrates that a cloud computing approach to automated telephone self-management support, coupled with home BP monitoring, may improve SBP control in LMICs. The intervention led to improvements in patients’ depressive symptoms, medication-related problems, perceived general health, and treatment satisfaction. Among patients with low literacy or significant needs for hypertension-related communication, the intervention led to a clinically significant improvement in SBP. Future studies should confirm these findings with larger samples and longer follow-up periods. The model may be relevant for the control of other NCDs such as diabetes, and the cloud computing structure could make such services available to patients in areas with little or no infrastructure for patient-centered health technologies.

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Disclosure Statement

No competing financial interests exist.

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