Title

Impact of Self-Monitoring of Blood Pressure on Processes of Hypertension Care and Long-Term Blood Pressure Control

Journal

Journal of the American Heart Association, 9(15)

ISSN

2047-9980

Authors

Bryant, Kelsey B
Sheppard, James P
Ruiz-Negrón, Natalia
et al.

Publication Date

2020-08-04

DOI

10.1161/jaha.120.016174

Peer reviewed

Journal of the American Heart Association

ORIGINAL RESEARCH

Impact of Self-Monitoring of Blood Pressure on Processes of Hypertension Care and Long-Term Blood Pressure Control

Kelsey B. Bryant, MD, MPH; James P. Sheppard, PhD; Natalia Ruiz-Negrón, PharmD; Ian M. Kronish, MD, MPH; Valy Fontil, MD, MAS; Jordan B. King, PharmD, MS; Mark J. Pletcher, MD, MPH; Kirsten Bibbins-Domingo, MD, PhD; Andrew E. Moran, MD, MPH; Richard J. McManus, MA, PhD, MBBS; Brandon K. Bellows, PharmD, MS

BACKGROUND: Self-monitoring of blood pressure (SMBP) improves blood pressure (BP) outcomes at 12-months, but information is lacking on how SMBP affects hypertension care processes and longer-term BP outcomes.

METHODS AND RESULTS: We pooled individual participant data from 4 randomized clinical trials of SMBP in the United Kingdom (combined n=2590) with varying intensities of support. Multivariable random effects regression was used to estimate the probability of antihypertensive intensification at 12 months for usual care versus SMBP. Using these data, we simulated 5-year BP control rates using a validated mathematical model. Trial participants were mostly older adults (mean age 66.6 years, SD 9.5), male (53.9%), and predominantly white (95.6%); mean baseline BP was 151.8/85.0 mm Hg. Compared with usual care, the likelihood of antihypertensive intensification increased with both SMBP with feedback to patient or provider alone (odds ratio 1.8, 95% CI 1.2–2.6) and with telemonitoring or self-management (3.3, 2.5–4.2). Over 5 years, we estimated 33.4% BP control (<140/90 mm Hg) with usual care (95% uncertainty interval 27.7%–39.4%). One year of SMBP with feedback to patient or provider alone achieved 33.9% (28.3%–40.3%) BP control and SMBP with telemonitoring or self-management 39.0% (33.1%–45.2%) over 5 years. If SMBP interventions and associated BP control processes were extended to 5 years, BP control increased to 52.4% (45.4%–59.8 %) and 72.1% (66.5%–77.6%), respectively.

CONCLUSIONS: One year of SMBP plus telemonitoring or self-management increases the likelihood of antihypertensive intensification and could improve BP control rates at 5 years; continuing SMBP for 5 years could further improve BP control.

Key Words: blood pressure ■ hypertension ■ self-monitoring of blood pressure ■ simulation modeling

There is growing evidence that self-monitoring of blood pressure (SMBP) with guided support beyond usual primary care improves BP control.[1,2] The TASMINH (Telemonitoring And Self-Management in the Control of Hypertension) trials demonstrated that SMBP plus support, including telemonitoring (remotely monitoring patients using communication technology) and self-management (self-titration of medications), significantly improves BP control compared with usual primary care.[3–6] The effect of the short-term BP control in these trials has been extrapolated in cost-effectiveness models, which suggest that the SMBP interventions are likely to be cost-effective provided that the BP effects are maintained for at least 3 years.[7–9] However, these models make assumptions about how SMBP affects clinical care processes (ie, antihypertensive intensification, time between visits) that result in BP lowering, which may not reflect persistent effects of these components on longer-term BP control.

Correspondence to: Brandon K. Bellows, PharmD, MS, Division of General Medicine, Columbia University, 622 West 168th Street, PH9-105, New York, NY 10032. E-mail: bkb2132@cumc.columbia.edu

Supplementary Materials for this article are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.120.016174

For Sources of Funding and Disclosures, see page 8.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- We used individual participant data from 4 randomized clinical trials of self-monitoring of blood pressure (SMBP) with varying levels of support (eg, feedback to patient or provider alone, telemonitoring or self-management) to examine the changes in the processes of hypertension care (eg, visit frequency, treatment intensification) that led to observed 1-year blood pressure improvements.
- We used a validated mathematical model to project the 5-year blood pressure outcomes resulting from 1 year of SMBP with varying levels of support based on the observed changes to hypertension care processes at 1 year.

What Are the Clinical Implications?

- We found that, compared with usual care, increased levels of support for SMBP significantly increased the likelihood of antihypertensive intensification after an uncontrolled blood pressure measurement.
- Compared with usual care, we projected significant improvements in blood pressure control at 5 years after 1 year of SMBP with telemonitoring or self-management; increasing the duration of SMBP to 5 years further improved blood pressure control.
- SMBP with increased levels of support, including telemonitoring or self-management, increases appropriate intensification of therapy and may be an effective way to improve long-term blood pressure outcomes.

Nonstandard Abbreviations and Acronyms

BPCM	Blood Pressure Control Model
SMBP	self-monitoring of blood pressure
TASMINH	Telemonitoring And Self-Management in the Control of Hypertension study

Simulation models are an efficient way to extrapolate observations from short-term clinical trials to project longer-term outcomes and thereby inform clinical guidelines and treatment decisions.[10–12] The BP Control Model (BPCM) is a validated computer simulation model that accurately predicts long-term BP outcomes driven by 5 essential clinical care processes: (1) time between clinic visits, (2) accuracy of BP measurements, (3) probability antihypertensive medications are intensified when BP is uncontrolled, (4) patient adherence to prescribed antihypertensive medications, and (5) expected BP reduction when antihypertensive treatment is intensified (dose increase or new medication added).[13,14]

We sought to examine the impact of SMBP with varying levels of support on (1) processes of hypertension care (ie, antihypertensive regimen intensification, frequency of provider encounters) and (2) 5-year BP and hypertension control outcomes. To accomplish this, we estimated hypertension clinical care process measures using pooled individual participant data from the TASMINH trials and, after entering these data into the BPCM, simulated expected long-term BP and hypertension outcomes expected from usual care versus SMBP strategies. We then varied the modeled assumptions about how hypertension clinical care processes would be sustained over a 5-year period.

METHODS

The TASMINH data used in the Phase 1 analysis may be available to researchers for independent analysis subject to data governance permissions and submission of an approved statistical analysis plan. The BPCM and key inputs used in the Phase 2 analysis are available to interested researchers upon reasonable request. Interested researchers can submit a 1- to 2-page research proposal and collaboration plan to Dr. Bellows (BPCM) and are requested to contact Dr. McManus to discuss access requirements (TASMINH data).

Phase 1: Effect of SMBP on Processes of Hypertension Care and BP Outcomes

TASMINH Trials

We pooled individual participant data from 4 TASMINH trials: TASMINH (N=440), TASMINH2 (N=527), TASMIN-SR (N=450), and TASMINH4 (N=1173).[1,4,6,8] Participants included in the TASMINH studies had uncontrolled hypertension at baseline and were recruited from primary care clinics in the United Kingdom (detailed descriptions, including eligibility criteria, in Table S1). Participants were randomized to receive either usual care alone or usual care with SMBP and support that varied according to the TASMINH trial design (Table 1).

At each study visit, BP was measured in the office using automated cuffs (Omron 705CP or BP TRU BPM 100 or 200). The primary outcome in each study was mean systolic BP (SBP) change from baseline with the SMBP intervention compared with usual care at 12 months. Additionally, each study collected data, antihypertensive regimen changes, and healthcare utilization (number of physician visits) for both trial arms.

All TASMINH studies contributing data received full ethical approval from an independent National Research Ethics Committee and all participants

Table 1. Summary of the Original TASMINH Trial SMBP Interventions

Study	SMBP Level[2] and Description of Intervention*
TASMINH[6]	Level 1—In-clinic SMBP: Patients performed SMBP in the clinic once each month and were given cards with BP goals and when to seek medical appointment
TASMINH4[4]	Level 2—Home SMBP: Patients performed SMBP at home 2 times per day, received instructions when to contact physician, and sent BP readings to provider through the mail Level 3—Home SMBP+telemonitoring: In addition to Level 2 home SMBP, telemonitoring service included patients sending BP readings to provider via text, alerted patients to contact office for very high or low BP readings, sent reminders if too few readings sent, and sent readings to general practitionerr office
TASMINH2[1] and TASMIN-SR[8]	Level 3—Home SMBP+self-titration: Patients performed SMBP at home 2 times per day and given a color-coded system to rate BP measurements. If BP was "above target" for ≥2 consecutive months, patients could self-titrate according to predetermined schedule

BP indicates blood pressure; SMBP, self-monitoring of BP; TASMIN-SR, Targets and Self-Management for the control of blood pressure in Stroke and at Risk groups; and TASMINH, Telemonitoring And Self-Management in the Control of Hypertension.

*All trials examined patients with uncontrolled BP in UK primary care settings. Usual care without SMBP was the comparator in each trial. No SMBP interventions included regular one-to-one contact with provider for BP management.

provided written informed consent. Only anonymized data were used in the analyses described here.

SMBP Interventions

The comparator arm in all of the TASMINH studies was usual primary care received at the participants' clinic with follow-up frequency at the discretion of their physician.[1,4,6,8] We classified the 4 TASMINH SMBP trial interventions into 3 levels of support, with degree of support increasing with each level (Table 1).[2,15] Level 1 consisted of monthly SMBP physically located in the patients' clinic and educational materials provided at the start of the trial without ongoing physician contact.[6] Level 2 consisted of monthly home SMBP, with instructions indicating when to contact the primary physician's office.[4] Level 3 consisted of monthly home SMBP with telemonitoring (patients sent BP readings to provider and received feedback via SMS text) and/or a prespecified BP management plan, which directed the patient to self-titrate antihypertensive medications when indicated.[1,4,8]

Outcomes

The primary outcome of the Phase 1 analysis was the association between SMBP (by level of intervention) and the hypertension clinical care processes (ie, physician visits, nonphysician visits, and antihypertensive regimen intensifications) and BP outcomes (SBP and diastolic BP [DBP] changes from baseline) at 12 months. We defined physician and nonphysician visits separately as the total number of in-person visits during the 12-month follow-up. In Phase 1, treatment intensification was defined as the addition of at least 1 new medication class.

Statistical Analysis

To determine the impact of SMBP interventions on the processes of hypertension care, we performed random effects regression analyses including the individual TASMINH study as a random effect. We estimated the probability of treatment intensification at 12 months by level of intervention (with usual care as the reference category), controlling for key components in the BPCM: baseline age, sex, and baseline SBP and DBP, number of antihypertensive medications at baseline, number of physician visits, nonphysician visits, and the number of visits with a controlled SBP and DBP. We used random effects generalized least squares linear regression models to predict mean cumulative number of physician and nonphysician office visits after 12 months of follow-up for each SMBP intervention level and controlled for age, sex, and baseline SBP and DBP.

To estimate the impact of SMBP interventions on changes in SBP and DBP at 12 months for each SMBP intervention level, we used random effects generalized least squares regression, again with the individual TASMINH study as a random effect. These models adjusted for key characteristics and events used in the BPCM: number of physician visits, number of nonphysician visits, number of antihypertensive medications at baseline, number of antihypertensive treatment regimen intensifications, age, sex, and baseline SBP and DBP. All analyses were performed using STATA version 14.1 (StataCorp LP, College Station, TX).

Phase 2: Simulating the Effect of SMBP Interventions on Long-Term BP Control Outcomes

BPCM Overview

The BPCM is an individual patient (ie, microsimulation) model that simulates the weekly processes of hypertension management under usual primary care and can be used to simulate BP management interventions (Figure S1).[13,14] Every week, the model determines if the patient had an office-based visit with a physician. At each office visit, the model estimates the patient's measured BP and, when uncontrolled, if the physician intensifies the patient's antihypertensive medication regimen. The model simulates treatment intensification by first by increasing the dose of

an existing antihypertensive medication, then subsequently adding a new antihypertensive medication. Finally, patients may become nonadherent to (ie, permanently discontinue) antihypertensive medications each week. For this analysis, we adapted the existing BPCM to include the pill-taking execution component of adherence (percentage of doses missed) and the impact it has on expected BP reduction, regression to the mean, and simulate SMBP support levels 1 to 3 (Data S1).

The BPCM has been shown to use hypertension care processes to accurately predict 5 to 10-year SBP, DBP, and BP control rates when compared with the large US-based observational Multi-Ethnic Study of Atherosclerosis (MESA), the Antihypertensive and Lipid Lowering Treatment to Prevent Heart Attack Trial (ALLHAT), and the Valsartan Antihypertensive Long-term Use Evaluation Trial (VALUE).[13,16–18] Inputs for the BPCM were derived from published literature and national sources (Table S2).

Simulated Population

The BPCM was designed using participants from the 2007–2014 National Health and Nutrition Examination Survey (NHANES). Similar to prior analyses, we created a population of NHANES participants with uncontrolled BP matching the characteristics of the pooled TASMINH studies (Data S1).[1,4,6,8]

Model Adaptations

To simulate the impact each SMBP support level had on the processes of hypertension care, we calibrated 2 key processes of hypertension care among US-based BPCM inputs to match the Phase 1 regression model predictions from the UK-based TASMINH studies. We first calibrated the frequency of physician visits and then the probability of adding at least one new antihypertensive class at 1 year. We did not match antihypertensive medication adherence as this was not collected by all of the TASMINH studies and rather used existing model inputs (see Model Calibration and Validation).[13] The expected blood pressure reduction from antihypertensive medications was derived from meta-analyses (Data S1, Table S3).[19,20]

Outcomes

Our primary outcome was simulated BP control rate (defined based on TASMINH trial thresholds as <140/90 mm Hg without diabetes mellitus or chronic kidney disease; <130/80 mm Hg with diabetes mellitus or chronic kidney disease) over 5 years. Secondary outcomes were mean SBP change, DBP change, and number of physician visits after 5 years.

Model Calibration and Validation

We validated the mean 12-month SBP and DBP changes predicted by the BPCM against the mean SBP and DBP regression estimates from the TASMINH studies described in Phase 1. For each simulated patient, we used the Phase 1 regression equations predicting changes in processes of care because of the level of intervention to determine their expected SBP and DBP changes and captured their BPCM simulated changes. As SMBP interventions may improve adherence,[21] we calibrated the US-based adherence parameters (Tables S3 and S4) of the model until mean SBP and DBP changes were within ±2.5 mm Hg of the regression-based expected mean changes at 12 months for each SMBP support level based on opinion of clinically significant BP changes informed by hypertension management experience.

Statistical Analysis

We simulated 1000 probabilistic iterations of 1000 hypothetical TASMINH trial patients (frequency matched to the pooled TASMINH studies) to compare BP reductions under each of the 4 different SMBP support levels to usual primary care over 5 years. For each probabilistic iteration, the model randomly selected model parameters from prespecified distributions. We defined the 95% uncertainty intervals (95% UI) as the 2.5th to 97.5th percentiles from the 1000 probabilistic iterations.

In the base-case analysis, we assumed that the SMBP intervention was implemented for 1 year, followed by return to usual care afterward. We also assumed that after SMBP intervention ended, the effect of SMBP on adherence would gradually decrease over time at a constant rate until it was no different than usual care by the end of 5 years (ie, 4 years after the end of the SMBP intervention). In the first of 2 alternative scenarios, we assumed that SMBP interventions were implemented for all 5 years (5-year SMBP intervention); thus, the impact on hypertension control processes and subsequent effect on BP was sustained for the entire 5 years. In the second scenario, we assumed that SMBP interventions were implemented for only 1 year, but the effect on patient medication adherence was sustained for 5 years. In a 2-way sensitivity analysis, we examined the effect of simultaneously changing the duration of SMBP interventions (from 1–4 years) and the time until adherence returned to usual care values (from 0–4 years). In another alternative scenario, we assumed no impact of SMBP on adherence over the entire time horizon. All Phase 2 analyses were performed using TreeAge Pro 2019 (TreeAge Software, Inc, Williamstown, MA) and R (R version 3.3.2, Vienna, Austria).

RESULTS

Phase 1: Effect of SMBP on Processes of Hypertension Care and BP Outcomes

Pooled TASMINH Population

TASMINH participants were mostly older adults (mean [SD] age 66.6 [9.5] years), male (53.9%), and largely white (95.6%). BP was assessed at baseline and after 6 and 12 months of follow-up. Mean baseline SBP was 151.8 (14.2) mm Hg; mean baseline DBP was 85.0 (9.8) mm Hg.

Antihypertensive Medication Intensification

After controlling for covariates in the pooled TASMINH studies, compared with usual care, SMBP interventions with more support, as opposed to self-monitoring alone, were associated with an increased likelihood of antihypertensive medication intensification by 12 months (Level 2 odds ratio [OR], 1.8; 95% CI, 1.2–2.6; Level 3 OR, 3.3; 95% CI, 2.5–4.2; Table 2). However, Level 1 SMBP interventions (SMBP measured at clinic) were not associated with an increased likelihood of medication intensification compared with usual care (OR, 0.7; 95% CI, 0.4–1.2). The odds of medication intensification were increased with each additional physician visit (OR 1.4; 95% CI, 1.3–1.6) or nonphysician visit (OR, 1.3; 95% CI, 1.2–1.4) during follow up.

Physician and Nonphysician Visits

There was no apparent trend in the association between SMBP support level and number of office visits. (Table 3 and Table S5). SMBP Level 1 was associated with a small increase in physician office visits (0.7; 95% CI, 0.4–1.0) compared with usual care; however, Level 2 was associated with a decrease (–1.2; 95% CI, –1.5 to –1.0) and Level 3 was not significantly different than usual care (–0.0; 95% CI, –0.2 to 0.2). Similarly, compared with usual care, Level 1 interventions were associated with a small increase in nonphysician visits (0.4; 95% CI, 0.2–0.6), whereas both Level 2 (–0.8; 95% CI, –0.9 to –0.6) and Level 3 (–0.4; 95% CI, –0.5 to –0.3) were associated with small decreases.

SBP and DBP Changes

Compared with the SBP change with usual care at 12 months (mean: –9.5 mm Hg), the adjusted SBP was 3.5 mm Hg higher (95% CI, 0.9–6.0) for SMBP Level 1, 3.8 mm Hg lower (95% CI, –5.8 to –1.8) for Level 2, and 5.4 mm Hg lower (95% CI, –6.9 to –3.8) for Level 3 interventions (Tables S6 and S7). Similarly, compared with the DBP change with usual care at 12 months (mean: –4.7 mm Hg), the adjusted DBP was no different for Level 1 (0.2 mm Hg; 95% CI, –1.3 to 1.3) but was significantly lower for both Level 2 (–1.5 mm Hg 95% CI, –2.5 to –0.4) and Level 3 (–1.5 mm Hg; 95% CI, –2.2 to –0.7) interventions (Tables S6 and S8).

Phase 2: Simulating Long-Term BP Control Outcomes

BPCM Calibration and Validation

The simulated population was similar to the pooled TASMINH population at baseline; mean age was 65.8 years (95% UI, 65.2–66.4), 53.9% (95% UI, 50.7–56.7%) were male, mean baseline SBP was 152.0 mm Hg (95% UI, 151.4–152.7), and mean DBP was 84.3 mm Hg (95% UI, 83.8–84.9) (Table S9). The calibrated BPCM accurately reproduced the regression analysis results in Phase 1. After calibration, all of the mean values for number of physician visits, antihypertensive medication intensification, SBP change, and DBP change at 12 months predicted by the BPCM in Phase 2 were within the prespecified validation ranges (Table S10).

Simulated Long-Term BP Outcomes

According to the BPCM, usual care would result in a mean SBP of 140.8 mm Hg (95% UI, 139.3–142.3),

Table 2. Association Between SMBP Intervention Support and Odds of Regimen Intensification During 12-Month Follow-Up

Variable	Odds Ratio	95% CI	
		Lower Limit	Upper Limit
Support of intervention (REF: usual care)			
Level 1	0.70	0.41	1.20
Level 2	1.80	1.20	2.60
Level 3	3.20	2.53	4.17

Model adjusted for number of physician visits, number of nonphysician visits, number of visits with BP controlled, age, sex, number of physician consultations, and baseline BP. Included 2266 patients from 4 studies. Analysis was a random effects logistic regression with study as a random effect. SMBP indicates self-monitoring of BP.

Table 3. Association Between SMBP Intervention Support With Number of Physician Visits During 12-Month Follow-Up

Variable	Beta Coefficient	95% CI	
		Lower Limit	Upper Limit
Support of intervention (REF: usual care)			
Level 1	0.70	0.37	1.04
Level 2	–1.24	–1.47	–1.00
Level 3	–0.03	–0.22	0.15

Model adjusted for age, sex, number of antihypertensive medications at baseline, and baseline BP. Included 2438 patients from 4 studies. Analysis was a random effects generalized least squares regression with study as a random effect. SMBP indicates self-monitoring of BP.

mean DBP of 77.5 mm Hg (95% UI, 76.7–78.3), and 33.4% BP control after 5 years (95% UI, 27.7–39.4%; Figure 1 and Table S11). In the base-case, in which all BP processes returned to usual care values at 12 months, 5-year BP control rates ended up similar to usual care with Level 1 (33.0% [95% UI, 27.7–39.4%]) and Level 2 (33.9% [95% UI, 28.3–40.3%]), and were improved with Level 3 (39.0% [95% UI, 33.1–45.2%]). In the first scenario in which SBPM-related BP process improvements persisted for all 5 years, 5-year BP control rates increased to 52.4% in Level 2 (95% UI, 45.4–59.8%) and to 72.1% in Level 3 (95% UI, 66.5–77.6%). In the second scenario that assumed adherence behavior was sustained for 5 years while other processes of care returned to usual care values, SMBP Levels 2 and 3 had BP control rates of 49.5% (95% UI, 43.7–56.0%) and 54.9% (95% UI, 49.0–61.3%), respectively.

Sensitivity Analysis

BP control rates were sensitive to both the duration of SMBP interventions and the time until adherence returned to usual care values in the 2-way sensitivity analysis (Figure 2). Prolonging the duration of SMBP or time until adherence returned to usual care values improved BP outcomes at 5 years. In the scenario analysis where we assumed no effect of SMBP on adherence, only Level 3 continued to result in improved BP control rates compared with usual care. At 5 years, Level 3 resulted in 36.7% BP control with only 1 year of SMBP and 53.5% BP control with 5 years of SMBP.

DISCUSSION

In this analysis based on pooled, individual participant data from 4 published SMBP trials (TAMSINH trials), we found that strategies with more support (Level 2 or 3) increase the probability of clinically indicated antihypertensive intensification, whereas self-monitoring alone (Level 1) does not differ from usual care. Using a mathematical model, we projected strategies with support may lead to substantial increases in hypertension control at 5 years. These data suggest that SMBP with cointerventions is an effective way to improve long-term blood pressure control by reducing clinical inertia around treatment intensification.

Prior studies have examined the impact of SMBP on adherence and clinical inertia, but to our knowledge this is the first to quantify the effect of SMBP on processes of routine hypertension care (ie, antihypertensive intensification, time between visits) over an extended time period.[21–24] The BP reductions projected by the BPCM in our study are consistent with observed findings from the few prior studies that examined the impact of SMBP on BP outcomes beyond 1 year.[24–26] However, none reported outcomes beyond 2 years. A trial of a tailored behavioral telephone intervention paired with SMBP found a nearly 4-mm Hg SBP reduction over 24 months compared with usual care.[24] Compared with usual care at 24 months, our model projected SBP reductions of 2.8 and 4.9 mm Hg with Level 2 and 3 SMBP interventions, respectively.

Meta-analyses have confirmed that SMBP accompanied by patient support consistently improves BP and the magnitude of this effect is directly associated

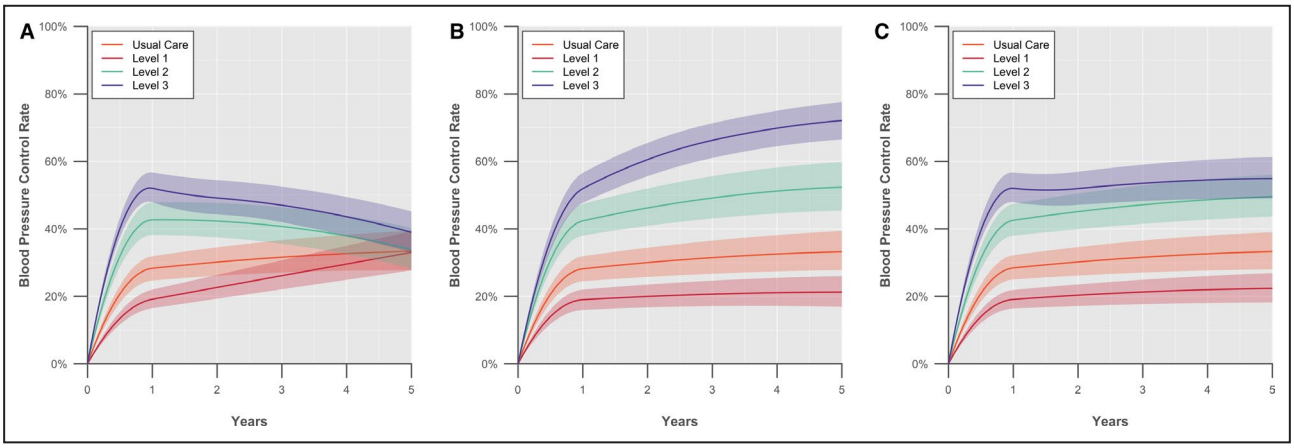


Figure 1. Long-term simulated blood pressure control rates for SMBP interventions.
(**A**) One year of SMBP followed by return to usual care; (**B**) 5 years of SMBP; (**C**) 1 year of SMBP with sustained adherence. The figure shows how blood pressure (BP) control changes over time when patients (**A**) return to usual care after 1 year of SMBP with various levels of support, (**B**) SMBP and the associated changes in hypertension care processes continues for 5 years, and (**C**) return to usual care after 1 year of SMBP but adherence behavior is sustained for 5 years. BP control is defined as BP <130/80 mm Hg with diabetes mellitus or chronic kidney disease and <140/90 mm Hg without chronic kidney disease or diabetes mellitus. The solid lines represent the mean BP control rate and the shaded areas the 95% uncertainty interval (2.5th to 97.5th percentiles); both derived from 1000 probabilistic iterations. SMBP levels are defined as SMBP in clinic (Level 1), home SMBP with feedback when requested by patient (Level 2), and SMBP with telemonitoring or self-management (Level 3). SMBP indicates self-monitoring of blood pressure.

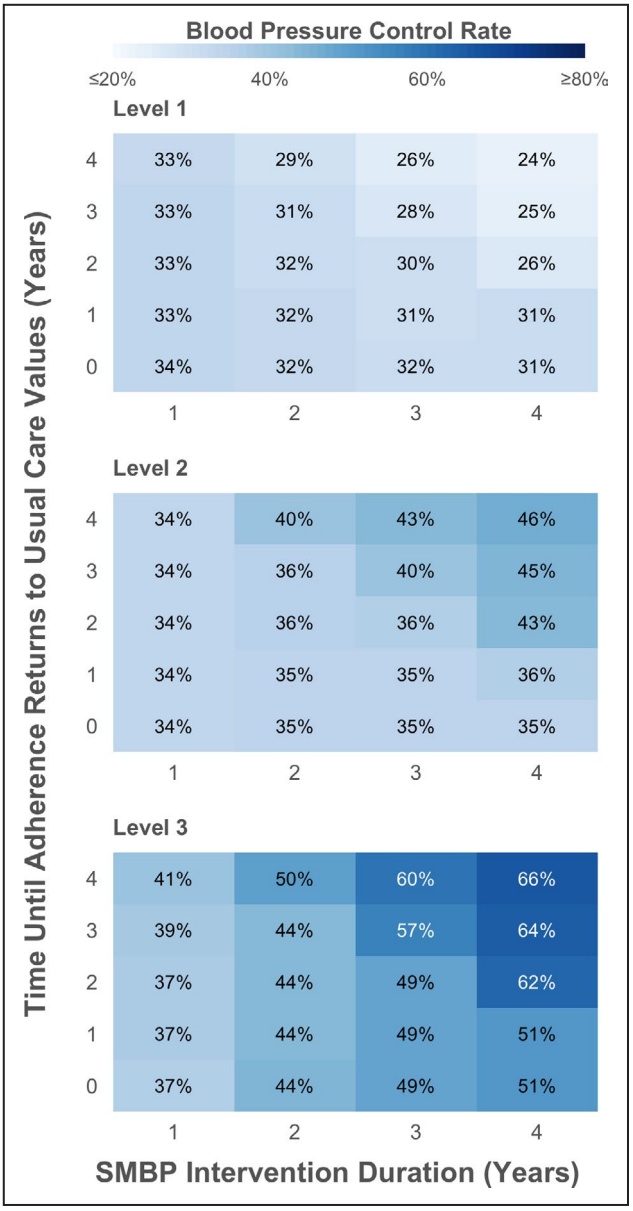


Figure 2. Five-year blood pressure control rates when varying SMBP duration and time period over which treatment adherence returns to usual care.
The figure shows the blood pressure (BP) control rate at 5 years when simultaneously varying the duration of SMBP from 1 to 5 years (*x*-axis) and how long it takes the impact of SMBP on adherence to return to usual care estimates (*y*-axis) in the BP Control Model. SMBP levels are defined as SMBP in clinic (Level 1), home SMBP with feedback when requested by patient (Level 2), and SMBP with telemonitoring or self-management (Level 3). BP Control defined as BP <130/80 mm Hg with diabetes mellitus or chronic kidney disease and <140/90 mm Hg without chronic kidney disease or diabetes mellitus. SMBP indicates self-monitoring of BP.

with the level of the support.[2,27,28] Several individual studies in US populations randomizing participants to SMBP with varying levels of support also demonstrate the observed improvements in BP control in the TASMINH studies.[29–31] Despite this evidence base, barriers to integrating SMBP into usual clinical practice remain.[32–34] In the United States and the United Kingdom, about 18% to 33% of adults have used some form of SMBP, but the level of support provided, if any, is unclear.[35,36] It is also unknown how effectively the BP information is communicated back to providers so that BP treatment may be intensified when BP is uncontrolled. In a qualitative study in the United Kingdom, patients using SMBP tended not to discuss their experience or BP results with their primary care providers,[37] and providers have indicated they would like more patient involvement in hypertension care, though their clinical workflow is not always structured to handle these tasks outside of usual care.[38] As previously demonstrated, without additional support or a cointervention, SMBP alone has little impact on BP outcomes.[2,27,28] This notion is confirmed in the differential rates of BP control by intervention level in the current study.

Lack of communication between patient and clinical team regarding BP measurement outside of usual care and high rates of clinical inertia may be mitigated by supported SMBP. Our results show that increased support of SMBP (Level 2 or 3) significantly reduces clinical inertia, an important barrier to achieving high rates of BP control. Self-titration, included in the Level 3 SMBP intervention in our study, may be a viable strategy to support SMBP, reduce clinical inertia, and improve BP outcomes.[39,40] Our findings support prior analyses that BP self-management, including self-titration, may be a cost-effective way to significantly improve BP control.[7–9] Our projections also show that healthcare providers should consider continuing SMBP interventions beyond 1 year to sustain improvements in BP control with supported SMBP.

Limitations

There are a few limitations to note when interpreting the results of our analyses. First, our covariate selection process for Phase 1 was restricted to those related to the processes of hypertension management that may be simulated in BPCM. There may be other important confounders or interaction terms we did not consider. Second, because antihypertensive adherence was not measured in all of the TASMINH studies and the association of SMBP support level with antihypertensive adherence is unknown, we manually calibrated the effect of SMBP on antihypertensive adherence in the BPCM. However, our calibrated estimates were similar to previously published ranges of observed antihypertensive adherence in SMBP trials.[21] Additionally, the BPCM assumes that processes of hypertension care are independent of one another and it does not account for interactions

that may exist (eg, physicians may be less likely to intensify medications in patients with poor adherence). The first TASMINH study found a slightly increased BP for Level 1 interventions compared with usual care, though other studies have demonstrated small, but not always statistically significant, decreases in BP for similar interventions.[2,6] In our analysis, Level 1 interventions were associated with lower adherence rates, which is perhaps reflective of individuals discontinuing antihypertensive medications based on measured BP, which may be subject to improper measurement technique and lead to an apparent worsening of BP control. Additionally, we did not explicitly model adverse medication events. However, our adherence rates were derived from literature-based estimates of antihypertensive discontinuation for any reason. Lastly, limited long-term data are available regarding the duration of BP changes after return to usual care and, to our knowledge, no data examine long-term (up to 5 years) sustained SMBP interventions.[41,42] However, our base-case approach, in which patients returned to usual care after the 12-month SMBP intervention, resulted in a similar difference in SBP between Level 3 SMBP and usual care to a study that examined SBP outcomes 54 months after a 12-month telemonitoring with pharmacist management intervention. At 18 months, the difference in SBP for Level 3 SMBP versus usual care was −5.5 (−6.0 to −4.9) in our analysis, which is comparable to the −6.6 (−10.7 to −2.5) for the intervention versus usual care in the published study. At 54 months, the difference in SBP was −2.3 (−2.8 to −1.7) in our simulation compared with −2.5 (−6.3 to 1.2) in the published study.[42]

CONCLUSIONS

In conclusion, our pooled analysis of individual participant data found that supported SMBP increased the likelihood of antihypertensive medication intensification over 12 months. Over 5 years, we projected that supported SMBP would significantly improve BP control compared with usual care. Our results underscore the importance of reducing clinical inertia in hypertension and that SMBP may be viable way to improve long-term BP outcomes.

ARTICLE INFORMATION

Received February 14, 2020; accepted June 8, 2020.

Affiliations

From the Columbia University, New York, NY (K.B.B., I.M.K., A.E.M., B.K.B.), Nuffield Department of Primary Care Health Sciences, University of Oxford, United Kingdom (J.P.S., R.J.M.); University of Utah, Salt Lake City, UT (N.R.-N., J.B.K.); SelectHealth, Murray, UT (N.R.-N.); and University of California at San Francisco, CA (V.F., M.J.P., K.B.-D.).

Acknowledgments

This work would not have been possible without the help of the patients and investigators from the TASMINH trials and NHANES.

Sources of Funding

Dr Bryant is supported by T32 HP 10260 from the Health Resources and Services Administration. Dr Sheppard receives funding from the Wellcome Trust/Royal Society via a Sir Henry Dale Fellowship (ref: 211182/Z/18/Z). He also receives funding from the National Institute for Health Research (NIHR) School for Primary Care Research and the NIHR Oxford Biomedical Research Centre at Oxford Health NHS Foundation Trust. Dr Fontil is supported by K23 HL136899 from the National Heart, Lung, and Blood Institute, Bethesda, MD. Dr Moran is supported by R01 HL130500-01A1 and R01 HL139837 from the National Heart, Lung, and Blood Institute, Bethesda, MD. Dr McManus is an NIHR Senior Investigator and receives support from the NIHR Thames Valley ARC and NIHR School for Primary Care Research. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care. Dr Bellows is supported by K01 HL140170 from the National Heart, Lung, and Blood Institute, Bethesda, MD.

Disclosures

Dr McManus has received BP monitors for research from Omron. The remaining authors have no disclosures to report.

Supplementary Materials

Data S1
Tables S1–S11
Figure S1
References 43–58

REFERENCES

1. Bray EP, Holder R, Mant J, McManus RJ. Does self-monitoring reduce blood pressure? Meta-analysis with meta-regression of randomized controlled trials. *Ann Med*. 2010;42:371–386.
2. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, Earle K, George J, Godwin M, Green BB, et al. Self-monitoring of blood pressure in hypertension: a systematic review and individual patient data meta-analysis. *PLoS Med*. 2017;14:e1002389.
3. McManus RJ, Mant J, Bray EP, Holder R, Jones MI, Greenfield S, Kaambwa B, Banting M, Bryan S, Little P, et al. Telemonitoring and self-management in the control of hypertension (TASMINH2): a randomised controlled trial. *Lancet*. 2010;376:163–172.
4. McManus RJ, Mant J, Franssen M, Nickless A, Schwartz C, Hodgkinson J, Bradburn P, Farmer A, Grant S, et al. Efficacy of self-monitored blood pressure, with or without telemonitoring, for titration of antihypertensive medication (TASMINH4): an unmasked randomised controlled trial. *Lancet*. 2018;391:949–959.
5. McManus RJ, Mant J, Haque MS, Bray EP, Bryan S, Greenfield SM, Jones MI, Jowett S, Little P, Penaloza C, et al. Effect of self-monitoring and medication self-titration on systolic blood pressure in hypertensive patients at high risk of cardiovascular disease: the TASMIN-SR randomized clinical trial. *JAMA*. 2014;312:799–808.
6. McManus RJ, Mant J, Roalfe A, Oakes RA, Bryan S, Pattison HM, Hobbs FD. Targets and self monitoring in hypertension: randomised controlled trial and cost effectiveness analysis. *BMJ*. 2005;331:493.
7. Penaloza-Ramos MC, Jowett S, Mant J, Schwartz C, Bray EP, Sayeed Haque M, Richard Hobbs FD, Little P, Bryan S, Williams B, et al. Cost-effectiveness of self-management of blood pressure in hypertensive patients over 70 years with suboptimal control and established cardiovascular disease or additional cardiovascular risk diseases (TASMIN-SR). *Eur J Prev Cardiol*. 2016;23:902–912.
8. Kaambwa B, Bryan S, Jowett S, Mant J, Bray EP, Hobbs FD, Holder R, Jones MI, Little P, Williams B, et al. Telemonitoring and self-management in the control of hypertension (TASMINH2): a cost-effectiveness analysis. *Eur J Prev Cardiol*. 2014;21:1517–1530.
9. Monahan M, Jowett S, Nickless A, Franssen M, Grant S, Greenfield S, Hobbs FDR, Hodgkinson J, Mant J, McManus RJ. Cost-effectiveness of telemonitoring and self-monitoring of blood pressure for antihypertensive titration in primary care (TASMINH4). *Hypertension*. 2019;73:1231–1239.

10. Abraham JM. Using microsimulation models to inform U.S. health policy making. *Health Serv Res*. 2013;48:686–695.
11. Smith BT, Smith PM, Harper S, Manuel DG, Mustard CA. Reducing social inequalities in health: the role of simulation modelling in chronic disease epidemiology to evaluate the impact of population health interventions. *J Epidemiol Community Health*. 2014;68:384–389.
12. Anderson JL, Heidenreich PA, Barnett PG, Creager MA, Fonarow GC, Gibbons RJ, Halperin JL, Hlatky MA, Jacobs AK, Mark DB, et al.; Measures AATFoP and Guidelines AATFoP. ACC/AHA statement on cost/value methodology in clinical practice guidelines and performance measures: a report of the American College of Cardiology/American Heart Association Task Force on Performance Measures and Task Force on Practice Guidelines. *Circulation*. 2014;129:2329–2345.
13. Bellows BK, Ruiz-Negron N, Bibbins-Domingo K, King JB, Pletcher MJ, Moran AE, Fontil V. Clinic-based strategies to reach United States million hearts 2022 blood pressure control goals. *Circ Cardiovasc Qual Outcomes*. 2019;12:e005624.
14. Fontil V, Bibbins-Domingo K, Kazi DS, Sidney S, Coxson PG, Khanna R, Victor RG, Pletcher MJ. Simulating strategies for improving control of hypertension among patients with usual source of care in the United States: the blood pressure control model. *J Gen Intern Med*. 2015;30:1147–1155.
15. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, Godwin M, Green B, Hebert P, Hobbs FDR, et al. Individual patient data meta-analysis of self-monitoring of blood pressure (BP-SMART): a protocol. *BMJ Open*. 2015;5:e008532.
16. Bild DE, Bluemke DA, Burke GL, Detrano R, Diez Roux AV, Folsom AR, Greenland P, Jacob DR Jr, Kronmal R, Liu K, et al. Multi-Ethnic Study of Atherosclerosis: objectives and design. *Am J Epidemiol*. 2002;156:871–881.
17. Major outcomes in high-risk hypertensive patients randomized to angiotensin-converting enzyme inhibitor or calcium channel blocker vs diuretic: the Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial (ALLHAT). *JAMA*. 2002;288:2981–2997.
18. Julius S, Weber MA, Kjeldsen SE, McInnes GT, Zanchetti A, Brunner HR, Laragh J, Schork MA, Hua TA, Amerena J, et al. The Valsartan Antihypertensive Long-Term Use Evaluation (VALUE) trial: outcomes in patients receiving monotherapy. *Hypertension*. 2006;48:385–391.
19. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. *BMJ*. 2009;338:b1665.
20. Law MR, Wald NJ, Morris JK, Jordan RE. Value of low dose combination treatment with blood pressure lowering drugs: analysis of 354 randomised trials. *BMJ*. 2003;326:1427.
21. Fletcher BR, Hartmann-Boyce J, Hinton L, McManus RJ. The effect of self-monitoring of blood pressure on medication adherence and lifestyle factors: a systematic review and meta-analysis. *Am J Hypertens*. 2015;28:1209–1221.
22. Bosworth HB, Olsen MK, Neary A, Orr M, Grubber J, Svetkey L, Adams M, Oddone EZ. Take Control of Your Blood Pressure (TCYB) study: a multifactorial tailored behavioral and educational intervention for achieving blood pressure control. *Patient Educ Couns*. 2008;70:338–347.
23. Barton AB, Okorodudu DE, Bosworth HB, Crowley MJ. Clinical inertia in a randomized trial of telemedicine-based chronic disease management: lessons learned. *Telemed J E Health*. 2018;24:742–748.
24. Bosworth HB, Olsen MK, Grubber JM, Neary AM, Orr MM, Powers BJ, Adams MB, Svetkey LP, Reed SD, Li Y, et al. Two self-management interventions to improve hypertension control: a randomized trial. *Ann Intern Med*. 2009;151:687–695.
25. Hebert PL, Sisk JE, Tuzzio L, Casabianca JM, Pogue VA, Wang JJ, Chen Y, Cowles C, McLaughlin MA. Nurse-led disease management for hypertension control in a diverse urban community: a randomized trial. *J Gen Intern Med*. 2012;27:630–639.
26. Milosavljevic A, Aspden T, Harrison J. Community pharmacist-led interventions and their impact on patients' medication adherence and other health outcomes: a systematic review. *Int J Pharm Pract*. 2018;26:387–397.
27. Mills KT, Obst KM, Shen W, Molina S, Zhang HJ, He H, Cooper LA, He J. Comparative effectiveness of implementation strategies for blood pressure control in hypertensive patients: a systematic review and meta-analysis. *Ann Intern Med*. 2018;168:110–120.
28. Uhlig K, Patel K, Ip S, Kitsios GD, Balk EM. Self-measured blood pressure monitoring in the management of hypertension: a systematic review and meta-analysis. *Ann Intern Med*. 2013;159:185–194.
29. Margolis KL, Asche SE, Bergdall AR, Dehmer SP, Groen SE, Kadrmas HM, Kerby TJ, Klotzle KJ, Maciosek MV, Michels RD, et al. Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control: a cluster randomized clinical trial. *JAMA*. 2013;310:46–56.
30. Bosworth HB, Powers BJ, Olsen MK, McCant F, Grubber J, Smith V, Gentry PW, Rose C, Van Houtven C, Wang V, et al. Home blood pressure management and improved blood pressure control: results from a randomized controlled trial. *Arch Intern Med*. 2011;171:1173–1180.
31. Green BB, Cook AJ, Ralston JD, Fishman PA, Catz SL, Carlson J, Carrell D, Tyll L, Larson EB, Thompson RS. Effectiveness of home blood pressure monitoring, Web communication, and pharmacist care on hypertension control: a randomized controlled trial. *JAMA*. 2008;299:2857–2867.
32. Liyanage-Don N, Fung D, Phillips E, Kronish IM. Implementing home blood pressure monitoring into clinical practice. *Curr Hypertens Rep*. 2019;21:14.
33. Carter EJ, Moise N, Alcantara C, Sullivan AM, Kronish IM. Patient barriers and facilitators to ambulatory and home blood pressure monitoring: a qualitative study. *Am J Hypertens*. 2018;31:919–927.
34. Kronish IM, Kent S, Moise N, Shimbo D, Safford MM, Kynerd RE, O'Beirne R, Sullivan A, Muntner P. Barriers to conducting ambulatory and home blood pressure monitoring during hypertension screening in the United States. *J Am Soc Hypertens*. 2017;11:573–580.
35. Ostchega Y, Zhang G, Kit BK, Nwankwo T. Factors associated with home blood pressure monitoring among US adults: National Health and Nutrition Examination Survey, 2011–2014. *Am J Hypertens*. 2017;30:1126–1132.
36. Baral-Grant S, Haque MS, Nouwen A, Greenfield SM, McManus RJ. Self-monitoring of blood pressure in hypertension: a UK primary care survey. *Int J Hypertens*. 2012;2012:582068.
37. Grant S, Greenfield SM, Nouwen A, McManus RJ. Improving management and effectiveness of home blood pressure monitoring: a qualitative UK primary care study. *Br J Gen Pract*. 2015;65:e776–e783.
38. Jones MI, Greenfield SM, Bray EP, Hobbs FR, Holder R, Little P, Mant J, Williams B, McManus RJ. Patient self-monitoring of blood pressure and self-titration of medication in primary care: the TASMINH2 trial qualitative study of health professionals' experiences. *Br J Gen Pract*. 2013;63:e378–e385.
39. Schwartz CL, Seyed-Safi A, Haque S, Bray EP, Greenfield S, Hobbs FDR, Little P, Mant J, Williams B, McManus RJ. Do patients actually do what we ask: patient fidelity and persistence to the Targets and Self-Management for the Control of Blood Pressure in Stroke and at Risk Groups blood pressure self-management intervention. *J Hypertens*. 2018;36:1753–1761.
40. Jones MI, Greenfield SM, Bray EP, Baral-Grant S, Hobbs FD, Holder R, Little P, Mant J, Virdee SK, Williams B, et al. Patients' experiences of self-monitoring blood pressure and self-titration of medication: the TASMINH2 trial qualitative study. *Br J Gen Pract*. 2012;62:e135–e142.
41. Maciejewski ML, Bosworth HB, Olsen MK, Smith VA, Edelman D, Powers BJ, Kaufman MA, Oddone EZ, Jackson GL. Do the benefits of participation in a hypertension self-management trial persist after patients resume usual care? *Circ Cardiovasc Qual Outcomes*. 2014;7:269–275.
42. Margolis KL, Asche SE, Dehmer SP, Bergdall AR, Green BB, Sperl-Hillen JM, Nyboer RA, Pawloski PA, Maciosek MV, Trower NK, 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:e181617.
43. Claxton AJ, Cramer J, Pierce C. A systematic review of the associations between dose regimens and medication compliance. *Clin Ther*. 2001;23:1296–1310.
44. Vrijens B, Vincze G, Kristanto P, Urquhart J, Burnier M. Adherence to prescribed antihypertensive drug treatments: longitudinal study of electronically compiled dosing histories. *BMJ*. 2008;336:1114–1117.
45. Iskedjian M, Einarson TR, MacKeigan LD, Shear N, Addis A, Mittmann N, Ilersich AL. Relationship between daily dose frequency and adherence to antihypertensive pharmacotherapy: evidence from a meta-analysis. *Clin Ther*. 2002;24:302–316.

46. Lowy A, Munk VC, Ong SH, Burnier M, Vrijens B, Tousset EP, Urquhart J. Effects on blood pressure and cardiovascular risk of variations in patients' adherence to prescribed antihypertensive drugs: role of duration of drug action. *Int J Clin Pract*. 2011;65:41–53.
47. Salam A, Atkins E, Sundstrom J, Hirakawa Y, Ettehad D, Emdin C, Neal B, Woodward M, Chalmers J, Berge E, et al.; A Blood Pressure Lowering Treatment Trialists C. Effects of blood pressure lowering on cardiovascular events, in the context of regression to the mean: a systematic review of randomized trials. *J Hypertens*. 2019;37:16–23.
48. Poisot T. The digitize package: extracting numerical data from scatterplots. *R J*. 2011;3:25–26.
49. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, DePalma SM, Gidding S, Jamerson KA, Jones DW, 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: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. 2018;71:e13–e115.
50. Sheppard JP, Stevens R, Gill P, Martin U, Godwin M, Hanley J, Heneghan C, Hobbs FD, Mant J, McKinstry B, et al. Predicting Out-of-Office Blood Pressure in the Clinic (PROOF-BP): derivation and validation of a tool to improve the accuracy of blood pressure measurement in clinical practice. *Hypertension*. 2016;67:941–950.
51. Sheppard JP, Martin U, Gill P, Stevens R, Hobbs FR, Mant J, Godwin M, Hanley J, McKinstry B, Myers M, et al. Prospective external validation of the Predicting Out-of-OFfice Blood Pressure (PROOF-BP) strategy for triaging ambulatory monitoring in the diagnosis and management of hypertension: observational cohort study. *BMJ*. 2018;361:k2478.
52. Kerr EA, Zikmund-Fisher BJ, Klamerus ML, Subramanian U, Hogan MM, Hofer TP. The role of clinical uncertainty in treatment decisions for diabetic patients with uncontrolled blood pressure. *Ann Intern Med*. 2008;148:717–727.
53. Selby JV, Uratsu CS, Fireman B, Schmittdiel JA, Peng T, Rodondi N, Karter AJ, Kerr EA. Treatment intensification and risk factor control: toward more clinically relevant quality measures. *Med Care*. 2009;47:395–402.
54. Desai N, Madhavankutty Saraswathy V, Hunter K, McFadden C. Prevalence of true therapeutic inertia in blood pressure control in an academic chronic kidney disease clinic. *J Clin Hypertens (Greenwich)*. 2013;15:375–379.
55. Turchin A, Goldberg SI, Shubina M, Einbinder JS, Conlin PR. Encounter frequency and blood pressure in hypertensive patients with diabetes mellitus. *Hypertension*. 2010;56:68–74.
56. Bolen SD, Samuels TA, Yeh HC, Marinopoulos SS, McGuire M, Abuid M, Brancati FL. Failure to intensify antihypertensive treatment by primary care providers: a cohort study in adults with diabetes mellitus and hypertension. *J Gen Intern Med*. 2008;23:543–550.
57. Franklin SS, Wt G, Wong ND, Larson MG, Weber MA, Kannel WB, Levy D. Hemodynamic patterns of age-related changes in blood pressure. The Framingham Heart Study. *Circulation*. 1997;96:308–315.
58. Kronish IM, Lynch AI, Oparil S, Whittle J, Davis BR, Simpson LM, Krousel-Wood M, Cushman WC, Chang TI, Muntner P. The association between antihypertensive medication nonadherence and visit-to-visit variability of blood pressure: findings from the Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial. *Hypertension*. 2016;68:39–45.

SUPPLEMENTAL MATERIAL

Data S1.

SUPPLEMENTAL METHODS

Blood Pressure Control Model Changes

Adherence – Pill-taking Execution

For this analysis, we first added the pill-taking execution component of adherence (i.e., taking medications exactly as prescribed). We derived the reduction in pill-taking execution, varied by number of antihypertensive medications, from two published meta-analyses of studies using electronic monitoring devices (**Table S4**).[43-45] In the model, each individual was randomly assigned at baseline the percentage of doses they would take exactly as prescribed for one through five antihypertensive medications.

Expected Blood Pressure Reduction

As in prior analyses, we used the results of meta-analyses to estimate the reduction in BP with each full- and half-standard dose medication added to a patient's regimen.[13, 14, 19, 20] As we separately model discontinuation, we calculated the potential BP reduction to account for the 25% of individuals reported to discontinue treatment in the meta-analysis by dividing the expected change by 0.75.[19]

We derived the expected BP reduction with incomplete pill-taking execution from an analysis that estimated the percent of the total potential BP reduction achieved by incomplete execution values.[46] As in that analysis, we assumed that SBP would decrease 5 mmHg per day when antihypertensives were not taken.[46] For DBP, we assumed a decrease of 1 mmHg per day when antihypertensives were not taken. From this, we developed seventh-order polynomial

regression models to predict the percent expected BP reduction due to incomplete pill-taking execution.

Similar to how we described adjustment for discontinuation above, we further divided the potential BP reduction by the expected percent of BP reduction achieved for each number of antihypertensive medications used to calculate the *total potential BP reduction* with treatment. For example, if the published Law et al. formula predicted an 8 mm Hg reduction in SBP with one full-standard dose antihypertensive medication, we estimated the total potential systolic blood pressure reduction while persistent as 8 mm Hg/(0.75*0.93) = 11.5 mm Hg, where the 0.75 accounts for the proportion of patients who discontinued in Law et al. and 0.93 is the expected percent BP reduction using the mean pill-taking execution described in the *Adherence – Pill-taking Execution* section above.

In the model, we estimated BP reduction achieved while persistent to antihypertensive medications by multiplying the total potential BP reduction by the predicted percent of BP reduction achieved with incomplete execution. If a patient discontinued their antihypertensive medication, we assumed they reverted back to their pre-treatment blood pressure.

Regression to the Mean

We used a published systematic review to generate estimates for changes in systolic and diastolic blood pressure due to regression to the mean stratified by baseline blood pressure.[47] The systematic review included 86 trials with a mean baseline age of 62 years, were largely male (66%), and had a mean baseline blood pressure of 146/85 mmHg. The trials included in the analysis had a relatively long follow-up period of 3.7 years. The extracted the “usual” blood pressure from each trial, which was derived from a combination of individual participant data, as reported in tables or text, estimated from published figures, and the final blood pressure at the

end of follow up. Regression to the mean was defined as the difference between the usual and baseline blood pressures.

We derived regression to the mean estimates for SBP and DBP from the published meta-analysis using the “digitize” R package.[47, 48] We used the average of the baseline and 3-6 months for the base-case model input. This was chosen as blood pressure management guidelines recommend: (1) using the "average of ≥2 readings obtained on ≥2 occasions" to estimate blood pressure and (2) reassessing elevated blood pressures (120-129/<80 mm Hg) and Stage 1 hypertension (130-139/80-89 mm Hg) with 10-year ASCVD risk <10% in 3-6 months.[49] We considered this group to meet both these criteria and represent current clinical practice. We assumed that changes to BP due to regression to the mean occurred linearly over the first 3 months of the time horizon and remained constant thereafter.[47]

Self-Measured Blood Pressure Monitoring Measurements

We modeled self-measured BP monitoring (SMBP) measurements using the validated Predicting Out-of-Office Blood Pressure in the Clinic (PROOF-BP) algorithm.[50, 51] In the BPCM, patients in Level 3 SMBP interventions could intensify their antihypertensive medication regimen at home when their SMBP was high according to the predetermined self-management plan described in the TASMINH-2 and TASMIN-SR studies.[1, 8] Accordingly, self-management was allowed a maximum of two times and was possible only after two consecutive months when SMBP was high, and could not occur if the physician had intensified their regimen in the previous week.

Simulated Blood Pressure Control Model Population

The simulation cohort was derived by pooling the 2007-2014 National Health and Nutrition Examination Survey (NHANES). We required individuals to have ≥3 measurements for both

systolic blood pressure (SBP) and diastolic blood pressure (DBP) and reported values for age, sex, race, body mass index, total cholesterol, low-density lipoprotein cholesterol, smoking status, diabetes, coronary heart disease, stroke, and serum creatinine. We also required to individuals to be diagnosed with hypertension (i.e., ever been told they have high BP or ever told to take or are currently taking a medication for hypertension) and have a usual source of care.

From eligible NHANES individuals, we used calibrated propensity score weighting to create a population that matched the baseline characteristics of the pooled Telemonitoring And Self-Management IN the control of Hypertension (TASMINH) trial participants. In the BP Control Model (BPCM) simulation, we used the propensity score weights to probabilistically sample (with replacement) 1000 simulated cohorts of 1000 individuals matching the TASMINH population.

To determine if the sampling procedure accurately reproduced the TASMINH population, we compared the baseline characteristics of the simulated population to the pooled TASMINH population. We considered a mean from each simulated cohort valid if it was within 2.5% of the pooled TASMINH mean. However, based on clinical judgement, we required the simulated baseline mean SBP and DBP to be within 2.5 mmHg of the TASMINH pooled means, and within 0.5 antihypertensive medications. We calculated the mean and 95% uncertainty interval (2.5^{th} to 97.5^{th} percentile) of the baseline characteristics from the 1000 simulated cohorts in the BPCM and determined how many had a mean value within the validation range.

Table S1. Summary of TASMINH Trials.

<table>
<tr><th>Population</th><th>Comparator Arms</th><th>Outcomes</th></tr>
<tr><td colspan="3">TASMINH[6] (2005)</td></tr>
<tr><td>Primary care patients from 8 clinics in south Birmingham (UK)

Inclusion criteria:
• Age 35-75
• Receiving HTN treatment
• One clinic BP reading ≥140/85 mmHg
• Included if second BP 140/85-200/100 mmHg

Exclusion criteria: Not specified
Baseline characteristics
<table>
<tr><th>N=441</th><th>Intervention</th><th>Control</th></tr>
<tr><td>Age</td><td>62.8 (8.5)</td><td>62.4 (9.9)</td></tr>
<tr><td>Male</td><td>52%</td><td>43%</td></tr>
<tr><td>White</td><td>95%</td><td>92%</td></tr>
</table></td><td>Control: Usual HTN care with family doctor. They received information on self-help methods to reduce BP.

Intervention: Monthly in-clinic SMBP. Given record card with BP target <140/85 mmHg or <140/80 mmHg with diabetes. Cards had information about goals and when to seek medical appointment.</td><td>BP Outcomes
<table>
<tr><th></th><th>Intervention</th><th>Control</th></tr>
<tr><td>Baseline SBP</td><td>157.9</td><td>155.0</td></tr>
<tr><td>12-mo. SBP</td><td>149.5</td><td>149.0</td></tr>
<tr><td>Adjusted* Difference</td><td colspan="2">2.7 (-1.2, 6.6)</td></tr>
<tr><td>Baseline DBP</td><td>88.7 (7.3)</td><td>88.0 (7.9)</td></tr>
<tr><td>12-mo. DBP</td><td>82.1</td><td>81.5</td></tr>
<tr><td>Adjusted* Difference</td><td colspan="2">0.1 (-2.3, 2.4)</td></tr>
</table>*Adjusted for practice, diabetic status, and sex</td></tr>
<tr><td colspan="3">TASMINH2[1] (2010)</td></tr>
<tr><td>Primary care patients in West Midlands, UK, identified by GP or electronic search.

Inclusion criteria:
• Age 35-85
• BP ≥140/90 mmHg
• Willing to monitor BP and titrate own BP meds

Exclusion criteria:
• BP ≥200/100 mmHg
• Postural hypotension
• Terminal disease
• Dementia
• BP not managed by family doctor
• Spouse already randomized</td><td>Control: Usual HTN care with family doctor consistent with national guidelines.

Intervention: Two home SMBP per day. Traffic-light color system to rate BP measurements, if “above target” for ≥2 months (≥4 days high/month), instructed to follow titration schedule.
Home targets: <130/85 mmHg or <130/75 mmHg with diabetes</td><td>BP Outcomes
<table>
<tr><th></th><th>Intervention</th><th>Control</th></tr>
<tr><td>Baseline SBP</td><td>151.9</td><td>152.0</td></tr>
<tr><td>12-mo. SBP</td><td>134.7</td><td>140.3</td></tr>
<tr><td>Adjusted* Difference</td><td colspan="2">-5.4 (-8.5, -2.4)</td></tr>
<tr><td>Baseline DBP</td><td>85.0</td><td>84.5</td></tr>
<tr><td>12-mo. DBP</td><td>77.5</td><td>79.8</td></tr>
<tr><td>Adjusted* Difference</td><td colspan="2">-2.7 (-4.2, -1.1)</td></tr>
</table>*Adjusted for sex, general practice, baseline SBP ≥150 mmHg, and diabetes and chronic kidney disease status.</td></tr>
</table>

<table>
<tr><th>Population</th><th>Comparator Arms</th><th>Outcomes</th></tr>
<tr><td>Baseline characteristics<table><tr><th>N=527</th><th>Intervention</th><th>Control</th></tr><tr><td>Age</td><td>66.6 (8.8)</td><td>66.2 (8.8)</td></tr><tr><td>Male</td><td>47%</td><td>47%</td></tr><tr><td>White</td><td>95%</td><td>92%</td></tr></table></td><td></td><td></td></tr>
<tr><td colspan="3">TASMIN-SR[8] (2014)</td></tr>
<tr><td>Primary care patients with history of CVD, diabetes, or CKD.

Inclusion criteria:
• Age ≥35
• At least one: History of CVD, diabetes, stage 3 CKD, or BP ≥130/80 mmHg
Exclusion criteria:
• Unable to self-monitor
• Dementia
• BP ≥180/100 mmHg
• Postural hypotension
• On ≥3 antihypertensives
• In another BP study or TASMINH2
• Spouse already randomized
• Terminal illness
• Pregnant
• BP not managed by family doctor
Baseline characteristics<table><tr><th>N=552</th><th>Intervention</th><th>Control</th></tr><tr><td>Age</td><td>69.3 (9.3)</td><td>69.6 (9.7)</td></tr><tr><td>Male</td><td>60%</td><td>59%</td></tr><tr><td>White</td><td>96%</td><td>97%</td></tr></table></td><td>Control: Usual HTN care with family doctor consistent with national guidelines.

Intervention: SMBP and self-titrate antihypertensives following pre-determined plan. When med changed needed according to pre-determined protocol, patient sent paper form to doctor without need for face to face visit. Very high (≥180/100 mmHg) or very low (<100 mmHg systolic) required patient to contact practice. Home management plan had 3 steps, if all three steps completed and further escalation needed, patient returned to practice for further instruction.</td><td>BP Outcomes<table><tr><th></th><th>Intervention</th><th>Control</th></tr><tr><td>Baseline SBP</td><td>143.5</td><td>144.2</td></tr><tr><td>12-mo. SBP</td><td>128.2</td><td>137.8</td></tr><tr><td>Adjusted* Difference</td><td colspan="2">-9.2 (-12.7, -5.7)</td></tr><tr><td>Baseline DBP</td><td>80.2</td><td>79.9</td></tr><tr><td>12-mo. DBP</td><td>73.8</td><td>76.3</td></tr><tr><td>Adjusted* Difference</td><td colspan="2">-3.4 (-5.1, -1.8)</td></tr></table>*Adjusted for baseline BP.</td></tr>
<tr><td colspan="3">TASMINH4[4] (2018)</td></tr>
</table>

<table>
<tr><th>Population</th><th>Comparator Arms</th><th>Outcomes</th></tr>
<tr>
<td>Primary care patients (142 different practices) with hypertension in UK identified using electronic searches.

Inclusion criteria:
• Age ≥35
• Known HTN
• BP ≥140/90 mmHg
• On at least 1 antihypertensive for 4 weeks

Exclusion criteria:
• Postural hypotension
• Atrial fibrillation
• Dementia
• Stage 4 or worse CKD or worse
• CKD with proteinuria

Baseline characteristics
<table>
<tr><th>N=1182</th><th>SMBP</th><th>SMBP+TM</th><th>Control</th></tr>
<tr><td>Age</td><td>67.0 (9.6)</td><td>67.0 (9.3)</td><td>66.8 (9.4)</td></tr>
<tr><td>Male</td><td>54%</td><td>53%</td><td>53%</td></tr>
<tr><td>White</td><td>95%</td><td>95%</td><td>98%</td></tr>
</table>
</td>
<td>Control: Usual HTN care with family doctor consistent with national guidelines.

SMBP: SMBP twice per day sent to practice weekly

SMBP+TM: SMBP with readings sent via text – TM service used algorithm that alerted patients to contact office for very high or low readings, sent reminders if too few readings sent, sent readings to GP office</td>
<td>BP Outcomes
<table>
<tr><th></th><th>SMBP</th><th>SMBP+TM</th><th>Control</th></tr>
<tr><td>Baseline SBP</td><td>152.9</td><td>153.2</td><td>153.1</td></tr>
<tr><td>12-mo. SBP</td><td>137.0</td><td>136.0</td><td>140.4</td></tr>
<tr><td>Adjusted* Difference</td><td>-3.5 (-5.8, -1.2)</td><td>-4.7 (-7.0, -2.4)</td><td>-</td></tr>
<tr><td>Baseline DBP</td><td>85.1</td><td>85.5</td><td>86.0</td></tr>
<tr><td>12-mo. DBP</td><td>77.8</td><td>78.7</td><td>79.7</td></tr>
<tr><td>Adjusted* Difference</td><td>-1.5 (-2.7, -0.2)</td><td>-1.3 (-2.5, -0.0)</td><td>-</td></tr>
</table>
*Adjusted for baseline covariates.</td>
</tr>
</table>

BP – blood pressure, CKD – chronic kidney disease, CVD – cardiovascular disease, DBP – diastolic blood pressure, HTN – hypertension, SBP – systolic blood pressure, SMBP – self-measured blood pressure monitoring, TM – telemonitoring.

Table S2. Blood Pressure Control Model Input Parameters.

Variable	Source	Mean	SD	Lower Bound	Upper Bound	Distribution
Probability of Intensifying Antihypertensive Medication						
Adding/titrating first antihypertensive during simulation						
SBP ≥160 mmHg or BP ≥140/90 mmHg with diabetes or chronic kidney disease	Published literature[52, 53]	0.33	0.03	0.31	0.44	Beta
SBP is uncontrolled but <160 mmHg or BP <140/90 mmHg with diabetes or chronic kidney disease	Published literature[54, 55]	0.21	0.03	0.21	0.31	Beta
Adding/titrating additional antihypertensive medications	Bolen et al.[56]	0.13	0.03	0.07	0.20	Beta
Calibration factors applied to means		Usual Care: 1.64	Level 1: 1.41	Level 2: 2.50	Level 3: 2.00	
Return Visit Interval (Weeks)						
BP controlled	Fontil et al.[14]	16.90	6.74	9.20	26.50	Gamma
*BP uncontrolled**	Turchin et al.[55] ~13.8 weeks					
Intercept (baseline weeks)		27.58	10.41	7.58	47.57	Gamma
Changes to intercept due to patient and visit characteristics						
Age (per year)		-0.15	0.01	-0.16	-0.12	Normal
Female (vs. male)		-0.56	0.41	-1.39	0.22	Normal
White (vs. other races/ethnicities)		-1.00	0.49	-1.95	-0.04	Normal
Last visit with primary care provider (vs. another provider)		-2.90	0.31	-3.51	-2.30	Normal
Antihypertensive medication added at the visit		-2.08	0.20	-2.47	-1.69	Normal

Variable	Source	Mean	SD	Lower Bound	Upper Bound	Distribution
Change in DBP since last visit (per mmHg increase)		-0.06	0.01	-0.07	-0.04	Normal
Calibration factors applied to mean for BP controlled and mean intercept for uncontrolled BP		Usual Care: 1.65	Level 1: 1.43	Level 2: 2.77	Level 3: 1.61	
Quadratic formula components of age-related BP change stratified by baseline SBP						
<120 mmHg	Franklin et al.[57]					
DBP						
Curvature component		-0.007	0.001	-0.008	-0.005	Normal
Curvature calibration factor		1.050	-	-	-	-
Slope component		-0.190	0.008	-0.210	-0.180	Normal
Slope calibration factor		0.650	-	-	-	-
SBP						
Curvature component		0.014	0.000	0.013	0.014	Normal
Curvature calibration factor		0.350	-	-	-	-
Slope component		0.570	0.038	0.470	0.620	Normal
Slope calibration factor		0.600	-	-	-	-
120-139 mmHg						
DBP						
Curvature component		-0.011	0.001	-0.012	-0.010	Normal
Curvature calibration factor		1.050	-	-	-	-
Slope component		-0.170	0.040	-0.260	-0.100	Normal
Slope calibration factor		1.000	-	-	-	-
SBP						
Curvature component		0.007	0.001	0.006	0.009	Normal

Variable	Source	Mean	SD	Lower Bound	Upper Bound	Distribution
Curvature calibration factor		0.350	-	-	-	-
Slope component		0.750	0.070	0.610	0.890	Normal
Slope calibration factor		0.600	-	-	-	-
140-159 mmHg						
DBP						
Curvature component		-0.019	0.001	-0.021	-0.018	Normal
Curvature calibration factor		0.650	-	-	-	-
Slope component		-0.110	0.008	-0.130	-0.100	Normal
Slope calibration factor		1.500	-	-	-	-
SBP						
Curvature component		0.001	0.003	-0.006	0.006	Normal
Curvature calibration factor		0.350	-	-	-	-
Slope component		1.180	0.020	1.140	1.220	Normal
Slope calibration factor		0.450	-	-	-	-
≥160 mmHg						
DBP						
Curvature component		-0.018	0.003	-0.024	-0.011	Normal
Curvature calibration factor		0.750	-	-	-	-
Slope component		0.020	0.045	-0.060	0.120	Normal
Slope calibration factor		-4.000	-	-	-	-
SBP						
Curvature component		0.013	0.005	0.004	0.025	Normal
Curvature calibration factor		0.350	-	-	-	-

Variable	Source	Mean	SD	Lower Bound	Upper Bound	Distribution
Slope component		1.970	0.140	1.730	2.290	Normal
Slope calibration factor		0.400	-	-	-	-
BP reduction with treatment						
Per full-standard dose added	Law et al. 2003 and 2009[19, 20]					
Mean DBP reduction at 90 mmHg		4.70	0.42	2.35	7.05	Gamma
Coefficient of reduction per mmHg decrease in pretreatment DBP		0.11	0.03	0.06	0.165	Gamma
Mean SBP reduction at 150 mmHg		8.70	0.36	4.35	13.05	Gamma
Coefficient of reduction per mmHg decrease in pretreatment SBP		0.10	0.03	0.05	0.150	Gamma
Per half-standard dose added						
Mean DBP reduction at 90 mmHg		3.70	0.31	3.10	4.3	Gamma
Coefficient of reduction per mmHg decrease in pretreatment DBP		0.09	0.02	0.05	0.13	Gamma
Mean SBP reduction at 150 mmHg		6.70	0.28	6.10	7.20	Gamma
Coefficient of reduction per mmHg decrease in pretreatment SBP		0.08	0.02	0.04	0.12	Gamma
BP visit-to-visit variability						
DBP - Adherent	Kronish et al.[58]	6.20	2.60	1.10	11.30	Normal
DBP - Nonadherent		6.80	2.80	1.31	12.29	Normal
SBP - Adherent		10.50	4.50	1.68	19.32	Normal
SBP - Nonadherent		11.40	4.90	1.80	21.00	Normal
BP Regression to the Mean						
SBP	Salam et al.[47]					
<120 mm Hg		4.06	3.44	-	-	Normal

Variable	Source	Mean	SD	Lower Bound	Upper Bound	Distribution
120-129 mm Hg		3.05	1.44	-	-	Normal
130-139 mm Hg		0.25	0.25	-	-	Normal
140-149 mm Hg		-1.78	0.62	-	-	Normal
150-159 mm Hg		-4.57	2.18	-	-	Normal
≥160 mm Hg		-9.14	2.80	-	-	Normal
DBP						
<70 mm Hg		2.19	1.85	-	-	Normal
70-79 mm Hg		0.61	0.29	-	-	Normal
80-89 mm Hg		-0.38	0.37	-	-	Normal
90-99 mm Hg		-3.11	1.08	-	-	Normal
≥100 mm Hg		-4.99	1.88	-	-	Normal
Expected BP Reduction Due to Incomplete Pill-taking Execution						
Derived Polynomial Regressions		*SBP*		*DBP*		
Intercept		0.001	-	-0.0001	-	-
First-order coefficient		-0.13	-	3.41	-	-
Second-order coefficient		-0.48	-	-4.39	-	-
Third-order coefficient	Lowy et al.[46]	24.25	-	2.55	-	-
Fourth-order coefficient		-60.90	-	-1.56	-	-
Fifth-order coefficient		59.58	-	1.53	-	-
Sixth-order coefficient		-23.81	-	-0.27	-	-
Seventh-order coefficient		2.49	-	-0.27	-	-

BP – blood pressure, DBP – diastolic blood pressure, SBP – systolic blood pressure. The table shows the model inputs, the source from which they were derived, and estimates of uncertainty in the model. Lower and upper bounds were preferentially derived from reported 95% confidence intervals or ranges or calculated using sample size or variance estimates as available. *When blood pressure was uncontrolled, the return visit

interval was calculated by adjusting the intercept based on the patient's and last visit's characteristics by the number of weeks indicated in the table.

Table S3. Calibrated Medication Persistence and Pill-Taking Execution Model Inputs.[43, 44]

	Usual Care	Level 1	Level 2	Level 3
1-year probability of discontinuation*	43.00%	49.88%	36.55%	36.55%
Pill-taking execution†				
1 Antihypertensive	85.00%	79.00%	95.00%	95.00%
2 Antihypertensives	76.79%	67.50%	92.26%	92.26%
3 Antihypertensives	73.50%	62.90%	91.17%	91.17%
≥4 Antihypertensives	62.00%	46.80%	87.33%	87.33%

*Probability of discontinuation at 1 year includes discontinuation for any reason.
†Pill-taking execution is the percentage of times antihypertensive medication is taken exactly as prescribed.

Table S4. Calibrated Usual Care Pill-Taking Adherence Inputs Compared to Published Meta-Analyses.

Pill-taking execution*	BPCM - Usual Care	Claxton et al. Meta-Analysis[43]	Iskedjian et al. Meta-Analysis[45]
1 Antihypertensive	85.00%	79.00%	91.40%
2 Antihypertensives	76.79%	69.00%	87.10%
3 Antihypertensives	73.50%	65.00%	83.20%
≥4 Antihypertensives	62.00%	51.00%	

*Pill-taking execution is the percentage of times antihypertensive medication is taken exactly as prescribed.

Table S5. Linear Regression of Number of Non-Physician Office Visits During 12-month Follow-up.

Variable	Beta Coefficient	95% Confidence Interval	
		Lower Limit	Upper Limit
Intensity of Intervention (REF: Usual Care)			
Level 1	0.40	0.21	0.59
Level 2	-0.76	-0.90	-0.63
Level 3	-0.43	-0.54	-0.32

DBP – diastolic blood pressure, SBP – systolic blood pressure.

Model adjusted for age, sex, number of antihypertensive medications at baseline, and baseline BP. Included 2,438 patients from 4 studies. Analysis was a random effects generalized least squares regression with study as a random effect.

Table S6. Observed Blood Pressure Changes Relative to Baseline and Usual Care at One Year by Level of Intervention in TASMINH.

Intervention	Baseline Mean	12-month Mean	Change from Baseline	Adjusted Difference vs. Usual Care*
Systolic Blood Pressure				
Usual Care	151.31	141.50	-9.81	-
Level 1	157.41	148.98	-8.43	3.46
Level 2	152.93	136.97	-15.96	-3.79
Level 3	150.45	133.54	-16.91	-5.37
Diastolic Blood Pressure				
Usual Care	84.82	79.84	-4.98	-
Level 1	88.92	82.98	-5.94	0.25
Level 2	85.07	77.80	-7.27	-1.46
Level 3	84.22	76.97	-7.25	-1.46

TASMINH – Telemonitoring And Self-Management IN the control of Hypertension.

*Adjusted for age, sex, baseline blood pressure, and baseline number of antihypertensive medications, number of physician consultations, non-physician consultations, and number of times treatment was intensified.

Table S7. Linear Regression of Systolic Blood Pressure During 12-month Follow-up.

Variable	Beta Coefficient	95% Confidence Interval	
		Lower Limit	Upper Limit
Intensity of Intervention (REF: Usual Care)			
Level 1	3.46	0.87	6.04
Level 2	-3.79	-5.82	-1.76
Level 3	-5.37	-6.90	-3.84

DBP – diastolic blood pressure, SBP – systolic blood pressure.

Model adjusted for age, sex, number of antihypertensive medications at baseline, baseline BP, number of physician consultations, non-physician consultations, and number of times treatment was intensified. Included 2,438 patients from 4 studies. Analysis was a random effects generalized least squares regression with study as a random effect.

Table S8. Linear Regression of Diastolic Blood Pressure During 12-month Follow-up.

Variable	Beta Coefficient	95% Confidence Interval	
		Lower Limit	Upper Limit
Intensity of Intervention (REF: Usual Care)			
Level 1	0.25	-1.05	1.54
Level 2	-1.46	-2.47	-0.44
Level 3	-1.46	-2.24	-0.69

DBP – diastolic blood pressure, SBP – systolic blood pressure.

Model adjusted for age, sex, number of antihypertensive medications at baseline, baseline BP, number of physician consultations, non-physician consultations, and number of times treatment was intensified. Included 2,438 patients from 4 studies. Analysis was a random effects generalized least squares regression with study as a random effect.

Table S9. Blood Pressure Control Model Validation of TAMSINH Population.

	TASMINH Mean or % (Validation Range)	BPCM	
		Mean or % (95% UI)	% in Validation Range
Demographics			
Age	66.6 (64.9, 68.3)	65.8 (65.2, 66.4)	100.0%
Male	53.9% (51.4%, 56.4%)	53.9% (50.7%, 56.7%)	88.8%
White	95.6% (93.1%, 98.1%)	95.5% (94.3%, 96.7%)	99.5%
Baseline BP Characteristics			
SBP	151.8 (149.3, 154.3)	152.0 (151.4, 152.7)	100.0%
DBP	85.0 (87.5, 82.5)	84.3 (83.8, 84.9)	100.0%
Number of antihypertensive medications	1.5 (1.0, 2.0)	1.4 (1.3, 1.4)	100.0%
Clinical Characteristics			
Body mass index	29.8 (29.1, 30.5)	30.5 (30.1, 30.8)	52.4%
Coronary heart disease history	5.3% (2.8%, 6.8%)	5.3% (4.0%, 7.0%)	100.0%
Stroke history	6.5% (4.0%, 9.0%)	6.4% (4.9%, 8.2%)	99.2%
Chronic kidney disease	12.7% (10.8%, 14.9%)	12.7% (10.9%, 14.6%)	99.0%
Diabetes	15.9% (13.4%, 18.4%)	16.1% (13.8%, 18.2%)	97.7%
Current Smoker	7.3% (4.8%, 9.8%)	7.3% (5.9%, 9.1%)	100.0%

95%UI – 95% uncertainty interval, BP – blood pressure, BPCM – Blood Pressure Control Model, DBP – diastolic blood pressure, SBP – systolic blood pressure, TASMINH – Telemonitoring And Self-Management IN the control of Hypertension.

The simulated population means and 95% uncertainty intervals (2.5^{th} to 97.5^{th} percentiles) are derived from 1,000 probabilistic iterations of the BPCM.

Table S10. Blood Pressure Control Model Validation of Predicted TAMSINH Processes of Care and Blood Pressure Outcomes at 12 Months.

	TASMINH Predicted Mean or % (Validation Range)	BPCM	
		Mean or % (95% UI)	% in Validation Range
Processes of BP Care			
Number of Physician Visits			
Usual Care	1.8 (1.6, 2.0)	1.7 (1.5, 2.0)	89.6%
Level 1	2.5 (2.3, 2.8)	2.4 (2.1, 2.8)	70.6%
Level 2	0.6 (0.5, 0.7)	0.6 (0.5, 0.6)	97.8%
Level 3	1.8 (1.6, 2.0)	1.7(1.6, 2.0)	94.0%
Antihypertensive Intensification Probability			
Usual Care	23.6% (21.2%, 26.0%)	22.6% (17.0%, 29.81%)	48.7%
Level 1	21.8% (19.6%, 24.0%)	20.7% (15.1%, 27.2%)	49.2%
Level 2	27.8% (25.0%, 30.6%)	29.2% (21.3%, 38.5%)	48.0%
Level 3	45.5% (41.0%, 50.1%)	46.6% (40.6%, 52.8%)	83.1%
BP Outcomes			
SBP Change			
Usual Care	-9.82 (-12.3, -7.3)	-9.5 (-11.6, -9.7)	100.0%
Level 1	-5.9 (-8.4, -3.4)	-7.2 (-7.9, -6.4)	100.0%
Level 2	-14.7 (-17.2, -12.2)	-13.0 (-14.3, -11.9)	91.4%
Level 3	-16.8 (-19.3, -14.3)	-16.0 (-17.2, -15.0)	99.9%
DBP Change			
Usual Care	-4.5 (-7.0, -2.0)	-4.4 (-4.8, -4.1)	100.0%
Level 1	-4.0 (-6.5, -1.5)	-4.0 (-4.3, -3.8)	100.0%
Level 2	-6.4 (-8.9, -3.9)	-5.1 (-5.6, -4.8)	100.0%
Level 3	-6.8 (-9.7, -4.7)	-6.0 (-6.4, -5.6)	100.0%

95%UI – 95% uncertainty interval, BP – blood pressure, BPCM – BP Control Model, DBP – diastolic BP, SBP – systolic BP, TASMINH – Telemonitoring And Self-Management IN the control of Hypertension.

The TASMINH predicted values were derived by applying the regression equations to simulated patients in the BPCM. The simulated population means and 95% uncertainty intervals (2.5^{th} to 97.5^{th} percentiles) are derived from 1,000 probabilistic iterations of the BPCM.

Table S11. 5-year Blood Pressure Outcomes from the Blood Pressure Control Model.

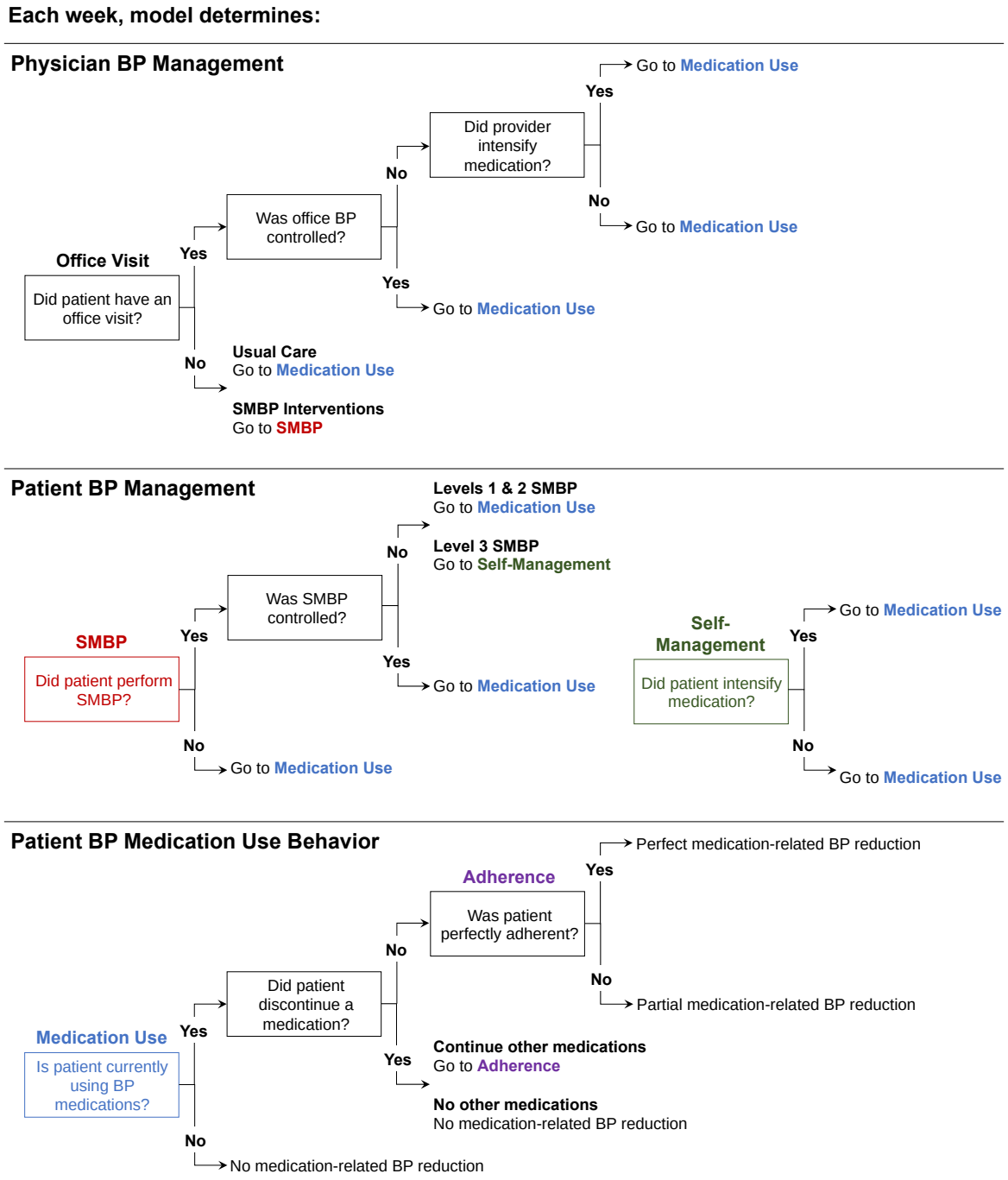
	Usual Care	Level 1	Level 2	Level 3
SBP (mmHg), Mean (95% UI)				
1-year SMBP	140.8 (139.3, 142.3)	141.0 (139.4, 142.5)	140.5 (139.5, 142.0)	139.2 (137.7, 140.5)
5-year SMBP	140.9 (139.2, 142.3)	144.1 (142.8, 145.4)	136.3 (134.1, 138.2)	129.3 (127.4, 130.9)
DBP (mmHg), Mean (95% UI)				
1-year SMP	77.5 (76.7, 78.3)	77.6 (76.8, 78.4)	77.3 (76.5, 78.1)	76.9 (76.1, 77.6)
5-year SMBP	77.6 (76.7, 78.4)	78.2 (77.3, 78.6)	76.7 (75.8, 77.4)	75.3 (74.6, 76.0)
Percent Controlled*, Mean (95% UI)				
1-year SMP	33.4 (27.7, 39.4)	33.0 (27.7, 39.3)	33.9 (28.3, 40.3)	39.0 (33.1, 45.2)
5-year SMBP	33.2 (27.8, 39.4)	21.3 (16.9, 26.0)	52.4 (45.4, 59.8)	72.1 (66.5, 77.6)

95%UI – 95% uncertainty interval, DBP – diastolic blood pressure, SMBP – self-measured blood pressure monitoring, SBP – systolic blood pressure.

The simulated means and 95% uncertainty intervals (2.5^{th} to 97.5^{th} percentiles) are derived from 1,000 probabilistic iterations of the BPCM.

*Percent controlled defined as BP <140/90 mmHg without diabetes or chronic kidney disease or <130/80 mmHg with diabetes or chronic kidney disease.

Figure S1. Structure of the Blood Pressure Control Model.



BP – blood pressure, SMBP – self-monitoring of blood pressure.

The figure shows the events that a patient may experience each week during the simulation.