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Review

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Self-Measured Blood Pressure Telemonitoring Programs: A Pragmatic How-to Guide

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Self-measured blood pressure (SMBP) telemonitoring is the process of securely storing and tele-transmitting reliably measured, patient self-performed blood pressure (BP) measurements to healthcare teams, while ensuring that these data are viewable and clinically actionable for the purposes of improving hypertension diagnosis and management. SMBP telemonitoring is a vital component of an overall hypertension control strategy. Herein, we present a pragmatic guide for implementing SMBP in clinical practice and provide a comprehensive list of resources to assist with implementation. Initial steps include defining program goals and scope, selecting the target population, staffing, choosing appropriate (clinically validated) BP devices with proper cuff sizes, and selecting a telemonitoring platform. Adherence to recommended data transmission, security, and data privacy requirements is essential. Clinical workflow implementation involves patient enrollment and training, review of telemonitored data, and initiating or titrating medications in a protocolized fashion based upon this information. Utilizing a team-based care structure is preferred and calculation of average BP for hypertension diagnosis and management is important to align with clinical best practice recommendations. Many stakeholders in the United States are engaged in overcoming challenges to SMBP program adoption. Major barriers include affordability, clinician and program reimbursement, availability of technological elements, challenges with interoperability, and time/workload constraints. Nevertheless, it is anticipated that uptake of SMBP telemonitoring, still at a nascent stage in many parts of the world, will continue to grow, propagated by increased clinician familiarity, broader platform availability, improvements in interoperability, and reductions in costs that occur with scale, competition, and technological innovation.

Keywords: blood pressure; blood pressure telemonitoring; digital health; home blood pressure; hypertension; programmatic care; self-measured blood pressure; team-based care.

Hypertension, defined as blood pressure (BP) ≥130/80 mm Hg, affects nearly 1 in 2 adults in the United States[1,2] and, when defined as a BP ≥140/90 mm Hg, is present in almost 1.3 billion adults globally.[3] It causes considerable morbidity and mortality, escalating substantially the risk of coronary artery disease, cerebrovascular disease, chronic kidney disease, heart failure, vascular dementia, and other serious sequelae.[4] Of the 91.7 million US adults with hypertension for whom antihypertensive medications and lifestyle modifications are recommended, 73.9% (61.8 million) remain uncontrolled and at risk.[2] Further, hypertensive disorders of pregnancy, including chronic hypertension, gestational hypertension, preeclampsia/eclampsia, and preeclampsia superimposed on chronic hypertension, have been increasing in prevalence for several decades and are a leading cause of maternal morbidity and mortality, particularly among Black and American Indian or Alaskan Native women.[5–10]

BP control in the United States has been falling, a trend exacerbated by COVID-19 pandemic isolation requirements,[3,11–16] which compromised care for chronic conditions and reduced availability of office BP readings.[17,18] Virtual visits, which replaced in-person care, were initially often devoid of high-quality BP measurements. However, as a result, adoption of self-measured BP (SMBP) monitoring has increased.[19]

SMBP is defined as the measurement of BP by an individual outside of a healthcare office, generally at home. SMBP enables collection of multiple BPs over time and calculation of average BP, which has greater prognostic accuracy compared with office BP, and allows recognition of white coat and masked effect.[19] Use of SMBP leads to improvements in BP control in patients with hypertension, when combined with care from dedicated clinical team members.[20–22] Clinical guidelines endorse use of SMBP for diagnosing hypertension and initiating or intensifying antihypertensive medication.[4,23] Both the 2020 *Surgeon General's Call to Action to Control Hypertension* and the 2022 *White House Blueprint for Addressing the Maternal Health Crisis* highlight SMBP as an important strategy to help achieve BP goals.[24,25]

Optimal SMBP telemonitoring requires close collaboration between patients and clinicians and requires patient training in

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proper positioning, technique, and measurement; recording of BP readings at home; remote transmission of BPs to the clinical team; and timely clinical action to initiate/modify the treatment plan accordingly.[26] In the United States, few persons with hypertension currently engage in optimal SMBP. Self-reported data from the 2019 Behavioral Risk Factor Surveillance System indicate that only 6.9% of individuals with hypertension performing SMBP transmitted readings via remote means.[27] The reasons for this deficit in BP telemonitoring capability are multifaceted, with both patient- and clinician-facing barriers responsible.[26]

SMBP telemonitoring programs cannot be optimally implemented without clear understanding of essential program requirements. The purpose of this review is to outline key considerations for implementing an SMBP telemonitoring program, including the technological requirements to operate a platform. An SMBP telemonitoring program is ideally offered within a broader hypertension control strategy, consisting of additional elements such as multidisciplinary team-based care, standardized treatment protocols, fixed-dose combination therapy, and medication adherence strategies.[28] See Table 1 for resources for implementing an SMBP telemonitoring program.

SMBP TELEMONITORING: CURRENT STATE

In the United States, numerous federal agencies and national organizations are working to support widespread SMBP telemonitoring implementation within clinical practice. These include Million Hearts, co-led by the Centers for Disease Control and Prevention and the Centers for Medicare & Medicaid Services; the National Hypertension Control Initiative from the Health Resources and Services Administration and the Department of Health and Human Services Office of Minority Health; the Department of Health and Human Services Federal Hypertension Control Leadership Council; the National

Table 1. Resources for Implementing an SMBP Telemonitoring Program

Program Aspect	Resource(s)
Develop an SMBP Device Loaner Program	• Target: BP — SMBP Loaner Device Agreement • Open Door Family Medical Centers — Blood Pressure Monitor Loan Agreement (English and Spanish) • Target: BP — Inventory Management • Target: BP — SMBP Patient Training Checklist – Loaner Device • NACHC — Self-Measured Blood Pressure Monitoring Implementation Guide for Health Care Delivery Organizations: Appendix Y: SMBP Loaner Program Policy & Procedure – Cleaning and Care of Home BP Monitors, Whitney M. Young, Jr. Health Center • AMA — Cleaning and disinfection procedure • Kaiser Permanente — PHASE SMBP Community of Practice: SMBP Loaner Pilot Model Design (pp. 15-22)
Assign Care Team Roles and Adapt the Workflow Accordingly	• NACHC — Self-Measured Blood Pressure Monitoring Implementation Guide for Health Care Delivery Organizations: Diagram 2: SMBP Model Design Checklist and Key Questions • NACHC — SMBP Implementation Toolkit: SMBP in Clinical Practice (pp. 3-4) • Target: BP — CME Course: Using SMBP to Diagnose and Manage HBP • NYC DOHMH — Patient Self-Monitoring of Blood Pressure: A Provider's Guide • NACHC — Self-Measurement: How patients and care teams are bringing blood pressure to control [video] • Million Hearts® — Self-Measured Blood Pressure Monitoring: Action Steps for Clinicians
Select SMBP Devices for Your Practice and/or Provide Patients with Guidance on SMBP Device Selection	• AMA — US Validated Device Listing • NACHC — Choosing-a-Home-BP-Monitor At-a-Glance-Comparison Tool • Table 3. Oscillometric blood pressure devices validated for accuracy during pregnancy. Ghazi L and Bello NA. Hypertension in Women Across the Lifespan. 2021. • StrideBP • Target: BP — Selecting a Cuff Size • NYC DOHMH — Patient Self-Monitoring of Blood Pressure: A Provider's Guide
Train Patients on SMBP Device Use And Proper Preparation And Positioning	• Target: BP — Device Accuracy Test • Target: BP — SMBP Patient Training Checklist • NACHC — Self-Measured Blood Pressure Monitoring Implementation Guide for Health Care Delivery Organizations: Appendix AC: Training Manual – Staff Checklist for SMBP Training, ARcare/KentuckyCare • Target: BP — SMBP Training Video [video] (English and Spanish) • NACHC — How to Use Your Home Blood Pressure Monitor [video] • Target: BP — How to Measure Your Blood Pressure At Home infographic • ACC — CardioSmart: How to Take Your Blood Pressure At Home
Develop a Process for Handling Patient-Generated BP Readings	• Million Hearts® — Self-Measured Blood Pressure Monitoring: Action Steps for Clinicians: Suggested SMBP Measurement Protocol • AMA — In-office BP Average Calculator • Target: BP — SMBP Average Calculator
Deploy an SMBP Measurement Protocol	• NACHC — SMBP Implementation Toolkit: SMBP in Clinical Practice (pp. 3-4) • NACHC — SMBP Implementation Guide: Sample Approach for Using SMBP Data to Control High Blood Pressure (pp.40-43) • Target: BP — A Look at Self-Measured Blood Pressure [video] (segment 6:50)
Use BP Telemonitoring Software Solutions	• PHII — Health IT Checklist for Blood Pressure Telemonitoring Software • NACHC — SMBP Implementation Toolkit: Optimizing Management of Patient-generated Health Data for SMBP Programs (pp. 10-12)
Use Standardized Wireless Data Transmission Protocols	• Continua Alliance as described at http://www.continuaalliance.org • Bluetooth BP Service 1.1.1 as described at https://www.bluetooth.com/specifications/specs/
Evaluate Your SMBP Program	• NACHC — SMBP Implementation Guide: Appendix B: NACHC Million Hearts SMBP Project Measure Specifications (p.29)

Association of Community Health Centers; MAP[BP] from the American Medical Association (AMA); and Target: BP, co-led by AMA and the American Heart Association.[29–35] These groups, and many additional partners, are tackling large-scale implementation challenges including providing educational resources, improving access to clinically validated SMBP devices, expanding SMBP device coverage and reimbursement for related clinical services, and developing technical standards to improve interoperability.

Outside of the United States, SMBP telemonitoring program adoption within routine clinical practice is at a much earlier stage. Many countries share similar challenges to the United States in implementing SMBP. Key implementation barriers, varying by jurisdiction, include lack of availability of high-quality culturally tailored SMBP solutions, insufficient technical expertise, absence of necessary digital infrastructure, lack of dedicated provider reimbursement or BP device purchase coverage, and technological (and general) illiteracy.[36] However, interest in implementing SMBP is growing; important use cases include delivering medical care to geographically remote jurisdictions and in aged care homes.[37] Countries including Singapore, China, England, and Japan are exploring or supporting large-scale early initiatives for SMBP telemonitoring.[38–40] It is anticipated that adoption of SMBP telemonitoring will continue to increase globally, albeit at a slower pace than in the United States.

PLANNING AN SMBP TELEMONITORING PROGRAM

When starting an SMBP telemonitoring program, it is helpful to define program scope and desired reach, how eligible patients will be identified, staffing requirements and roles, and training needs. This informs development of protocols that integrate program-generated clinical decisions into care processes and workflows, which subsequently optimizes ability to improve BP control. The National Association of Community Health Centers, through their work with Million Hearts, has developed the *Self-Measured BP Monitoring (SMBP) Implementation Toolkit* that provides a template for identifying resources required for an SMBP telemonitoring protocol (Tables 2 and 3).[41]

Table 2. SMBP protocol design checklist

Protocol elements (Check applicable elements)	Decisions/notes
☐ **Determine which SMBP devices to use** Choose a validated upper arm device. Consider whether it comes with an XL cuff, Bluetooth capability, memory storage capacity, multiple users, ease of use, insurance coverage, cost	Selected SMBP device:
☐ **Determine which "patient facing" app you will use**	Selected app:
☐ **Determine how patients will obtain SMBP devices**	☐ Loaned ☐ Purchased by health center (for patient to keep) ☐ Purchased by patient ☐ Purchased by supporting organization (for patient to keep) ☐ Purchased through insurer
☐ **Determine how patients will physically receive their SMBP device**, if loaned or purchased by other than the patient	☐ Full face-to-face visit ☐ Mailed to patient ☐ Quick pick-up at health center ☐ Staff delivers to patient
☐ **Determine number of SMBP devices to purchase** (if loaned, plan on 3 devices per care team)	☐ Number of SMBP devices to purchase: ▪ Patient keeps: _____ ▪ To loan: _____
☐ **Determine number of cuff sizes to purchase** *Note: 50% of health center patients required XL cuff sizes among the 10 health centers that participated in the NACHC Accelerating SMBP Project.* *Recommendation: choose a validated SMBP device that has cuff options that fit arms over 42 cm in circumference*	☐ Number of Standard/Large Cuffs (fits arm sizes 22–42 cm) ▪ Patient keeps: _____ ▪ To loan: _____ ☐ Number of Extra-Large Cuffs (fits arm sizes 43–54 cm) ▪ Patient keeps: _____ ▪ To loan: _____
Complete this section only if you intend to loan SMBP devices.	
☐ **Determine how long patients will keep SMBP devices** (if loaned; e.g., 2 weeks, 1 month, etc.)	Our protocol:
☐ **Determine how patients will return SMBP devices**	Our protocol:
☐ **Determine what controls to put in place if patients do not return SMBP devices** (e.g., # of phone calls, # letters, # text messages, etc.)	Our protocol:
☐ **Determine where SMBP devices will be physically stored** (consider separate locations for "clean" vs. "dirty")	Our protocol:
☐ **Determine how SMBP devices are tracked, inventoried, cleaned, and managed**	Our protocol:
☐ **Determine how the patient will connect with the SMBP Trainer** (e.g., warm hand-off, follow-up visit, etc.)	Our protocol:
☐ **Determine SMBP training curriculum/resources** (e.g., What is SMBP Protocol (2 measurements, AM and PM for 7 days); how to use the device; how to take BP at home properly (technique) how to communicate measurements to care team; what to do for an out-of-range BP; loaner agreement)	Our protocol:

Abbreviation: SMBP, self-measured blood pressure. Adapted from the National Association of Community Health Centers Self-measured Blood Pressure Monitoring (SMBP) Implementation Toolkit. https://www.nachc.org/wp-content/uploads/2020/12/SMBP-Toolkit_FINAL.pdf.

Table 3. Key SMBP telemonitoring program personnel

Protocol elements (Check applicable elements)	Staff person(s) name or role
☐ **SMBP Coordinator** Has authority, time, and skills to coordinate all aspects SMBP implementation	
☐ **SMBP Trainers** At least one per site; educates patient on how to use the home BP monitor, how to get home BP readings back to the care team, how often to do measurements, and proper technique	**Site 1** — Available Daily for a Warm Handoff? ☐ Yes ☐ No **Site 2** — Available Daily for a Warm Handoff? ☐ Yes ☐ No **Site 3** — Available Daily for a Warm Handoff? ☐ Yes ☐ No
☐ **SMBP Device Manager** Tracks, inventories, cleans, calibrates, stores home BP monitors	**Site 1** — **Site 2** — **Site 3** —
☐ **SMBP Clinical Champion** Has time to facilitate implementation success, key influencer	**Site 1** — **Site 2** — **Site 3** —
☐ **SMBP Outreach Coordinator** Coordinates contacting patients to recommend SMBP and after they initiate SMBP to ensure understanding of proper measurement technique, etc.	
☐ **SMBP Data Manager** Receives, possibly enters, prepares, and manages SMBP data	
☐ Determine who recommends SMBP to the patient at the point of care	☐ Clinician ☐ Medical Assistant ☐ Nurse ☐ Pharmacist ☐ Other

Abbreviation: SMBP, self-measured blood pressure. Adapted from the National Association of Community Health Centers Self-measured Blood Pressure Monitoring (SMBP) Implementation Toolkit. https://www.nachc.org/wp-content/uploads/2020/12/SMBP-Toolkit_FINAL.pdf.

Program scope

Program scope may vary according to resource availability, but a comprehensive program that includes hypertension diagnosis and management is ideal. Examples of program scope objectives include[42]:

- Improving timely and accurate hypertension diagnosis, including ruling out white coat and masked hypertension.
- Titrating medications in diagnosed patients.
- Managing chronic or gestational hypertension in pregnant and postpartum women.
- Focusing on high-risk patients (e.g., BP ≥160/100 mm Hg, existing cardiovascular disease, or multiple cardiovascular risk factors).
- Engaging patients who have medication adherence barriers.
- Enhancing services for existing chronic disease programs/populations.
- Engaging patients who are better served out of the clinic.
- Improving engagement of patients with chronic conditions.

Identifying eligible patients

Once the SMBP telemonitoring program scope has been identified, it is helpful to characterize the eligible patient population because this provides insights into patient profiles/volumes and facilitates proper program resourcing and staffing. Prioritizing high-risk or underserviced subgroups may be desirable to maximize impact. For example, a program may focus on patients with a systolic BP of ≥160 mm Hg, those with no recorded BP in the last year, or those who are untreated or under-treated. A report can be created to monitor progress using electronic health record (EHR) registry functionality or population health management software (Table 4).

Table 4. Sample population report to manage and evaluate SMBP

Comparison of uncontrolled and controlled hypertensive patients[a]		
Description	**% of uncontrolled patients**	**% of controlled patients**
Black/African American; Non-Hispanic		
Female		
Aged 35–64 years old		
New to the practice in the last year (No medical visit prior to the reporting period)		
Uncontrolled prior to measurement year (Last BP before this year ≥140/90 mm Hg)		
Retained in care this measurement year (≥2 visits in this measurement year, with at least 1 visit in the last 6 months)		
Last systolic BP in measurement period <140 mm Hg		
Last systolic BP in measurement period 140–149 mm Hg		
Last systolic BP in measurement period 150–159 mm Hg		
Last systolic BP in measurement period >160 mm Hg		
No BP measurement in the last 12 months		
Prescribed ≥2 antihypertensive medications		
On monotherapy		
Not on any antihypertensive medications		

Abbreviations: BP, blood pressure; SMBP, self-measured blood pressure.
[a]Age, gender, and ethnicity are practice defined and specific. Ideally, this report can provide a list of patients fitting the descriptions for outreach and prioritization purposes.

Staffing considerations

Relying solely on clinicians to implement an SMBP program is usually impractical and unsustainable because of time and workload constraints. SMBP program success is optimized by employing team-based, interdisciplinary care models that dedicate staff to the outreach and enrollment process, patient training, management and monitoring of submitted SMBP readings, and interpretation of SMBP readings for hypertension treatment adjustment. Clinical pharmacists, nurses, medical assistants, community health workers, health professions students, and staff from other community organizations (e.g., local public health departments, local YMCAs, or volunteers such as Americorps) are potential resources.[26,42] A robust SMBP telemonitoring program may benefit from clinical champions to

facilitate implementation, an overall program coordinator with the authority, time, and skillset to coordinate implementation, and a device manager, if permanent or loaned devices are being provided to patients (Table 3).

SMBP DEVICES

General considerations

SMBP device features vary with respect to available cuff sizes, number of users supported, memory storage capacity, BP averaging capability, and wireless data transmission capability.[43] Extra options may increase device cost. Use of clinically validated automated upper arm devices is recommended.[19] Validated wrist devices may be appropriate for some patients with larger or conical arms but user error is more common in these devices and their use may require additional training.[19]

Patients may use their own SMBP devices, or devices may be provided to them through the program, either permanently or in a loaned capacity. Device selection may vary based on insurance coverage, cost, and technical literacy.[26] Allowing patients to use their own devices, or those preferred by their insurance companies, often leads to use of multiple device manufacturers, models, and software applications which may complicate workflow. In these cases, the program may benefit from deploying device-agnostic (i.e., not tied to a specific device) BP telemonitoring software solutions (Table 1).[41,44] Use of 1 or 2 SMBP device types may simplify enrollment processes, support adoption of standard workflows, and lead to cost savings.

SMBP device loaner programs may be a feasible way to supply patients with devices though they require additional staff time and logistics. For example, staff are needed to manage inventory, service, and clean devices before redeployment, and reclaim devices from patients to allocate to others. Reclaiming devices may interrupt ongoing patient self-monitoring and reduce patient engagement.

Cuff size selection

Using a BP cuff that is too large or too small can produce inaccurate readings. For example, BP measured with a smaller-than-recommended cuff may lead to a 4- to 11-mm Hg average SBP overestimation.[45] Additionally, BP cuff sizing is specific to each manufacturer and what one manufacturer refers to as a "large adult" cuff may be considered by other manufacturers to be "extra large," "extended," or "wide-range."[43,46] Therefore, patients may benefit from accurate arm circumference measurement and being told their actual arm circumference (i.e., the measured value in centimeters) rather than which cuff size to purchase (i.e., large or extra large). Currently, only 4 clinically validated SMBP devices have cuff options >42 cm.[46] A high percentage (50%) of patients with hypertension required cuffs >42 cm in previous SMBP programs.[42] Practices may consider choosing SMBP devices—in particular, those with cuff sizes large enough to accommodate their patients—rather than insurance companies making this determination.

Clinical validation of devices

All SMBP devices sold in the United States have been cleared by the Food and Drug Administration; however, devices with additional, documented, independent validation for clinical accuracy are preferred. Clinically validated SMBP devices can be found on the US Blood Pressure Validated Device Listing or, internationally, from STRIDE BP.[46,47] When using SMBP for hypertensive disorders of pregnancy, additional attention should be paid to those specifically validated for pregnancy (see Table 1).[47,48]

DATA AND TECHNOLOGY

Telemonitoring platforms that support patients' abilities to engage in optimal SMBP include Bluetooth or cellular-enabled connected SMBP devices, intermediary devices that receive and relay information, servers with the capacity to receive SMBP-related data, secure storage of data received, and a robust clinical portal for clinicians to digest and address patient-generated BP data (Figure 1).

Wireless connectivity

SMBP devices should be able to transmit BP readings electronically and automatically. The most pervasive form of wireless data transmission is Bluetooth-enabled technology. A typical use case involves pairing a Bluetooth-enabled SMBP device with a smartphone or tablet with a patient-facing application that gathers BP data (Table 1). Bluetooth is a short-range wireless standard that allows an SMBP device to communicate with a smartphone, tablet, computer, or hub and is widely available and relatively inexpensive. However, its stability and ease of use is dependent on operating systems and device compatibility. Ensuring that the SMBP device is connected to the smartphone application and submitting readings may require additional support from the practice team.[26] Another consideration when choosing a platform is storage security. Applications that securely store BP values locally may avoid losing readings if internet connectivity is intermittent.

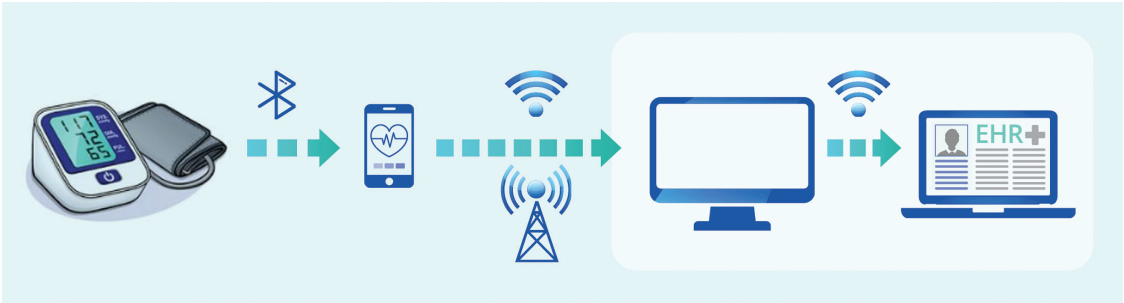

Figure 1. SMBP data flow diagram. Abbreviation: SMBP, self-measured blood pressure. (Reprinted with permission from the National Association of Community Health Centers Self-measured Blood Pressure Monitoring [SMBP] Implementation Toolkit. https://www.nachc.org/wp-content/uploads/2020/12/SMBP-Toolkit_FINAL.pdf.)

An alternative to Bluetooth wireless data transmission for SMBP devices is cellular or Long-Term Evolution (LTE) data transmission. LTE sends data directly to a cloud without the need for a receiving/relaying device; however, fewer clinically validated SMBP devices with cellular functionality are available. Furthermore, there may be additional costs for data plans and usage and these devices may not work well in regions where LTE networks are limited.

Receiving and relaying devices

Smartphones or tablets containing an installed software application and paired with a Bluetooth-enabled SMBP device are commonly used to accomplish this task. Relaying devices allow patients to use their mobile device(s). Alternatively, a specialized home hub (LTE standard) can be used which can be configured for multiple vital sign devices (BP, scales, pulse oximeters, and glucometers). But this method will incur additional data plan costs. Hub-based options, or applications that connect to multiple devices, may be more cost effective when implementing more comprehensive remote monitoring programs for medically fragile patients (e.g., monitoring post-acute care discharge) rather than for SMBP programs that are focused specifically on BP telemonitoring.

Health information exchange servers

A server is a high-powered computer that provides functionality for other programs or devices. A server that can receive secure, encrypted data transmission from a smartphone, tablet, or home hub; provide a single point in the cloud to which SMBP readings and contextual data like time of readings and device make and model can be forwarded and stored securely; and allow hubs to be remotely managed may be of benefit to SMBP telemonitoring programs. These exchange servers are typically provided by telemonitoring vendors as part of a telemonitoring service and act as gateways, translating device data into different formats. The recommended format for intersystem communication in the healthcare sector is Health Level 7 (HL7) Fast Healthcare Interoperability Resource (FHIR) framework, which defines the communication protocol for data exchange.[49]

Security and data privacy

Securely protecting patient data and assuring privacy are recommended components of all telemonitoring systems[36,44] and include:

1. Compliance with privacy, consent, and other regulatory requirements.
2. Protection against identity and data loss theft.
3. Ability to safeguard effectiveness.
4. Ability to maintain data integrity and privacy while using real-world public networks.

SMBP monitoring is typically being "prescribed" by care delivery organizations as part of their hypertension management programs and telemonitoring vendors can provide the technological elements required for a successful program. Accordingly, a Business Associates Agreement (BAA) should be signed between these 2 parties that outlines responsibilities and deliverables. Vendors of telemonitoring solutions are familiar with security frameworks and can adapt to local requirements.

Patient-generated BP readings should be housed on HIPAA-compliant secure servers. Typically, these are cloud-based and use HL7 FHIR-compliant communication protocols. Data, once stored with at-rest encryption protocols to prevent unauthorized access (i.e., Advanced Encryption Standard 256-bit), can then be accessed via a secure web portal through a Hypertext Transfer Protocol encrypted by Transport Layer Security (HTTPS-TLS). Access to the server's highly protected network is typically authenticated via a unique username and password identifier and additional protection can be implemented with a 2-factor authentication requirement.

Provider-facing web-based portals vs. EHR integration

SMBP telemonitoring programs often rely on a provider-facing or clinician web portal to display patients' SMBP data. Direct integration into the EHR is another option. This can vary in complexity, from a relatively simple integration that enables the average SMBP value to be regularly sent to a dedicated field in the EHR to a more complex configuration that creates a secure, one-click launch of the telemonitoring platform from the EHR with automatic login. Web portals often contain more functionality than can be offered through direct EHR integration and are used for different purposes depending on the team member:

- Outreach and enrollment staff use the portal to ensure newly enrolled patients are submitting BPs.
- Program monitoring staff review the population enrolled in the program, identify patients in need of medication titration, those ready for graduation, and those who require reminders to submit their BP readings regularly.
- Clinicians and pharmacists use the portal to look at individual readings or clinically analyze diurnal trends to inform medication changes.

Clinical portals also require an additional login, separate from the EHR login. EHR integrations offer single sign-on capability. This allows the web-based portal to be embedded into the EHR and requires no additional login procedures; sign-on capability may be a better solution to ease clinician burden and retain full portal functionality. However, resource requirements for EHR integration can be significant.

Another advantage of web portals is that they offer features such as a patient roster view; this view is easily sortable by BP level, or other metrics, and improves efficiency. It also allows staff to calculate the mean BP flexibly over different time periods and aligns with clinical best practices for diagnosing and managing hypertension using SMBP.[4] Optional useful features include clinical decision support tools and alerts for severely elevated BP readings.

SMBP PROGRAM CLINICAL WORKFLOW

Once the SMBP-related hardware and software have been purchased and installed, patient enrollment and training can begin, which is followed by data collection and management of patient-generated SMBP readings, interpretation of readings by the clinical team, and resultant modifications of patients' hypertension care plans to improve BP control. Programs may also want to evaluate the impact of their efforts.

Patient enrollment and training

Successful SMBP telemonitoring programs use a multifaceted recruitment approach that includes patient outreach and referral from other healthcare team members within the organization. During the enrollment process, specially trained staff acclimate the patient to the technology and reinforce the importance of BP control and taking their BP per their clinician-recommended protocol. A complete cycle of SMBP is generally defined as 2

measurements, 1 minute apart, in the morning and evening for a 7-day period (28 measurements), with a minimum of 3 days (12 measurements).[4] An average BP is calculated from all measurements from the 7-day period into 1 systolic BP average and 1 diastolic BP average. This overall BP average is used for diagnosis and treatment decisions.[4] Enrollment staff may provide patients technical assistance on downloading and using necessary applications and transmitting their SMBP readings to the clinical team.

Enrollment staff are well poised to measure patients' arm circumferences, teach patients proper SMBP preparation and positioning, and train patients to accurately use their device (see Table 1 for resources). Asking the patient to perform a "teach-back" by reproducing the process from start to finish and confirming that that BP readings are being transmitted to the web portal may be useful. Enrollment staff can also view the clinical portal to ensure that BP readings from newly enrolled patients are being submitted. If successful data transmission is not occurring, staff can perform outreach to troubleshoot the device, connectivity, and the overall process being used to submit readings.

SMBP data management and monitoring and adjusting the care plan

The next step in the process is to review and monitor the SMBP readings submitted by the patient. A telemonitoring process, as described above, is used to create viewable data via a clinical portal or within the EHR. Using devices that do not offer tele-transmission of BP readings requires the patient to maintain a manual log of BP readings and is prone to reporting bias.[50,51] Staff must then review and average the BP readings manually or use a spreadsheet software program (e.g., Microsoft Excel).

A clinical portal that houses BP readings for all patients enrolled at the practice enables sorting and viewing of data to facilitate efficient BP monitoring between regular office visits or as part of a virtual care program. Using a standardized hypertension treatment algorithm[52] within an established SMBP clinical workflow (Figure 2), the care team can analyze the SMBP readings and apply clinical decision-making to evaluate need for medication adjustment. By interpreting SMBP data, issues with medication adherence may also become apparent and flagged for discussion. Staff can also encourage patients to continue taking and submitting SMBP readings or congratulate them on reaching BP control and share next steps for maintaining control. Clinical pharmacists can be particularly effective in the role of monitoring and adjusting care plans as they are able to recommend medication adherence strategies such as blister packaging or refill synchronization to minimize patient trips to the pharmacy.

Program evaluation

Program evaluation will vary and should be aligned with overall program goals and targets. Key components to consider are BP levels, proportion controlled, time to BP control, and performance in prespecified subgroups of interest. A sample program evaluation chart is provided in Table 4.

BARRIERS TO SMBP IMPLEMENTATION

Policy and health systems level

Many barriers exist to widespread adoption and use of SMBP in the United States, particularly at the policy or health systems level. These barriers, which are well documented, also exist globally and include affordability, lack of SMBP device coverage and reimbursement for related clinical services, requirements to understand and adhere to data transfer standards and privacy protections, broadband access availability, and sourcing appropriate cuff sizes for larger arms.[26,19] Challenges related to patient connection fees, EHR limitations, and misalignment of quality measures are additional policy/health systems level barriers and are discussed below.[26,19]

Some technology companies that support SMBP (or broader remote physiologic monitoring models) may require per patient connection fees based on a care delivery organization's entire patient panel—that is, including all patients, rather than those actively engaged in SMBP. These fees may be charged on top of device and technical support costs for integration or troubleshooting and may make SMBP programs cost prohibitive.

Many EHRs lack a structured data field to document average BP as part of the base software package, which has stymied effective and efficient use of SMBP telemonitoring. Without a dedicated field to record and display average BP, care teams must develop local solutions or pay for a custom configuration, yielding an array of fragmented workarounds and adaptations that may not be readily queried or able to be included in automated reports.[53] Many national organizations are advocating for average BP to be included in the draft United States Core Data for Interoperability version 4 (USCDIv4),[54] which would require EHR vendors to include the average BP data element in their off-the-shelf product. As of the writing of this article, average BP was included in the draft final USCDIv4, however, until the US Office of the National Coordinator for Health Information Technology (ONC) adopts average BP into the final USCDIv4 and regulates its requirement, this issue remains unresolved. Having a required EHR field for average BP would also make it available for use in clinical quality reporting, clinical decision support, and quality improvement.[26] Recently, the HL7 CodeX FHIR Accelerator Cardiovascular Health Domain (CardX) was convened. CardX represents a wide cross-section of stakeholders working to improve hypertension control by leveraging FHIR-based interoperability through a hypertension management use case.[55] The use case team is currently working on leveraging and extending existing technical standards to represent average BP in accurate, meaningful, and actionable terms to facilitate SMBP data exchange.

Quality measures could also be updated to facilitate and encourage SMBP. While current BP control clinical quality measures allow for the use of SMBP readings to assess BP control, modification of measure specifications need to clarify that average BPs from SMBP may be used.[19,56] Since performance measures like BP control often are central to value-based care contracts and other financial incentives, this misalignment is a significant barrier to implementing current evidence-based US guideline recommendations to utilize and implement SMBP.[4,53]

Clinic-level barriers

Clinic-level barriers range from concerns about time and workload requirements related to using SMBP (especially by physicians); lack of clinician confidence in and awareness of the accuracy/quality of SMBP data; insufficient conviction that patients are capable of and desire to use SMBP; and confusion about how SMBP can be used as an evidence-based strategy.[26,42,57]

Leveraging team members for SMBP tasks that do not have to be performed by the clinician could address clinician concerns about workload. Accordingly, clinicians may benefit from exposure to care models that include other care team members, or even volunteers, accomplishing nonclinical SMBP tasks, like training and outreach support.[42]

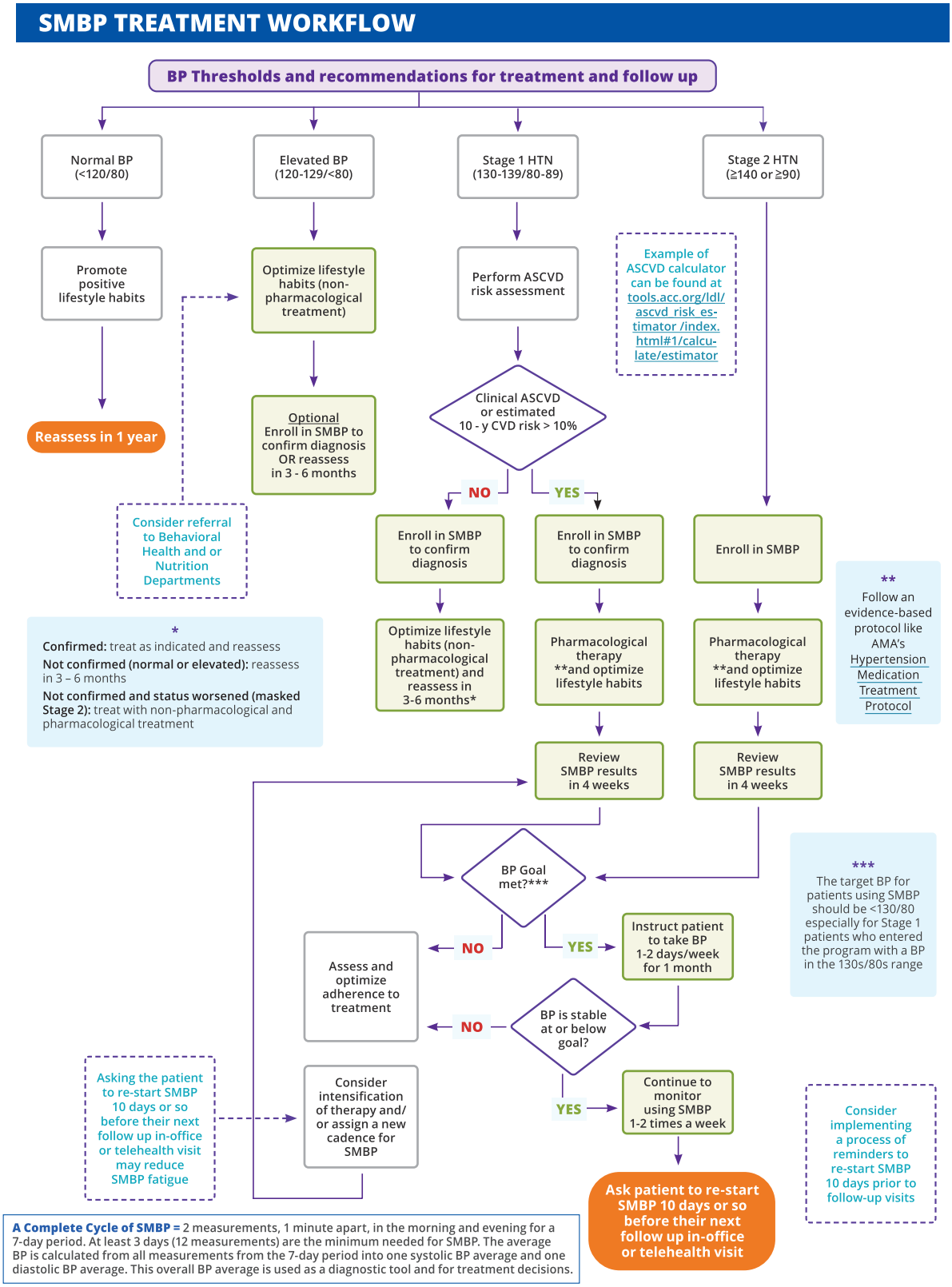

Figure 2. SMBP treatment workflow example. Abbreviations: AMA, American Medical Association; ASCVD, atherosclerotic cardiovascular disease; BP, blood pressure; CVD, cardiovascular disease; HTN, hypertension; SMBP, self-measured blood pressure. (Reprinted with permission from the National Association of Community Health Centers Self-measured Blood Pressure Monitoring (SMBP) Implementation Toolkit. https://www.nachc.org/wp-content/uploads/2020/12/SMBP-Toolkit_FINAL.pdf.)

Wider education for clinicians about the accuracy of SMBP data could improve confidence in its use. Similarly, clinician education on patients' capacity for SMBP and the positive patient engagement that results from its use could mitigate barriers stemming from clinician beliefs.[57]

Broader education conveying how to use SMBP effectively in clinical hypertension care may also help facilitate wider use. SMBP is evidence based when paired with clinical supports[21,22]—if SMBP is implemented in isolation (e.g., a patient receives or is instructed to purchase an SMBP device without follow-up or disconnected from medication management interventions), improved BP outcomes beyond usual care do not occur.[58] This misunderstanding of what constitutes an SMBP program could cause organizations to conclude inappropriately that the return on investment does not justify the investment in SMBP.

CONCLUSION AND FUTURE DIRECTIONS

SMBP telemonitoring programs continue to evolve and their successful implementation to improve BP control requires consideration of the recommended elements described herein. SMBP telemonitoring is considered a vital component of an overall hypertension control strategy and many stakeholders are actively engaged in facilitating implementation in the United States. On a global level, SMBP telemonitoring is at a more nascent stage but continued adoption is expected. Going forward, it is expected that the many challenges that exist to proper implementation will be overcome by improving understanding of how to implement and maintain a program, combined with improvements in technology, broader platform availability, innovations in interoperability, alignment of reimbursement with workload, modifications to clinical quality measures, and reductions in costs that occur with scale, competition, and technological innovation.

DISCLOSURE

R.S.P. is the Chief Executive Officer of mmHg, a provider of digital health software solutions, including cardiometabolic platforms-as-a-service.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily reflect the official position of the Centers for Disease Control and Prevention.

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