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IMPLEMENTATION TO INCREASE BLOOD PRESSURE CONTROL: WHAT WORKS? (JEFFREY BRETTLER AND KRISTI REYNOLDS, SECTION EDITORS)

Implementing Home Blood Pressure Monitoring into Clinical Practice

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Abstract

Purpose of Review To review data supporting the use of home blood pressure monitoring (HBPM) and provide practical guidance to clinicians wishing to incorporate HBPM into their practice.

Recent Findings HBPM more accurately reflects the risk of cardiovascular events than office blood pressure measurement. In addition, there is high-quality evidence that HBPM combined with clinical support improves blood pressure control. Therefore, HBPM is increasingly recommended by guidelines to confirm the diagnosis of hypertension and evaluate the efficacy of blood pressure-lowering medications. Nevertheless, HBPM use remains low due to barriers from the patient, clinician, and healthcare system level. Understanding these barriers is crucial for developing strategies to effectively implement HBPM into routine clinical practice.

Summary HBPM is a valuable adjunct to office blood pressure measurement for diagnosing hypertension and guiding antihypertensive therapy. Following recommended best practices can facilitate the successful implementation of HBPM and impact how hypertension is managed in the primary care setting.

Keywords Home blood pressure monitoring · Ambulatory blood pressure monitoring · Hypertension · Screening · Implementation · Barriers

Introduction

Hypertension is one of the most prevalent medical conditions, affecting 30% of adults in the USA [1] and more than 1 billion people worldwide [2]. It is an independent risk factor for coronary artery disease, congestive heart failure, chronic kidney disease, and stroke [3–7], a leading cause of cardiovascular and overall mortality [7], and one of the largest contributors to global burden of disease, generating 7% of disability adjusted life years [8]. Given the prevalence and consequences of hypertension, achieving blood pressure (BP) control has become a central goal of numerous public health programs, including the Million Hearts Initiative [9] and the Improving Health Outcomes Initiative [10]. Despite substantial improvements in hypertension awareness, diagnosis, and treatment, an estimated 50% of patients still do not meet recommended BP targets [11••, 12, 13].

An essential component of hypertension management is accurate BP measurement. Hypertension has traditionally been diagnosed based on BP readings obtained in the clinical setting [6, 14]. However, since the first attempts at out-of-office BP testing were made in the 1930s, it has become apparent that significant discrepancies exist between readings obtained in the office versus in the home [4, 6, 14, 15]. Office BP is often higher than home BP, leading to incorrect diagnosis of hypertension in 15–30% of cases, a phenomenon known as "white coat hypertension" [1, 14, 16]. Additionally, some patients may have normal office BP but elevated out-of-office BP, a phenotype called "masked hypertension" [15]. Other disadvantages of office BP measurement (OBPM) include a relatively limited number of readings and lack of evidence supporting the diagnostic accuracy of any one specific OBPM protocol [1, 6].

This article is part of the Topical Collection on *Implementation to Increase Blood Pressure Control: What Works?*

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Due to the limitations in OBPM, in 2015, the US Preventative Services Task Force (USPSTF) updated its hypertension screening recommendations to include confirmation of elevated BP outside of the office setting prior to making a new hypertension diagnosis [6]. Two methods for measuring BP outside of the office are home blood pressure monitoring (HBPM) and ambulatory blood pressure monitoring (ABPM). In HBPM, patients are provided with automatic oscillometric devices and are asked to measure their BP at home following a standardized protocol over the course of several days [6]. In ABPM, patients wear a BP monitoring device that records BP at regular intervals over a 24-h period, including during sleep [6]. Both approaches allow for repeated BP measurements and greater ecological validity, leading to improved diagnostic accuracy [4, 6, 15]. There is also growing evidence that these forms of out-of-office BP measurement are more strongly predictive of cardiovascular outcomes, such as coronary artery disease, stroke, and mortality [6, 11••, 13, 17–34]. For example, for every 10 mmHg increase in ambulatory systolic BP, there is 1.11–1.42 increased risk of cardiovascular events or mortality, 1.28–1.40 increased risk of stroke, and 1.02–1.13 increased risk of all-cause mortality, even after adjusting for office BP [6]. Similar elevated risks are seen with HBPM, in which every 10 mmHg increase in BP is correlated with 1.17–1.23 increased risk of cardiovascular events or mortality, 1.39 increased risk of stroke, and 1.22 increased risk of all-cause mortality [6].

Other options for monitoring out-of-office BP include home BP measurement by visiting healthcare providers or kiosk-based BP monitoring at various community locations, such as pharmacies or grocery stores [6]. Unfortunately, there are no standardized protocols for these methods, and they are not recommended by any official organization [6]. Further research is needed on the diagnostic accuracy of such approaches before they can be recommended for public use [6].

HBPM not only provides a more predictive measure of BP but also offers the opportunity to move hypertension management outside of the doctor's office, thereby empowering patients to play a greater role in self-managing their health. This paper provides an overview of recent advances in HBPM, as well as expert recommendations on how to effectively incorporate HBPM into clinical practice. We discuss HBPM indications, guidelines, and impact on cardiovascular health outcomes. We also outline major barriers to HBPM implementation and offer strategies for overcoming them.

Methods

We conducted a scoping review to identify key articles published within the last 5 years relevant to the implementation of HBPM. We searched Ovid MEDLINE and EMBASE from inception to July 2018 using a combination of subject headings and free text terms to represent HBPM and implementation. Terms included *hypertension*, *blood pressure*, *BP*, *monitoring*, *recording*, *measuring*, *self*, *home*, *implementation*, and *health care delivery*. Our initial search generated 77 potentially relevant articles. Two authors reviewed their titles and abstracts and selected 45 potentially relevant articles for full-text review, 30 of which were ultimately included in this paper. The 15 excluded articles were either not relevant to HBPM or were not viewed as sufficiently high impact to be included. Reference lists of selected articles were also manually searched and experts were surveyed to identify other relevant studies. These were then classified as (1) identifying patient, clinician, or healthcare systems barriers to HBPM implementation; (2) examining the effect of HBPM on clinical outcomes; (3) describing guidelines or consensus statements regarding optimal HBPM protocol; or (4) evaluating strategies for successful HBPM implementation.

Findings

Indications for HBPM

The primary indications for HBPM are confirming elevated office BP in patients with undiagnosed hypertension and monitoring BP trends in patients with known hypertension [35]. Hypertension guidelines from multiple countries have recommended incorporating HBPM into clinical practice [35]. In 2008, the American Heart Association, American Society of Hypertension, and Preventive Cardiovascular Nurses Association released a joint statement calling for greater implementation and reimbursement of HBPM [36]. The European Society of Hypertension published similar recommendations in their guidelines for BP self-monitoring [37]. The 2011 UK National Institute for Health and Care Excellence (NICE) guidelines [38], the 2014 Japanese Society of Hypertension guidelines [39], the 2015 Canadian diagnostic algorithm [40], the 2017 American College of Cardiology/American Heart Association guidelines [41••], and the 2017 updated USPSTF guidelines [6] all recommend the routine use of HBPM or ABPM to diagnose hypertension and help dictate therapy.

Advantages of HBPM

HBPM tends to be more accessible and acceptable to patients [4, 15, 35, 42], relatively inexpensive to implement [4, 35], and potentially more reproducible than either OBPM or ABPM [43–45]. Additionally, by enabling self-monitoring and feedback, HBPM has been shown to increase patient engagement [4, 11••, 35, 42], improve medication adherence [4, 42, 46–49], and decrease clinical inertia in escalating pharmacotherapy [4, 5, 11••, 42, 47, 50]. Although conventional

HBPM devices cannot determine circadian variations in BP, they do provide data over an extended period of time, allowing for the identification of BP trends [4, 11••, 15, 42]. Several newer HBPM devices are capable of nocturnal BP measurement, providing good correlation with nighttime ABPM readings [35, 51–54].

There is strong evidence to support that HBPM can lead to clinically significant reductions in BP among hypertensive patients [4, 11••, 47, 55–60, 61•]. One systematic review of 52 prospective comparative studies showed that HBPM alone versus usual care resulted in an average 3.9 mmHg decrease in systolic blood pressure (SBP) and 2.4 mmHg decrease in diastolic blood pressure (DBP) after 6 months, though this difference disappeared when extended to 12 months [56]. However, when HBPM was combined with additional support, such as BP education or pharmacist interventions, there was a sustained reduction in BP (3.4–8.9 mmHg for SBP and 1.9–4.4 mmHg for DBP) even after 12 months [56]. Another meta-analysis of 25 randomized controlled trials (RCTs) found that HBPM alone did not have a significant BP-lowering effect, but when combined with additional support (e.g., patient counseling, pharmacist management, telemonitoring), HBPM resulted in significant and sustained BP reductions that were proportional to the intensity of the co-intervention [57••].

Clinical trials suggest that the mechanism underlying the benefit of HBPM relates to increased antihypertensive prescribing, though improved medication adherence and lifestyle modification may also play a role (Fig. 1) [57••]. McManus et al. conducted the TASMINH trials, a series of RCTs in the UK examining self-monitoring, self-titration, and telemonitoring in the management of hypertension [58–60, 61•]. In 2010, the TASMINH2 trial showed that patients who engaged in self-monitoring of BP and self-titration of antihypertensive drugs combined with telemonitoring interventions had a 5.4-mmHg greater decrease in SBP and a 2.7-mmHg greater decrease in DBP than controls after 1 year, corresponding to a 20% reduced risk of coronary disease and 10% reduced risk of stroke [58]. A follow-up study found that this intervention was cost-effective and associated with improved quality of life [59]. In 2014, they applied self-monitoring with an individualized medication self-titration algorithm to a group of high-risk hypertensive patients and found significant reductions in both SBP and DBP [60]. The magnitude of BP lowering increased over time and correlated with higher doses and numbers of medications (particularly thiazide diuretics and calcium channel blockers) without a significant increase in adverse drug effects [60]. In the most recent iteration of this study, the 2018 TASMINH4 trial, hypertensive patients were randomized into self-monitoring alone, self-monitoring plus telemonitoring, or usual care [61•]. Both intervention groups had significantly lower SBP after 1 year, though this occurred at a faster rate in the combined self-monitoring plus telemonitoring group [61•].

Comparison Between HBPM and ABPM

There is currently a larger and more robust body of evidence supporting the use of ABPM for diagnosing hypertension, which has led the USPSTF to recommend ABPM as the gold standard for out-of-office BP measurement [6]. Nevertheless, there is high-quality data suggesting HBPM is an acceptable alternative when ABPM cannot be performed [6]. Multiple studies have demonstrated good correlation between HBPM and ABPM for accurately diagnosing sustained normotension, white coat hypertension, and masked hypertension in both treated and untreated patients [62–65], with sensitivity and specificity ranging from 60 to 90% [35].

Nevertheless, discrepancies do exist between the two methods, and they are therefore not considered diagnostically equivalent [6, 35, 66, 67]. One study of patients in China found differences of up to 10 mmHg between ABPM and HBPM readings, leading to under-diagnosis of hypertension through HBPM in more than 25% of patients, though the generalizability of this study to Western populations is uncertain [66]. Two other population-based studies in Italy [67] and Japan [68] suggested that there might be unique prognostic information from HBPM and ABPM. Finally, a recent study showed that ABPM was superior to HBPM for diagnosing masked hypertension [69].

Conducting HBPM

Choosing a Home BP Monitor

Home BP monitors belong to the family of oscillometric devices, consisting of an inflatable cuff and a device that measures the amplitude of pressure oscillations [70]. BP is then computed based on internal proprietary algorithms [15]. Choosing a validated home BP monitor is an important step toward enhancing the accuracy of home BP readings. Four organizations—the US Association for the Advancement of Medical Instrumentation, the British Hypertension Society, the European Society of Hypertension, and the International Organization for Standardization—have validated protocols that grade each device for accuracy by comparing it against manual sphygmomanometers [70]. An international initiative was recently undertaken to develop a single universal validation standard that will eventually replace all prior validation protocols [71]. Validated devices are listed on several websites organized by hypertension specialists, including the British and Irish Society of Hypertension and Hypertension Canada [70] The American Medical Association (AMA) also has a similar website that is currently under development (personal communication, Michael Rakotz, MD). Additionally, devices must be approved for use in specific patient conditions, such as arrhythmias, childhood, or pregnancy, though there is variability in the extent to which devices are validated for these special populations [37]. For example, a recent systematic

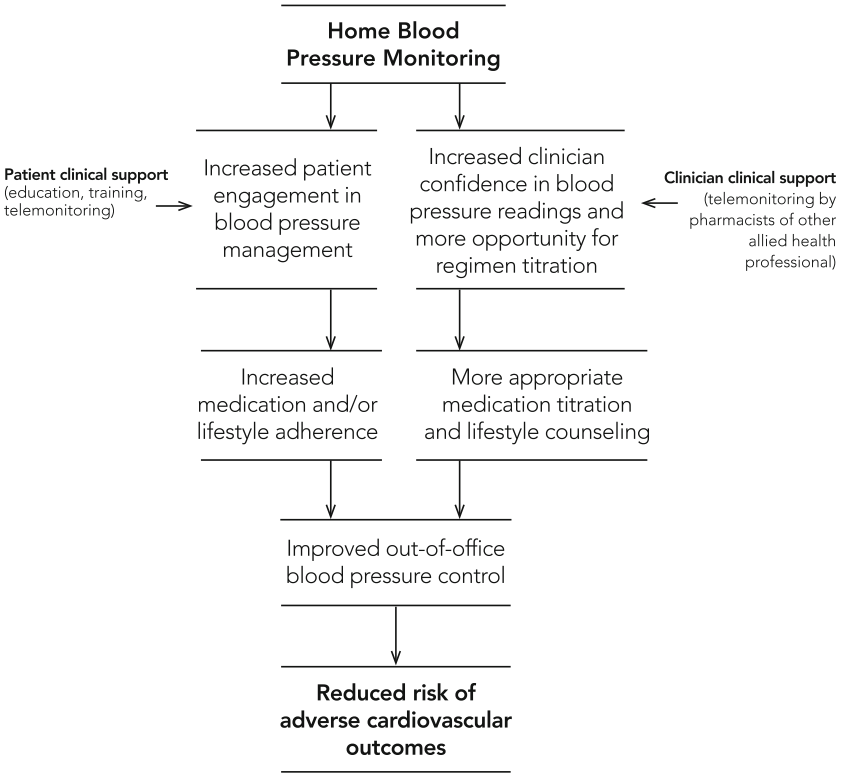

Fig. 1 Conceptual model for how home blood pressure monitoring (HBPM) may improve blood pressure control and cardiovascular disease (CVD) outcomes. Through self-monitoring and feedback, patients may gain increased confidence in the importance of taking their medications and following lifestyle therapy to achieve blood pressure control and may feel more engaged in the process of controlling their blood pressure, particularly if supported by ancillary providers. This in turn may improve patient adherence to blood pressure-lowering therapies. At the same time, HBPM may lead to more opportunities for clinicians to uptitrate medications and more confidence that they are treating "true" blood pressure rather than white coat effects. This may lead to more rapid uptitration of blood pressure medications, even between office visits, especially if supported by ancillary clinical staff. HBPM will also lead clinicians to titrate medications to home blood pressure, which is more highly correlated to CVD outcomes than office blood pressure and thus may result in a greater reduction in CVD risk

review found that two-thirds of BP devices that passed a validation protocol in pregnant woman did so with at least one protocol violation, calling into question the accuracy of the results [72•]. Similarly, in a group of 17 studies evaluating the validity of ambulatory, home, and clinic BP monitoring devices among pregnant women with preeclampsia, five home devices and three clinic devices were validated but all of the supportive studies included protocol violations [72•].

There is debate in the field as to whether patients should bring their devices to a physician's office to ensure they are validated and properly functioning [10]. The AMA recommends checking two readings on an office oscillometric device and three readings on the patient's home BP device [73]. If the average office and home device readings differ by more than 10 mmHg, the home device should not be used [73]. While this approach may be appropriate for devices without validation data available, some point out that office devices do not necessarily represent the gold standard, as the mercury sphygmomanometers used in official validation protocols are frequently unavailable in clinical settings. Moreover, this small number of readings is insufficient to verify that the home device is well-calibrated. Perhaps most important, such a protocol is burdensome to office staff and challenging to implement. Thus, we recommend that providers encourage patients to choose from among validated home BP devices.

It is essential that patients use the correct cuff size to avoid overestimating or underestimating their true BP [74]. The length of the cuff bladder should be 80% of the patient's arm circumference while the width of the cuff bladder should be at least 40% of the patient's arm circumference [10]. The European Society of Hypertension recommends an automated oscillometric device or a manually-inflated cuff that measures BP at the upper arm [75]. Wrist or finger cuffs are not recommended as they are generally less accurate, but can be used as an alternative to upper arm cuffs in patients with large arm circumference or extreme obesity [75].

Devices vary with respect to certain attributes that can facilitate HBPM, including storage features that keep a log of BP readings or teletransmission options that can transfer BP data wirelessly to a phone or computer [76]. These devices cost anywhere from $30–100 depending on their functionality [55]. Though more expensive than traditional BP monitors, such devices reduce the burden on patients to manually record their BP readings and may result in more accurate and complete data collection [70].

Measurement Protocol

Proper BP measurement technique is essential to ensure the accuracy of home BP readings. In contrast to ABPM, which seeks to measure BP in the midst of everyday activities, HBPM is intended to capture the resting BP [15, 70]. The most common recommendation with respect to frequency of monitoring is to measure BP twice in the morning and twice in the evening with serial readings taken 1 min apart [70]. Measurements from the first day of monitoring are discarded and the remainder are averaged to obtain a mean BP [70]. Though several guidelines based on expert opinion recommend that HBPM be performed for seven consecutive days [70], a recent study of community-dwelling adults not on antihypertensive medication showed that a minimum of 3 days of consecutive HBPM was sufficient to reliably diagnose hypertension [77]. Thus, while 28 readings over 7 days is a simple way to counsel patients, it may be clinically sufficient and less burdensome to recommend as few as six readings over 3 days. Unlike ABPM, which provides separate averages for daytime and nighttime BP readings, there are currently no recommendations to record morning and evening HBPM readings separately. Instead, HBPM measurements are typically averaged all together to obtain an overall BP reading. However, some providers may find separate averages helpful for optimizing the timing of antihypertensive medications.

Prior to each BP measurement, patients should be advised to avoid caffeine, tobacco, and vigorous exercise as these have a vasopressor effect and can lead to overestimates of resting BP [4]. Pain, stress, or extreme temperatures can also produce inaccurate readings [4]. Patients should empty their bladders and sit quietly in a chair for 5 min prior to taking a BP measurement, keeping their legs uncrossed, feet flat on the floor, back supported, and arm at heart level [37, 75]. Placing the cuff above or below the level of the heart can result in BP discrepancies of up to 0.7 mmHg/cm due to hydrostatic pressure changes [4]. The inflatable bladder should be placed over bare skin at the midpoint of the upper arm and should be appropriately sized. Patients should avoid talking, active listening, or other stimulating activities while BP is being measured [10]. Not adhering to these techniques can cause discrepancies of up to 2–50 mmHg in SBP and 2–11 mmHg in DBP, which is large enough to influence management decisions [75]. In general, HBPM should be performed 1 week prior to a clinic visit, 4 weeks after a change in antihypertensive medication, or at longer intervals for continued monitoring [4].

Recording BP Readings

In the past, experts recommended that patients document their BP values in a journal or diary immediately after measurement to avoid misrecording data [4]. However, it is important to recognize that home BP readings reported by patients frequently differ from the actual values automatically stored in the device memory [35]. With recent advances in home BP monitors, patients should be encouraged to purchase devices with automatic recording functions, many of which can store up to 120 readings per machine. Some devices are approved to have their data wirelessly linked to smart phones or the electronic medical record (EMR) in a HIPAA-compliant manner [78, 79]. While wirelessly linking data to the EMR can facilitate remote monitoring, clinicians have expressed concerns about the increased workload and responsibility associated with managing large amounts of patient BP data during and between clinical visits [80, 81].

Interpreting Home BP Readings

Home BP Thresholds An average home BP reading ≥ 135/85 mmHg has conventionally been used as the threshold for diagnosing hypertension, corresponding to an office BP of 140/90 mmHg [70]. However, these thresholds were based on cross-sectional comparisons of home and office BPs rather than outcome-based data [82]. They also primarily involved populations in Europe, Australia, and Asia and thus are not necessarily generalizable to US patients [41••]. The 2017 ACC/AHA guidelines were based upon a large review of prospective cohort studies using outcome-based or regression-based approaches to determine which ABPM and HBPM values corresponded to specific office BP measurements [83]. They found that as office BP declines, it more closely resembles home BP. The guidelines now recommend using a lower office BP threshold of 130/80 mmHg for diagnosing hypertension, which is equivalent to a home BP goal of 130/80 mmHg [83].

BP Phenotypes Four primary BP phenotypes can be identified by comparing office and home BPs [70]. Two phenotypes reflect agreement between office and home readings: sustained normotension, in which BP is normal in both settings, and sustained hypertension, in which BP is elevated in both settings [70]. Sustained normotension is associated with the lowest risk of adverse cardiovascular events, while sustained hypertension is usually associated with the highest risk [70].

White coat hypertension refers to elevated office BP but normal BP outside of the clinical setting [15]. Prevalence of white coat hypertension varies widely, ranging from 5 to 65% when using the gold standard of ABPM and 16 to 55% when using HBPM as an alternative [70]. When the same phenomenon of elevated office BP but normal home BP occurs in patients already on antihypertensive medication, it is known as white coat effect [70]. The preponderance of studies suggests that white coat hypertension does not confer a higher risk of adverse cardiovascular events compared to

normotension [70]. For instance, a population-based analysis of 2046 Finnish patients showed no difference in cardiovascular events between those with white coat hypertension and normotension [84], and another international study of 7295 elderly patients with hypertension showed that neither white coat hypertension nor white coat effect was associated with higher rates of fatal or nonfatal cardiovascular events [85]. Detection of white coat hypertension using HBPM can spare patients from unnecessary treatment and reduce wasteful healthcare spending [4, 41••]. However, some studies suggest that white coat hypertension may represent an intermediate-risk phenotype between normotension and sustained hypertension [4, 85, 86]. An analysis of 3027 patients from the Dallas Heart Study showed that white coat hypertension was associated with twice the risk of end-organ damage and cardiovascular events compared to normotension [86]. A study of 6458 patients from the International Database of Home Blood Pressure found 1.42 times higher risk of cardiovascular events and mortality among those with white coat hypertension, though no difference in risk among those with white coat effect [85]. Patients with white coat hypertension are also at increased risk of developing sustained hypertension and type 2 diabetes [4]. Thus, guidelines recommend that patients with white coat hypertension undergo periodic (e.g., annual) screening with office and out-of-office BP measurement [87].

The fourth phenotype, masked hypertension, is defined as normal office BP but elevated out-of-office BP [15]. It occurs in 14–30% of patients and is associated with an increased risk of adverse outcomes as well as subclinical cardiovascular disease that is on par with or even higher than the risk of sustained hypertension [70, 88]. A retrospective analysis of patients from the International Database of Home Blood Pressure revealed a significantly increased risk of nonfatal myocardial infarction, coronary interventions, heart failure, permanent pacemaker placement, stroke, and cardiovascular mortality among patients with masked hypertension regardless of treatment status [85]. The Dallas Heart Study found that 17.8% of participants had masked hypertension and were at significantly higher risk of end-organ damage and cardiovascular events [86]. The Jackson Heart Study of 972 African American patients found that 34.4% had masked hypertension, which was associated with multiple signs of target organ dysfunction, including higher carotid artery intimal thickness, left ventricular mass index, and urinary albumin/creatinine ratio [89]. A study of 1492 patients with chronic renal insufficiency found that 27.8% had masked hypertension with more severe renal and cardiovascular organ damage, such as lower glomerular filtration rates, higher proteinuria, greater arterial stiffness, and larger left ventricular mass [90]. Given the high prevalence and consequences of unrecognized masked hypertension, HBPM should be considered for early detection and initiation of therapy, even among patients with normal office BP.

Barriers and Facilitators to HBPM Implementation

Patient Factors

There are a number of factors at the patient level that can make implementing HBPM difficult (Table 1). Although nearly 25% of US adults (49% of hypertensive adults and 14% of normotensive adults) report owning a sphygmomanometer and checking their BP at home [91], multiple studies have shown that they often lack the knowledge and skills required to correctly perform HBPM, partially due to insufficient formal training [15, 78, 92–95]. One survey of hypertensive patients in Canada revealed that only 8% had received specific training on HBPM technique [96], while another showed that only 18% of those who measured their BP at home were adherent with all recommended performance parameters [95]. A similar study conducted in the US found that only 13% of patients enrolled in a HBPM program were sufficiently compliant with BP measurement guidelines to ensure reliable readings [97]. Common knowledge gaps included appropriate arm and body positioning, frequency of readings, timing of measurements, duration of rest prior to measurement, proper cuff size and placement, necessity of voiding prior to measurement, and importance of refraining from other activities while obtaining readings [78, 92–95]. Studies have also repeatedly shown that patients measure their BP using invalid devices [94, 95], fail to record their BP readings [93, 95, 96], exclude certain BP readings from their logbooks [95], and inconsistently provide their logbooks for physician review [93, 95–97]. Poor adherence to HBPM guidelines increases the likelihood of obtaining invalid BP readings with subsequently inaccurate diagnosis and management [95].

Acceptability of and attitudes toward HBPM can also influence the successful implementation of a HBPM program. Several studies have investigated patient perceptions of HBPM in a variety of contexts and mostly show favorable attitudes. One descriptive study in the Netherlands utilized patient focus groups to show that although none of the participants had previously heard of, been offered, or undergone HBPM, they felt it would be a simple, effective, and non-intrusive method for monitoring BP outside of the office setting [98]. An implementation study of a BP self-monitoring program in the USA found that 91% of participants felt the instructions for taking BP readings were "easy to follow," while 80% felt the program improved their BP measurement skills and made them more actively engaged in their care [97]. A focus group of underserved patients in New York City revealed overwhelmingly positive attitudes toward HBPM, as it was thought to provide more accurate diagnosis and avoid unnecessary medication [99•]. Patients did express concerns about the accuracy of home BP readings, adequacy of training on measurement techniques, remembering to monitor BP regularly, and costs of purchasing a device. They found HBPM to

Table 1 Barriers and facilitators to implementing home blood pressure monitoring into clinical practice

Barriers	Facilitators
Patient level	
• HBPM protocol burdensome to incorporate into daily schedule	• Provide formal HBPM training
• Insufficient knowledge about HBPM protocol and how to identify validated home BP devices	• Provide patients with logbook to document HBPM values
• Concerns about accuracy of home BP readings	• Encourage patients to set reminders or alarms on phone
• Anxiety produced by elevated BP readings	• Provide patients with clear instructions for when to contact the office with low or high BP readings
• Lack of confidence in ability to conduct HBPM protocol	• Provide clinical support between visits through phone calls, emails, or face-to-face visits with treating physicians or allied health professionals (e.g., pharmacists, nurses, care managers)
• Difficulty remembering to adhere to HBPM protocol	
• Lack of confidence in the benefits of HBPM	
• Costs of purchasing a home BP device	• Make loaner HBPM devices available to patients
• Uncertainty about how to respond to abnormal home BP readings	• Provide patient materials on low-cost and validated home BP devices
Clinician level	
• Insufficient knowledge about the evidence supporting HBPM	• Educate providers about how to conduct HBPM
• Insufficient knowledge about how to train and interpret HBPM	• Train office staff to assist clinicians in teaching patients how to conduct HBPM
• Lack of confidence in patients' ability to correctly measure HBPM using validated devices	• Familiarize clinicians with HBPM devices that are validated, covered by insurance, store BP readings, and can potentially transmit readings to the electronic health record
• Lack of access to HBPM readings at office visits	
• Concern about increasing patient BP-related anxiety and associated office visits/phone calls	• Incorporate computerized decision support systems (e.g., HBPM alerts/order sets incorporated into electronic health record)
• Burdensome logistics of ordering HBPM and accessing results	
• Insufficient time and resources to effectively implement HBPM	• Synthesize home BP data for clinicians (e.g., provide reports with average SBP and DBP across a recent time period)
• Lack of reimbursement for HBPM implementation	• Provide clinician incentives for use of HBPM (e.g., make HBPM billable, incorporate HBPM into quality metrics)
	• Incorporate HBPM data into electronic health record
Healthcare system level	
• Lack of insurance coverage for home blood pressure devices	• Advocate for increased coverage for home BP devices and HBPM telemonitoring clinical support services
• Lack of reimbursement for HBPM implementation	• Promote large-scale studies evaluating the cost-effectiveness of HBPM from healthcare system and payer perspectives
• Lack of strong evidence supporting the cost-effectiveness of HBPM	

be more convenient than ABPM due to fewer readings, measuring only during the daytime, and monitoring in the comfort of their home. Patients viewed HBPM as a way to become more actively engaged in their health and felt confident in their ability to carry out HBPM testing, especially if it had been explicitly recommended by their physician [99•].

Multiple studies have explored associations between patient demographic factors and the likelihood of consistent engagement in HBPM. One such study examined data from the National Health and Nutrition Examination Survey (NHANES) and found that 16.7% of participants performed HBPM at least monthly [91]. Frequency of HBPM was more common among those who were older, diabetic, and obese or had known hypertension that was treated and well-controlled [91]. Participants with health insurance, middle-income level, and higher healthcare utilization were also more likely to engage in HBPM [91].

Patient race and ethnicity are also associated with HBPM use and acceptability. A study of 770 participants from the UK found that patients of South Asian and African Caribbean descent were less accepting of HBPM compared to other ethnic groups and therefore less likely to complete the program [100]. Possible underlying factors included patient confidence in their ability to carry out HBPM procedures, remembering to take measurements at the appropriate time of day, and accuracy of BP monitoring equipment being used [100]. Racial and ethnic differences in HBPM were also seen in the aforementioned NHANES study, which found that non-Hispanic Blacks were most likely to engage in HBPM at least monthly (19%), followed by non-Hispanic Asians (16.8%), non-

Hispanic Whites (15.7%), and Hispanics (12.9%) [91]. These differences may be related to variability in hypertension awareness, insurance coverage for HBPM devices [70], or physician counseling on HBPM [101].

Clinician Factors

Although many clinicians agree that OBPM alone is inadequate for accurate diagnosis of hypertension [42, 47, 80], there remains significant variability in clinician attitudes toward and use of HBPM. A survey of Canadian primary care physicians found that although 63% often or almost always advised HBPM for their hypertensive patients, only 13% favored home BP readings over those obtained in the office for confirming the diagnosis and 19% for initiating therapy [96]. Another larger-scale study involving clinicians from 77 countries found that 87% continued to base treatment decisions primarily on office BP readings [102]. However, more recent studies suggest that these practice patterns may be shifting, with HBPM now being recommended by 67% of primary care physicians in Spain [103], 58% in the UK, and 20–50% in the USA [104•], possibly in response to recent updates in hypertension guidelines from NICE [38] and the USPSTF [6].

When asked about perceived barriers to effective HBPM implementation, factors commonly cited by physicians included skepticism about patients' ability to correctly carry out HBPM due to inadequate training, significant time commitment, and low health literacy [97, 98, 103–105]; doubts about the accuracy of HBPM readings due to protocol deviations and use of invalid devices [80, 96, 104•, 106]; and concerns that patients might become overly anxious about high BP readings [47, 80, 96, 104•, 106]. Whereas some physicians felt that HBPM was an empowering patient experience leading to increased treatment adherence and fewer clinic visits, others worried that patients might actually feel disempowered by uncertainty over how to respond to high home BP readings and thus rely more heavily on their doctors for guidance [106]. Providers themselves reported feeling unsure about how to train patients in HBPM procedures, as well as how to accurately interpret the readings and incorporate them into clinical practice [47, 80, 97, 103, 104•]. One survey of general practitioners in the UK found that the majority used higher home BP thresholds for diagnosing or treating hypertension than recommended by national guidelines, and nearly half applied a correction factor to home BP readings (on average, 8 mmHg were subtracted from reported home SBP readings) even though this is not recommended by HBPM protocols [42]. This may have been due to inadequate knowledge about HBPM, distrust of patient self-measurement, and/or fear of over-diagnosis [42].

Interestingly, many of these clinician concerns may be addressable. For example, the TASMINH2 study found that high HBPM readings did not significantly increase patient anxiety nor lead to more frequent consultations with primary care providers [58]. Another study exploring implementation of a new HBPM program found that, after receipt of a brief training, 84% of providers felt comfortable training patients on the HBPM protocol and 68% believed the process required minimal time and effort [97].

Healthcare Systems Factors

The healthcare system can pose a number of barriers to effective HBPM implementation. Although validated HBPM devices are relatively inexpensive and readily accessible [95], a recent study of hypertensive patients showed that 14% did not own a home BP monitor due to high out-of-pocket costs [36]. In the USA, HBPM devices are not covered by Medicare Part B, though may be covered by some supplemental plans under Medicare Part C [55]. Private insurance companies and state Medicaid programs provide variable reimbursement for HBPM devices depending on the payer [55].

Most insurers do not provide reimbursement for the clinical work involved in conducting HBPM, partially due to concerns that HBPM is not cost-effective [107]. These concerns are not entirely unjustified—the economic evidence for HBPM has been mixed, with some studies reporting reduced costs per quality-adjusted life year, and others showing no difference or even increased costs compared to office BP monitoring alone [55, 108–110]. A systematic review by the Community Preventative Services Task Force found insufficient evidence for the cost-effectiveness of HBPM when used alone but strong support for its cost-effectiveness when combined with team-based management [55].

Exploring this question in greater depth, Arrieta et al. applied a decision-analytic model to data from the NHANES to determine the relative cost-effectiveness of HBPM for the diagnosis and treatment of hypertension [107]. They found that reimbursement for HBPM could save money for insurance companies in as little as 1 year, with progressively increasing return on investment over longer periods of time. These savings were more pronounced when HBPM was used to diagnose hypertension in patients < 65 years old and to monitor hypertension treatment in patients ≥ 65 years old. The authors postulated that, in younger individuals with a lower overall prevalence of hypertension, HBPM generates savings by reducing the number of false-positive hypertension diagnoses and avoiding unnecessary treatment. Among older individuals with a higher prevalence of hypertension and other cardiovascular risk factors, HBPM helps ensure adequate BP control, thereby minimizing the likelihood of costly adverse events [107]. Based on these findings, the authors argue that insurance company reimbursement for HBPM would result in durable savings while simultaneously improving the quality of hypertension diagnosis and management [107].

Strategies for Overcoming Barriers

Given the evidence supporting HBPM for more effective BP control, it is important to consider strategies for overcoming barriers to widespread uptake (Table 1). Implementation science represents an emerging set of methodologies for better understanding barriers from the context of key stakeholders and using this information to bridge the gap between evidence and practice [5, 104•].

Much of the patient and clinician anxiety about proper HBPM technique can be addressed by providing formal training in the office setting. Passive interventions, such as posters, handouts, or informational booklets, are relatively simple and inexpensive educational tools but tend to be less effective unless patients are very self-motivated or have high health literacy [80, 95]. Interactive training sessions in which patients work with a healthcare provider to observe and practice proper HBPM protocol have been shown to result in high skill retention over several months [111]. Patients who receive formal training are also more likely to purchase a HBPM device and adhere to monitoring [80]. Training should follow a standardized protocol and recruit non-physician staff to alleviate the burden on primary care providers [80, 99•]. Patients should be provided with a chart for recording their BP readings and instructed to bring it to follow-up visits [80]. Clinicians should encourage patients to set reminders or alarms prompting them to check their BP on schedule [99•]. Ensuring that patients understand how to interpret their BP readings and which values should trigger them to contact their physician may help assuage patient anxiety surrounding HBPM [47]. Additional support in the form of phone calls, emails, or in-person follow-up to assess compliance, answer questions, and provide troubleshooting can also help patients feel more confident and motivated [5, 80, 95]. Combining regular "health coaching" sessions, focused on lifestyle modification and medication adherence, with HBPM can lead to sustained behavioral changes as well as objective reductions in BP [112]. Of course, such interventions are more expensive, time-consuming, and labor-intensive and may not always be feasible or cost-effective for a practice to implement [5]. Offering patient support at key time points, such as at the start of HBPM or when medications are being uptitrated, can help optimize the use of limited resources [5]. Further research is needed to determine the ideal level of support [5].

One of the barriers to HBPM implementation has been provider concern about patients taking measurements incorrectly, leading to loss of confidence in the accuracy of readings [5, 96–98, 104•, 106]. Clinicians should encourage patients to bring their devices to the office so they can demonstrate and get direct feedback on their BP measurement technique [15, 55]. Other members of the healthcare team, including medical assistants or registered nurses, can be trained to review BP measurement protocol with patients and thereby offload the work from the physicians [99•, 104•]. Another alternative is to store commonly used HBPM devices in the office and make them available for patient training purposes [80]. Clinicians are encouraged to familiarize themselves with BP monitors in nearby pharmacies to learn which validated devices are commonly available. They can then recommend a few of these devices by brand name and model type with options that vary based on cost and number of features. Clinicians may also learn which devices are commonly covered by insurers. Even without coverage, validated devices can be purchased for as little as $30. Most home monitors can also be purchased online, and providing patients with information for online ordering of recommended devices may be useful. Some practices have even purchased validated HBPM devices for patient loan [80, 97]. Others encourage patient purchasing by reminding them that devices can be shared among family and friends [99•].

Smartphone applications represent another approach to increasing patient engagement in HBPM. One survey analyzed 107 smartphone-based applications for hypertension management and found that 72% had BP tracking capabilities, 22% included medication adherence tools, and 37% provided hypertension education [113]. These technologies have the potential to promote communication between patients and physicians, improve compliance with antihypertensives, and increase awareness of hypertension risk factors [76]. However, none have been approved for use as medical devices by the US Food and Drug Administration or the European Commission, and there are currently no standardized or secure methods to validate these applications against a gold standard in hypertensive patients [76].

Providers should educate themselves about HBPM guidelines so they feel comfortable with recommended procedures, BP targets, and thresholds for initiating or titrating antihypertensive medications [47]. Clinician training on hypertension management, best practices, and effective communication with patients may also be helpful [112]. One group designed the CARE approach for providing patients with supportive counseling during a HBPM intervention, which involved congratulating patients on their successes, asking if they had question or concerns, reassuring patients when they expressed anxiety, and encouraging them to continue adhering to HBPM protocol [106]. Providing physicians with periodic summaries of patient BP outcomes can be used to overcome clinical inertia and guide further treatment decisions [112]. Electronic decision support systems that incorporate HBPM alerts or order sets into the EMR may promote HBPM prescribing and facilitate patient BP lowering [112].

Overcoming healthcare systems barriers is perhaps the most challenging aspect of successful HBPM implementation. Restructuring how HBPM is implemented on an individual practice level, with greater focus on team-based care, is likely to be helpful [112]. Studies have shown that collaboration between physicians and non-physicians, including nurses, care managers, and pharmacists, is particularly effective for

facilitating patient compliance, avoiding provider burnout, and achieving objective BP reductions [112]. Despite the widespread acceptance, availability, and measurable health impact of HBPM, there are currently few financial incentives promoting its use. Some promising approaches to increase HBPM prescribing include making it a formal quality metric or billable item [114]. The latter process is already underway, with Medicare having recently added billable codes for remote patient BP monitoring [115]. Large-scale cost-effectiveness studies conducted over longer periods of time may be needed prior to widespread policy change [107]. Newer forms of BP telemonitoring are also currently being developed and warrant further research to determine their healthcare savings potential [76, 78].

Conclusions

HBPM represents a promising approach to improving the diagnosis and treatment of hypertension. It has been shown to reflect true BP more accurately than office measurements, capture hidden phenotypes such as white coat or masked hypertension, and result in clinically significant BP lowering over time. As guidelines increasingly recommend the routine use of HBPM, it is important to consider strategies to facilitate effective implementation. Identifying and addressing common barriers to HBPM is essential for successfully incorporating this valuable tool into clinical practice.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no conflicts of interest relevant to this manuscript.

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- • Of importance
- •• Of major importance

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