Received: 23 March 2018 | Accepted: 23 March 2018

DOI: 10.1111/jch.13284

SPECIAL ISSUE

WILEY

Home blood pressure monitoring in the 21st century

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Funding information
R.M. is supported by an NIHR Professorship and by the NIHR Oxford CLAHRC.

Home blood pressure monitoring provides multiple measurements in the usual environment of each individual, allows the detection of intermediate hypertension phenotypes (white-coat and masked hypertension), and appears to have superior prognostic value compared to the conventional office blood pressure measurements. Accumulating evidence suggests that home blood pressure monitoring improves long-term hypertension control rates. Moreover, it is widely available, relatively inexpensive, and well accepted by patients. Thus, current guidelines recommend home blood pressure monitoring as an essential method for the evaluation of almost all untreated and treated patients with suspected or treated hypertension. Validated automated upper-arm cuff devices with automated storage and averaging of readings should be used. The home blood pressure monitoring schedule for 4 to 7 days with exclusion of the first day (12–24 readings) should be averaged to provide values for decision making.

1 | INTRODUCTION

Guidelines for the management of hypertension in Europe, the United States, Japan, and elsewhere[1–5] state that out-of-office blood pressure (BP) monitoring, using self-monitoring by patients at home, as well as 24-hour ambulatory BP monitoring (ABPM), is essential for the confirmation and the long-term management of hypertension. There is strong evidence that home BP monitoring (HBPM) allows the detection of intermediate hypertension phenotypes (white-coat and masked hypertension) and is superior to conventional office BP (OBP) measurements in predicting cardiovascular events.[1–8] HBPM is widely available in many countries and well accepted by patients and has several advantages but also some limitations (Table 1).[1-8]

TABLE 1 Advantages and limitations of home blood pressure (BP) monitoring[1–7]

Advantages	Limitations
• Large number of measurements (days, weeks, or months) • In the usual environment of each individual • More reproducible than with office BP • Identifies white-coat and masked hypertension phenomena in untreated and treated patients • Free of placebo effect • Closer association with preclinical organ damage than office BP • Predicts cardiovascular events more accurately than office BP • Avoids observer error and bias (automated electronic devices) • Avoids misreporting bias of self-measurements by patients (only with electronic devices with automated memory, PC link, or telemonitoring) • Improves BP control when used for treatment titration in primary care • Improves compliance with long-term drug treatment • Improves hypertension control rates • Need of minimal training (with automated devices) • Good acceptance by patients with hypertension for long-term use • Wide availability in most countries. • Cost-effective	• Most devices available on the market have not been validated for accuracy using an established protocol • Possible misreporting (overreporting or underreporting) of BP readings (prevented with automated memory) • Need of user training (minimal with automated devices) and medical supervision • May induce anxiety and too frequent monitoring • Some patients self-modify drug treatment on the basis of casual BP readings • Measurements are performed only under standardized conditions (sitting at home), not reflecting usual daily activities • Inability to monitor BP during nighttime sleep (possible with novel home monitors) • Questionable accuracy of automated oscillometric devices in the presence of arrhythmias

2 | CLINICAL RELEVANCE

HBPM as well as ABPM provide multiple BP measurements away from the artificial and office setting and in the usual environment of each individual, thereby allowing a more accurate and representative assessment than OBP. Several cross-sectional studies have investigated the diagnostic performance of HBPM, usually by taking ABPM as a reference method. Despite the heterogeneity in their design (eg, selected phenotypes of hypertension, patient characteristics, treatment status, and comorbidities), these studies suggest considerable diagnostic agreement between HBPM and ABPM, with sensitivity and specificity values ranging from 60% to 90% depending on each specific study design.[8,9]

HBPM is performed under standardized conditions (only in the sitting posture and at home), whereas ABPM is performed in fully ambulatory conditions and posture (at home or work, during routine daily activities and without a period of sitting rest before measurements, and during sleep).[1–8] Despite these differences, average HBPM and daytime ABPM appear to have similar normalcy thresholds, reproducibility, diagnostic accuracy for white-coat and masked hypertension, and prognostic value, with all these features being superior to those of conventional OBP measurements.[1–8] However, the two methods are not fully interchangeable, as demonstrated in two outcome population studies (the PAMELA [Pressioni Arteriose Monitorate e Loro Associazioni][10] and Ohasama trials[11]) where patients with elevated ambulatory but low home BP values or the reverse were at increased cardiovascular risk compared with patients with normotension (low home and ambulatory BP) but at lower risk compared with patients with sustained hypertension (high home and ambulatory BP), implying additive prognostic information provided by each method. Thus, the two methods should be regarded as complementary rather than competitive in the assessment of elevated BP.

In terms of predictive value, several studies have suggested that raised HBPM is associated with subclinical target organ damage—mainly assessed by echocardiographic left ventricular mass index—to a higher degree compared with OBP and similar to ABPM.[12] More importantly, prospective outcome studies demonstrated the superiority of HBPM over OBP in terms of cardiovascular risk prediction. In 1998, the Ohasama study in Japan was the first to demonstrate that HBPM has stronger predictive value for mortality than OBP in the general population.[13] Subsequently, meta-analyses of aggregate and individual participants' data from several outcome studies suggest that HBPM remains a significant predictor of cardiovascular mortality and cardiovascular events after adjusting for OBP and allows more accurate risk stratification than OBP, particularly in cases of masked hypertension.[14,15]

Because of its diagnostic accuracy and prognostic ability, HBPM plays a crucial role in the long-term management of treated hypertension. Outcome studies have demonstrated that on-treatment HBPM has superior prognostic value than OBP.[16,17] Advantages of using HBPM are: (1) in treated patients, the phenomena of white-coat effect and masked uncontrolled hypertension are as common as white-coat and masked hypertension in untreated patients and can be identified by HBPM or ABPM; (2) HBPM is widely available in many countries and is inexpensive (in fact, patients have decided to cover the cost of the technique themselves); (3) most patients prefer HBPM rather than ABPM for out-of-office BP evaluation, particularly for repeated long-term use, because it causes less discomfort and restriction of daily activities and sleep[18]; and (4) this method motivates patients by increasing their awareness and getting them actively involved in their BP monitoring and long-term control. Several randomized controlled trials have shown that patients with treated hypertension who perform HBPM have improved hypertension control rates, which are caused by improved long-term adherence to drug therapy.[19–21] A recent study showed that primary care physicians who use HBPM in their patients to titrate antihypertensive medication achieved better BP control than using office measurements, whether or not using telemonitoring,[20] while this result in other studies was specifically achieved by combining HBPM with remote telemonitoring.[22]

Treatment adjustment based on HBPM has been shown to improve cardiovascular outcome.[23] Data comparing HBPM with ABPM

for treatment initiation and titration showed no differences in BP control after 1 year, as well as in treatment-induced changes in preclinical target organ damage.[23]

3 | CLINICAL INDICATIONS

The main clinical indications for HBPM include the confirmation of elevated BP in untreated and treated patients and the detection of the white-coat and masked hypertension phenomena, and the long-term follow-up of BP control in treated hypertension.[1–5] The main advantages and differences of HBPM compared with office and ambulatory BP are presented in Table 2.

In the past decade, hypertension guidelines around the world have increasingly endorsed the wide application of HBPM in the management of hypertension in clinical practice.[1–5] In 2008, the European Society of Hypertension[1] and the American Heart Association/American Society of Hypertension[3] recommended the use of HBPM in almost all cases of suspected or treated hypertension. In 2011, the UK National Institute for Health and Care Excellence (NICE) guidelines recommended that the diagnosis of hypertension should always be confirmed by ABPM, and that HBPM would be a suitable alternative in patients unable to tolerate ABPM.[24] The 2014 guidelines by the Japanese Society of Hypertension recommended HBPM as well as ABPM for the diagnosis of white-coat, masked, and sustained hypertension and for the evaluation of treatment effect and duration.[4] Moreover, it was stated that in case of diagnostic discrepancy between office and home BP measurements, the latter should have priority for decisions.[4] In 2015, the Canadian diagnostic algorithm proposed HBPM for confirmation of hypertension if ABPM is not available.[25] The 2017 US guidelines recommend HBPM or ABPM to be used for the detection of white-coat and masked hypertension in untreated patients, whereas HBPM has primary role for detecting these phenomena in treated patients (confirmation with ABPM is needed in masked uncontrolled hypertension detected by HBPM).[5]

Advancement in HBPM devices technology extends their application in clinical practice. Novel automated HBPM devices allow the efficient screening for atrial fibrillation during routine BP measurement in the elderly with considerable diagnostic accuracy.[26] In addition, novel HBPM devices, which allow automated monitoring during nighttime sleep, have been developed. Studies have shown that nighttime HBPM is feasible and, compared with nighttime ABPM, provides similar nighttime BP values with satisfactory agreement in detecting nondipping status and preclinical organ damage.[27]

4 | CLINICAL APPLICATION

The recommendations for practical application of HBPM are provided in Table 3.

TABLE 2 Comparison of the features of office, ambulatory, and home BP measurements[1,7]

Feature	Office	Ambulatory	Home
Detection of white-coat hypertension	–	++	++
Detection of masked hypertension	–	++	++
Assessment of nighttime BP level and dip	–	++	+
Assessment of morning BP surge	–	++	–
Assessment of morning hypertension	+/–	++	++
Assessment of antihypertensive drug action	+	++	++
Assessment of duration of drug action	+/–	++	+
Long-term follow-up of hypertension	++	+/–	++
Improvement of patients' compliance	+	–	++
Improvement of hypertension control rate	+	–	++
Reproducibility	–	++	++
Prognostic value	+	++	++
Availability	++	–	++
Cost	–	–	++

BP, blood pressure.

Devices

Automated electronic (oscillometric) upper-arm cuff devices are currently recommended for HBPM, since these are user-friendly, relatively cheap, devoid of observer bias, and require little training and maintenance.[1–5] Only devices that have passed the criteria of established validation protocols should be used. Aneroid auscultatory devices are not generally recommended for self-measurements by patients at home, as they require observer skills, training, and more regular calibration, which usually are not feasible in general practice. Hybrid mercury-free auscultatory devices have also been developed, which are accurate and require less maintenance than aneroid devices, yet they also have observer-related drawbacks. Some automated wrist devices have passed the internationally accepted validation protocols; however, these are regarded as less accurate than upper-arm devices, mainly because of anatomical differentiations of the wrist and difficulty in following the correct wrist position (at heart level and relaxed).[1–5] Updated lists of validated devices are available at several websites (www.bihsoc.org, www.medaval.org, and www.dableducational.org).

The use of a cuff of appropriate size for the arm circumference of each individual is important for the accuracy of BP measurements.[1–5] As a general rule, the length of the inflatable bladder

TABLE 3 Recommendations for practical application of self-home blood pressure (BP) monitoring[1–7]

Device	Automated electronic (oscillometric) upper-arm cuff device validated according to an established protocol
Cuff size	Bladder size to fit the individual's arm circumference
Conditions	Relaxed and after 5 minutes of sitting rest. Back supported, arm relaxed and supported with middle of upper arm at heart level, legs uncrossed, feet flat on the floor. No talking during measurements.
Monitoring schedule	Seven-day monitoring before each office visit, with duplicate morning and evening measurements (before drug intake). Not less than 4 days and fewer than 12 readings.
Evaluation	Calculation of average BP of all readings (at least 12 after discarding readings of the first day). Casual BP readings have little clinical relevance.
Interpretation	Home hypertension: ≥135/85 mm Hg; normal home BP: <130/80 mm Hg; home BP 130–135/80–85 mm Hg is borderline.
Long-term monitoring	One or two duplicate measurements per week. Too frequent monitoring (eg, every day) and self-modification of treatment on the basis of casual measurements to be avoided.

should cover 75% to 100% of the arm circumference and the width should be about half of the length, yet some oscillometric devices might give accurate measurements with smaller cuffs or wide range cuffs.[1] Cuffs that are too small for the arm circumference tend to overestimate BP (common in obese patients), whereas cuffs that are too large (in children or lean patients) tend to underestimate BP. It is generally recommended that patients with an arm circumference >32 cm should use a cuff larger than the standard size, while those with an arm circumference <24 cm should use a smaller cuff than the standard.[1]

Monitoring conditions, procedure, and schedule

The conditions for undertaking HBPM should be similar to those recommended for OBP[1–5]: the patient should be relaxed and in the sitting posture, with the back supported and the legs uncrossed and feet flat on the floor, in a quiet room at a comfortable temperature, and a few minutes of rest should precede the measurement.[1–5] The patient should avoid smoking, caffeinated beverages, or exercise within 30 minutes before BP measurements. Talking during the resting period and BP measurements should be avoided.[1–5] The cuff should be placed at heart level with the center of the bladder over the brachial artery and the bottom of the cuff directly above the antecubital fossa.[1–5]

Regarding the monitoring schedule, current European and US guidelines recommend a standard 7-day HBPM schedule for the initial evaluation of BP levels (untreated patients), after any change in the treatment regimen, and also before any routine visit to the doctor (for treated patients with hypertension). This should include duplicate measurements (with 1-minute interval) in the morning (before drug intake if treated) and the evening for 7 days (at least 4 days).[1–8] Readings from the first HBPM day should be discarded, as they might be higher and more variable than the next days.[1–8] Thus, HBPM for 4 to 7 days and then exclusion of the first day (leaving 12 to 24 readings) should be averaged to give values for decision making.[1–8] For the long-term follow-up of patients with treated hypertension, HBPM once or twice per week or less frequently seems to be appropriate to ensure maintenance of adequate BP control.[1]

Reporting of home BP values

Unbiased reporting of all self-home BP readings must be ensured, as it has been shown that HBPM readings reported by patients frequently differ from the actually measured values automatically stored in the device memory (overreporting or underreporting of self-measurements).[1–8] Objective reporting can be ensured with home monitors, which have automated storage of all BP readings in memory or PC download or with telemonitoring.[1–3,5] Patients should be asked to record their HBPM readings on a form according to the recommended monitoring schedule.

Diagnostic threshold and interpretation

Based on the available evidence derived from meta-analyses of cross-sectional and long-term observational studies, current guidelines recommend a hypertension threshold for average home BP of 135/85 mm Hg, which is the same as for awake ABPM.[1–4] Average levels exceeding this threshold are considered elevated. Average systolic home BP levels ranging between 130 and 135 mm Hg and diastolic between 80 and 85 mm Hg are regarded as borderline, and those <130/80 mm Hg as normal.[2] The 2017 US guidelines recommend a threshold at 130/80 mm Hg (office or home BP) for confirmation of uncontrolled hypertension,[5] which is in line with normal home BP according to the European recommendations.[2]

5 | CONCLUSIONS

Current guidelines strongly recommend HBPM for out-of-office BP evaluation in almost all untreated and treated patients with elevated BP, with a similar role as ABPM. Considerable evidence on the diagnostic and prognostic value of HBPM supports its primary

role in hypertension management and in improving hypertension control, which is further augmented by its wide availability, low cost, and good acceptance by patients. A 7-day HBPM monitoring schedule (a minimum 4 days and the exclusion of the first one) is recommended before each office visit, taken using validated automated upper-arm cuff devices with automated storage and averaging of readings.

CONFLICT OF INTEREST

G.S. and G.P. conducted validation studies for various manufacturers and advised manufacturers on device development. K.K. received grants from the Japan Agency for Medical Research and Development, the Ministry of Education, Culture, Sports, Science and Technology, and the Council for Science, Technology and Innovation, Japan; research funding from Omron Healthcare, Fukuda Denshi, A&D, and Daiichi Sankyo; and honoraria from Omron Healthcare. R.M. received BP monitoring equipment for research purposes from Omron and Lloyds Pharmacies; and is Chair of the British Hypertension Society Blood Pressure Monitoring Working Party, which oversees validation studies for various manufacturers. T.O. and Y.I. received research support from Omron Healthcare. A.K. has nothing to declare.

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How to cite this article: Stergiou GS, Kario K, Kollias A, et al. Home blood pressure monitoring in the 21st century. *J Clin Hypertens*. 2018;20:1116–1121. https://doi.org/10.1111/jch.13284