Chapter 3
Home Blood Pressure Measurements

Nadia Boubouchairopoulou and George S. Stergiou

Introduction

Despite the fact that conventional measurement of blood pressure (BP) in the office (OBP) is regarded as the gold standard for both the diagnosis and long-term management of hypertension, it is recognized that it may lead to incorrect clinical decisions. The white-coat and the masked hypertension phenomenon are very common with OBP measurements and associated with intermediate cardiovascular risk that lies between that of normotension and hypertension [1, 2]. Furthermore, the small number of BP readings, the unusual setting, and the observer bias further weaken the reliability of OBP in the diagnosis and management of hypertension [3].

In the last decades, self-monitoring of BP by patients at home (HBPM) and 24-h ambulatory BP monitoring (ABPM) have both gained ground compared to OBPM for hypertension management, aiming to overcome the abovementioned drawbacks. Both these BP measurement methods present several similarities, as they provide multiple measurements taken in the individual's usual environment. However, they also important differences, as HBPM is performed only at home and in the sitting posture, whereas ABPM is performed in ambulatory conditions, at work, at home and during sleep [4, 5]. Therefore, it is still debated whether their role in the clinical management of hypertension is interchangeable or complementary [4, 6, 7].

Unlike ABPM, the clinical value of which is strongly supported by evidence from short-term and longitudinal trials, HBPM has been less well investigated. Recently, evidence has accumulated from studies investigating the diagnostic value of HBPM and its association with target organ damage and cardiovascular risk,

N. Boubouchairopoulou, M.Sc. • G.S. Stergiou, M.D., FRCP (✉)
Hypertension Center STRIDE-7, National and Kapodistrian University of Athens, Third Department of Medicine, Sotiria Hospital, 152 Mesogion Avenue, Athens 11527, Greece
e-mail: gstergi@med.uoa.gr

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aiming to support the utility of this method as an indispensable tool for the initial evaluation of elevated BP, for treatment initiation and adjustment, as well as for long-term follow-up of treated hypertensives [1].

Clinical Value of HBPM

Diagnostic Value

Several studies during the last decade have demonstrated the efficiency of HBPM in diagnosing hypertensive patients and identifying the white-coat and masked hypertension phenomena which remain undetected with OBP measurements, by investigating the sensitivity and specificity of HBPM and considering ABPM as reference method [1].

HBPM appeared to be more efficient in identifying normotensive individuals but less accurate in detecting truly hypertensives, as it was associated with high specificity and negative predictive value (>80 %) but relatively lower sensitivity and positive predictive value (60–70 %) [1, 8]. Nevertheless, these results should be interpreted with caution as ABPM was used as reference method in most of the studies. Thus, these conclusions are based on the assumption that ABPM is perfectly reproducible and reliable, which certainly is not the case. Moreover, the diagnostic disagreement between the two methods in several cases was minimal and clinically irrelevant, and mostly present in subjects whose BP levels were very close to the diagnostic thresholds [1, 9].

As mentioned above, the usefulness of HBPM is manifested through the identification of white-coat and masked hypertension phenomena, which remain undiagnosed and inadequately treated when considering exclusively OBP measurements [4, 10–12]. White-coat hypertension is defined by normal HBPM (<135/85 mmHg) but elevated OBP values (≥140/90 mmHg systolic/diastolic BP, or both), thus not truly reflecting the "true" BP of an individual [1]. These individuals should not be considered as normotensives, as they present an intermediate cardiovascular risk between normotensives and hypertensives and are more likely to develop sustained hypertension within the next years [13]. On the other hand, masked hypertensives have elevated HBPM (≥135/85 mmHg) but normal OBP levels (<140/90 mmHg), and are associated with preclinical target organ damage and cardiovascular risk similar to sustained hypertensives. Masked hypertension is often present in treated patients reflecting the peak effect of morning antihypertensive drug treatment on OBP measurements and trough or plateau effect using morning and evening HBPM respectively. When the diagnosis of these phenomena is confirmed by repeat OBP and HBPM or ABPM measurements, the administration of antihypertensive therapy should be considered, especially in subjects with high total cardiovascular risk [1, 12].

The diagnostic accuracy of HBPM, its good reproducibility, its ability to provide a large number of measurements, its wide availability and the minimum effort

required for its application, should lead to its wide implementation as primary diagnostic method for hypertension diagnosis and identification of white-coat and masked hypertension [5].

Treatment Titration

The long-term use of HBPM by patients treated for hypertension is recommended by recent guidelines as it enhances their compliance to therapy, and prevents them from adhering to therapy only before an office visit, a phenomenon known as "white-coat adherence" which is associated with increased cardiovascular risk [4, 10]. Poor compliance is indeed the most common cause of resistant hypertension despite the fact that patients are administered intensive antihypertensive treatment [14]. HBPM not only prevents normotensive individuals from receiving unnecessary medication, but also enables physicians to closely monitor BP of treated hypertensive patients. With HBPM treated hypertensive patients might receive less intensive therapy with equal protection from target organ damage [1, 8, 15]. However, there is incomplete evidence on the possible effects on target organ damage progression with antihypertensive treatment because the studies with long-term therapy and HBPM or ABPM are very few and in cases with contradictory results [16, 17].

HBPM has the unique advantage to enables patients to take multiple measurements not only through a period of time of weeks, but also months and even years and at minimal cost. Thus, it is undeniably more suitable for long-term follow-up of normotensives at high risk and of treated hypertensives compared to ABPM or OBPM [3, 18].

Prediction of Preclinical Organ Damage

The association of HBPM with several indices of preclinical damage, including echocardiographic left ventricular mass and index (LVM and LVMI), urinary albumin excretion rate, glomerular filtration rate, carotid intima-media thickness and pulse wave velocity, has been investigated. In these studies HBPM has been proven to be superior to OBP [1, 4, 15, 18], while when considering the strength of the association with several indices, the results were comparable with those obtained by ABPM and superior to these by OBP [1, 18].

Two meta-analyses have concluded that HBPM is a stronger predictor of LVMI, urinary albumin excretion rate and even silent cerebrovascular disease compared to OBP, with the strongest evidence reported for LVMI and fewer studies with weaker associations for other indices [19, 20]. Systolic BP assessed by both HBPM and ABPM is more closely correlated with LVMI than OBP, demonstrating the advantage of the two out-of-office BP measurement methods, and preliminary evidence suggests that HBPM might be superior even to ABPM [12].

Prognostic Value

The ultimate criterion to identify a useful method for the assessment of a cardiovascular risk factor in clinical practice is its actual ability to predict future cardiovascular events. Two meta-analyses have investigated the evidence sourced from outcome trials assessing the prognostic ability of HBPM compared to OBP measurements [21, 22]. Both were based on data from 8 prospective studies and 17,688 patients followed for 3.2–10.9 years, which resulted in the availability of information based on almost 100,000 person/years of follow-up and showed HPBM to be superior to OBP measurements, with this difference being beyond chance for systolic BP. Moreover in the meta-analysis by Ward et al., even when HBPM was adjusted for OBP, it still retained its prognostic ability, whereas OBP lost its significance after adjustment for HBPM [22]. Thus, the availability of reliable HBPM is likely to make OBP measurements obsolete in terms of cardiovascular events prediction [23].

Nocturnal HBPM

ABPM is considered as the gold standard in assessing nocturnal BP which has been shown to predict cardiovascular events in all populations and appears to be the aspect of the 24 h BP profile that has the strongest prognostic ability. Whether the nocturnal BP dip during sleep or the morning BP surge upon the morning rise contributes more in the cardiovascular risk prediction it is still debatable [24].

New technological advancement of HBPM devices offer the option to evaluate nocturnal BP on repeated days by patients at home [24]. These innovative HBPM devices are usually programmed to take 3 automated hourly BP readings at sleep for 3 consecutive nights, providing thereby a similar number of nocturnal BP readings as the usual 24-h ABPM. Studies have shown that daytime and nighttime BP assessed by these novel HBPM devices has similar levels as those obtained by conventional 24-h ABPM and there is satisfactory agreement between the two methods in identifying non-dippers [25]. Taking also into account that these measurements can be repeated for longer periods than these of ABPM, HBPM can be regarded as an appealing alternative [24, 26, 27].

Advantages and Limitations (Table 3.1)

Advantages

HBPM is widely available in general practice, with a relatively low-cost (in fact patients usually decide to cover themselves the cost of the devices) and is well accepted by patients for long-term use [1], highlighting its potential use as primary method of BP monitoring for both physicians and patients [10, 15, 28].

Table 3.1 Advantages and limitations of home blood pressure monitoring

Advantages	Limitations
Need of minimal training (with automated devices) Large sample of blood pressure readings Absence of placebo effect Absence of observer error and bias (automated devices with memory or PC link) Good reproducibility Detection of white-coat and masked hypertension phenomena Association with preclinical organ damage Prediction of cardiovascular events Wide availability Good acceptance by users Improvement of patients' compliance with drug therapy Improvement of hypertension control rates Cost-effectiveness	Devices often not properly validated Misreporting (over- or under-) of readings by patients Need of user training (minimal with automated devices) and medical supervision May induce anxiety in some patients Some patients may self-modify their drug treatment on the basis of casual BP readings Measurements do not reflect usual daily activities Inability to monitor nocturnal BP (possible with some novel home monitors) Questionable accuracy of oscillometric devices in the presence of arrhythmias

Indeed, from the physicians' point of view HBPM can be considered as superior to OBP and similar to ABPM in terms of reproducibility, which is mainly attributed to the large number of readings obtained [28]. Moreover, as aforementioned, the evaluation of BP in the patients' usual environment enables the accurate diagnosis of hypertension through the identification of the white coat and the masked hypertension phenomena, which both affect almost one third of treated and untreated subjects attending hypertension clinics [28]. Particularly in treated patients, HBPM has been proved to enhance their compliance by involving them in their monitoring, thereby leading to improved hypertension control rates [4, 29].

In line with the above, recent studies have shown HBPM to be highly cost-effective, through the need of fewer clinic visits, more adequate treatment adjustment and avoidance of unnecessary treatment in white coat hypertensives [4, 12, 30]. However, its cost-effectiveness has not been thoroughly investigated and more studies should be performed [3].

Limitations

Despite its many advantages, HBPM inevitably presents some limitations which occasionally restrict its use. Self HBPM may induce anxiety which leads to BP increase and also to excessive monitoring, while sometimes the conditions under which the measurements are taken are not representative (stress, pain, etc.) and providing false evidence and overestimating BP levels [3, 28]. This can induce some patients to perform self-modification of their drug treatment without medical consultation on the basis of casual home BP measurement (high or low) [3, 4].

Patients' usual misreporting of their self-taken BP readings still remains the "Achilles' heel" of HBPM, leading in over- or under treatment, especially in high risk hypertensives or those with high BP variability [4, 12, 31]. There is evidence that less than 70 % of HBPM readings reported by patients to the doctor are usually identical to those recorded by the device. Electronic HBPM devices with automated memory or PC link and home-telemonitoring can all prevent misreporting and ensure an unbiased and reliable HBPM evaluation.

It should be mentioned that even if HBPM is performed under ideal circumstances, it only provides BP readings at home and in the sitting posture, whereas ABPM provides BP data in dynamic conditions, at work, at home, and also during sleep [5]. Nevertheless, even ABPM is not truly ambulatory, since patients have to stay still during each measurement.

Clinical Application (Table 3.2)

The current European and American guidelines recommend HBPM to be used in the long-term follow-up of almost all subjects with treated hypertension and also in untreated subjects for the initial evaluation of elevated BP [32, 33]. However, HBPM should be always applied after adequate training and under close medical supervision.

Devices

HBPM can be performed using auscultatory aneroid devices, or electronic arm, wrist or finger devices. Regular calibration of devices and training of patients are important prerequisites for the use of auscultatory method. Considering the fact that for the wide application of HBPM the aforementioned prerequisites are not feasible

Table 3.2 Practical recommendations for optimal application of home blood pressure monitoring

Device	Automated upper-arm device validated according an established protocol.
Cuff	Bladder size according to individual arm circumference.
Conditions	Relaxed, after 5 min sitting rest.
Monitoring schedule	7-days monitoring before each office visit with duplicate morning (before drug intake) and evening measurements. Not fewer than 3 days (12 readings).
Evaluation	Calculation of average BP of all readings after discarding the first day. Casual readings have little clinical relevance.
Diagnostic thresholds	Normal home BP: <130/80 mmHg; Hypertension: ≥135/85 mmHg; Intermediate levels are considered borderline.
Long-term follow up	1–2 duplicate measurements per week. Too frequent monitoring and self-modification of treatment on the basis of casual measurements to be avoided.

but rather unrealistic, automated electronic devices, especially these using an oscillometric algorithm and having an arm cuff are currently recommended for HBPM. Auscultatory devices might be preferred only in case of arrhythmias, or pre-eclampsia, yet these indications are also debatable. Some wrist devices have passed the internationally accepted validation protocols, however they are regarded as less accurate than upper arm devices, mainly because of anatomical differentiations of the wrist, and of difficulty in following the correct wrist position (at heart level and relaxed) [4, 8, 12]. On the other hand, finger devices are not accurate and have been withdrawn from the market [4, 8, 12].

The accuracy of electronic BP monitors should be tested against conventional mercury sphygmomanometry according to established validation protocols. The US Association for the Advancement of Medical Instrumentation (AAMI) in 1987 [34] and the British Hypertension Society in 1990 [35] have developed the first protocols for devices' validation, and both have been later revised. In 2002 the European Society of Hypertension International Protocol has been developed, requiring considerably smaller sample size and therefore being widely accepted and applied worldwide [36]. However, many of the electronic devices for HBPM available on the market have not been subjected to independent validation or have failed [12]. Updated lists of devices which have passed at least one of the aforementioned validation protocols are available at the British Hypertension Society website (www.bhsoc.org) and the Medaval website for the evaluation of BP monitors (www.medaval.org). The fact that a device has passed a validation protocol does not guarantee that it will provide accurate readings to each individual [12]. Indeed, in some cases, even a BP monitor that has achieved passing grades may present a measurement error of more than 5 or 10 mmHg compared to mercury sphygmomanometer for reasons which remain rather unclear and might be related to the individual's arterial wall properties.

The use of a cuff with inflatable bladder of appropriate size for the arm of each individual is of equal importance as the accuracy of the HBPM device [8]. The length of the inflatable bladder should cover 80–100 % of the arm circumference and the width should be about half of the length. Cuffs which are too small for the arm size tend to overestimate BP (common in obese subjects), whereas cuffs which are too large (in children or lean women) tend to underestimate BP. It is recommended that subjects with arm circumference larger than 32 cm should use a cuff larger than the standard size, while those with arm circumference smaller than 24 cm a smaller cuff than the standard [4].

Methodology

The European Society of Hypertension [37] and the American Heart Association [5] guidelines for HBPM recommend that patients should perform a standard HBPM schedule for the initial evaluation of BP levels (untreated subjects) and before each visit to the physician (for treated hypertensives). The recommended HBPM

schedule includes duplicate measurements (with one minute interval) in the morning (before drug intake if treated), and the evening for 7 routine work days (and not less than 3 days), with weekends preferably excluded as the corresponding BP values are usually lower than in workdays [3, 12]. However, for the long-term follow-up of treated hypertensives, HBPM once or twice per week seems to be appropriate to ensure maintenance of adequate BP control [4, 12]. In all cases, individuals should ensure that they are in sitting posture with supported back and arm and uncrossed legs, and that BP measurements are taken after 5 min rest. Moreover, the cuff must be placed on the nondominant arm, at the heart's level and the centre of the bladder should be placed over the brachial artery. Talking during the measurement and coffee or smoking for at least 30 min before the measurement should be discouraged [4].

All HBPM readings should be recorded in a form, or better automatically saved on the device memory or PC [4]. A total of 24 HBPM readings (7 days) should be routinely obtained for clinical decision making and 12 readings seems to be the minimum acceptable sample. The first day HBPM readings should be better discarded particularly when less that the full 7-day schedule has been obtained, as they are typically higher and more variable than the next days [4].

Interpretation

The HBPM interpretation is based on assessing the average BP of 7 days (minimum 3), whereas casual BP readings little clinical value. As mentioned above, the average home BP of all readings is calculated after discarding those of the first day [4].

According to the European and American guidelines, the hypertension threshold for average home BP is 135/85 mmHg, which is the same as for awake ABPM [3, 4, 8]. Levels exceeding this threshold are considered elevated. Home BP levels ranging between 130 and 135 mmHg for systolic and 80–85 mmHg diastolic BP are regarded as borderline (pre-hypertension range), and those <130/80 mmHg as normal [3, 12]. Comparison between the morning and evening home BP values are particularly useful in treated hypertensives for the evaluation of the duration of antihypertensive drug action and the 24 h BP control [12].

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