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BLOOD PRESSURE MONITORING AND MANAGEMENT (G OGEDEGBE AND JA STAESSEN, SECTION EDITORS)

Home Blood Pressure Monitoring: Primary Role in Hypertension Management

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Abstract In the last two decades, considerable evidence on home blood pressure monitoring has accumulated and current guidelines recommend its wide application in clinical practice. First, several outcome studies have shown that the ability of home blood pressure measurements in predicting preclinical target organ damage and cardiovascular events is superior to that of the conventional office blood pressure measurements and similar to that of 24-hour ambulatory monitoring. Second, cross-sectional studies showed considerable agreement of home blood pressure measurements with ambulatory monitoring in detecting the white-coat and masked hypertension phenomena, in both untreated and treated subjects. Third, studies have shown larger blood pressure decline by using home blood pressure monitoring instead of office measurements for treatment adjustment. Fourth, in treated hypertensives, home blood pressure monitoring has been shown to improve long-term adherence to antihypertensive drug treatment and thus, has improved hypertension control rates. These data suggest that home blood pressure should no longer be regarded as only a screening tool that requires confirmation by ambulatory monitoring. Provided that an unbiased assessment is obtained according to current recommendations, home blood pressure monitoring should have primary role in diagnosis, treatment adjustment, and long-term follow-up of most cases with hypertension.

Keywords Adjustment · Ambulatory blood pressure · Decision-making · Diagnosis · Self-measurement · Treatment

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Introduction

Although the measurement of blood pressure (BP) in the office has been the cornerstone for hypertension diagnosis and management for decades, it is recognized that this method might often be misleading, mainly due to the white-coat and masked hypertension phenomena, which are common in both untreated and treated subjects [1–3•]. It is therefore recognized that, for the reliable evaluation of elevated BP, evaluation out of the office using 24-hour ambulatory (ABPM) or self-home BP monitoring (HBPM) is often required [1–3•]. Although there is general agreement on the need for using these two out-of-office BP measurement methods for decision-making in hypertension in clinical practice, the specific role of each method has not been fully clarified and there is still no consensus on whether they are interchangeable [1–3•].

This article aims to present the current evidence on HBPM and the advantages of its application as a primary method for BP evaluation in clinical practice. The barriers that in the past have prevented the reliance of decision-making exclusively based on HBPM, and the existing limitations and potential solutions for optimal HBPM are discussed. Eventually, this article focuses on the evidence for using HBPM in each one of the three stages of hypertension management, including: (i) initial evaluation of BP level and accurate diagnosis; (ii) drug treatment initiation and titration; and (iii) long-term follow-up of treated hypertension.

HBPM in Predicting Organ Damage and Cardiovascular Events

Although in the last three decades HBPM has been widely used in clinical practice in several countries, the available evidence on the main research questions that need to be addressed prior to wide application has been delayed by

almost one decade compared to ABPM [2, 3•]. Therefore, until recently the limited relevant evidence, particularly on the prognostic ability of HBPM, has prevented hypertension societies from recommending this method to play a primary role in hypertension management.

In the last decade, considerable evidence with regard to all the clinical research issues of HBPM has accumulated [2, 4•, 5–8]. Several cross-sectional studies evaluated the association of HBPM with indices of preclinical organ damage at the level of the heart, the kidney, and the arteries, and showed superiority compared to the conventional office measurements and similar correlations as with ABPM [2, 5, 9]. More importantly, several outcome studies demonstrated the prognostic value of HBPM to be superior to that of the conventional office BP measurements [4•, 7, 8]. A single study compared HBPM with ABPM and office BP measurements, yet only two HBPM readings were obtained and therefore, the potential of this method has not been exhausted [10]. Recent meta-analyses of outcome studies using HBPM or ABPM suggested a similar ability of the two methods in predicting cardiovascular risk [4•, 11].

HBPM in Diagnosis

Several cross-sectional studies investigated the diagnostic performance of HBPM by providing data on sensitivity, specificity, positive and negative diagnostic value, and diagnostic agreement by taking ABPM as reference method (Table 1) [6, 12–22]. These studies have differences in inclusion criteria, participants' characteristics, and endpoints (white-coat effect, white-coat hypertension, sustained hypertension). However, taken together, these data suggest considerable diagnostic agreement between the two methods, with consistently high specificity and negative predictive value (>80 %) and lower sensitivity and positive predictive value (60–70 %) (Table 1).

There are three important comments to make in regard to the diagnostic agreement between HBPM and ABPM. First, this disagreement is partially attributed to the imperfect reproducibility of both methods [23]. Second, most of the disagreement is "arithmetical" rather than "clinically relevant" (>5 mmHg), and is observed in subjects with BP levels close to the diagnostic thresholds [24]. Third, disagreement between the two methods does not necessarily mean that ABPM, which in the abovementioned studies was taken as reference, is the "reliable" method. It has been shown that each of the two methods independently and incrementally contributes to increased cardiovascular risk [10].

Although HBPM might be appropriate for the initial diagnostic evaluation of most cases with elevated BP, ABPM if available might be more suitable when an unbiased evaluation is required within 24 hours, particularly in subjects who do not wish to perform HBPM. Moreover, ABPM has the advantage of assessing BP during sleep [3•]. However, novel HBPM devices allow nocturnal monitoring and have shown good agreement with ABPM in detecting non-dippers [25].

HBPM in treatment adjustment

There are several different lines of evidence that support the usefulness of HBPM in treatment initiation and titration. In treated subjects the phenomena of white-coat and masked hypertension are as common as in untreated ones and can be identified by HBPM or ABPM [4•, 21•, 26]. Several cross-sectional studies confirmed the similar diagnostic reliability of

Table 1 Diagnostic value of home blood pressure monitoring in untreated subjects compared to ambulatory monitoring taken as reference

Study	Population (n)	Diagnosis	Sen/Sp/PPV/NPV	Agreement (kappa)
Nesbitt et al., 1997 [12]	79	H	48/93/NR/NR	NR
Stergiou et al., 1998 [13]	189[a]	WCE	57/85/57/85	0.42
Stergiou et al., 2000 [14]	133	H	74/76/84/63	0.47
		WCH	61/79/48/86	0.37
Masding et al., 2001 [15]	55[b]	H	100/79/90/NR	NR
Hond et al., 2003 [16]	247	H	68/89/33/97	0.38
Stergiou et al., 2004 [17]	138	WCE	56/87/52/89	0.42
Bayó et al., 2006 [18]	190	WCH	50/76/59/69	NR
Shimbo et al., 2009 [19]	229	H	100/44/94/100	NR
McGowan et al., 2010 [20]	87[a]	H	NR	0.56
Nasothimiou et al., 2012 [21•]	361	H	91/82/90/83	0.73
		WCH	50/93/52/93	0.44
		MH	67/98/78/96	0.40
Almeida et al., 2013 [22]	158[a]	H	3-day: 84/84/72/92	0.65
			5-day: 62/73/52/82	0.66

n number, *Sen* sensitivity, *Sp* specificity, *PPV* positive predictive value, *NPV* negative predictive value, *H* hypertension, *WCE* white-coat effect, *WCH* white-coat hypertension, *MH* masked hypertension, *NR* not reported

[a] Untreated and treated subjects

[b] Diabetic subjects

HBPM in identifying these phenomena in treated and in untreated subjects [6, 21•], and also in subjects with resistant hypertension [26] (Table 2) [13, 17, 21•, 26–29]. More importantly, a recent meta-analysis of outcome trials confirmed the prognostic significance of the white-coat and masked hypertension phenomena detected by HBPM in untreated as well in treated subjects [4•].

The association between treatment-induced changes in home, ambulatory, and office BP with treatment-induced changes in preclinical organ damage have been investigated in two studies. In the Study on Ambulatory Monitoring of Blood Pressure and Lisinopril Evaluation (SAMPLE) in 206 hypertensives followed for 12 months, the treatment-induced regression in left ventricular hypertrophy was more closely associated with treatment-induced changes in ambulatory than in office or home BP [30]. However, the potential of HBPM has not been exhausted in this study, because only two home readings were obtained, whereas it is recommended to take a minimum of 12 readings and discard those of the first day [2]. Another study in 116 hypertensives with 13.4 months of follow-up showed that treatment-induced changes in both 24-hour ABPM and 7-day HBPM were more closely related than office BP measurements with treatment-induced changes in organ damage (echocardiographic left ventricular mass index, pulse wave velocity, albuminuria) [9]. Interestingly, there were differences between HBPM and ABPM in their associations with the changes in different indices or organ damage, which implies that they are complementary rather than interchangeable methods in monitoring the effects of antihypertensive treatment on target organ damage [9].

A challenging question is whether treatment adjustment can be effectively based on HBPM. Nine randomized studies compared treatment titration based on HBPM against either conventional clinic BP measurements (seven studies) [31–37] or ABPM (two studies) [38, 39•] (Table 3). There are important differences among these studies in inclusion criteria, population characteristics, BP measurement methodology, BP goals, and duration of follow-up. Three of the studies have used the same threshold for office and home BP [32, 33, 35], which is not in line with current guidelines [2] and led to inferior BP control with HBPM. Four other studies showed larger BP decline with treatment adjustment based on HBPM rather than office BP measurements (Table 3). Two studies compared treatment adjustment based on HBPM versus ABPM. The first one in 98 subjects followed for six months found no difference in BP control when using HBPM or ABPM for treatment adjustment [38]. The second one randomized 116 subjects to treatment initiation and titration based either on HBPM alone or on combined use of office and ambulatory BP [39•]. After an average follow-up of 13.4 months there was no difference between the two arms in BP decline and hypertension control assessed by HBPM or ABPM and, more importantly, there was no difference in several indices of preclinical target organ damage (echocardiographic left ventricular mass index, pulse wave velocity and albumin excretion) [39•].

HBPM in long-term follow-up

The primary role of HBPM in the long-term follow-up of treated hypertension is well-established and supported by recent guidelines that recommend its use in almost all treated subjects [2].

Table 2 Diagnostic value of home blood pressure monitoring in treated subjects compared to ambulatory monitoring taken as reference

Study	Population (*n*)	Diagnosis	Sen/Sp/PPV/NPV	Agreement (kappa)
Stergiou et al., 1998 [13]	189[a]	WCE	57/85/57/85	0.42
Comas et al., 1999 [27]	58	WCP	84/82/70/91	NR
Llisterri et al., 2003 [28]	124	H	97/63/NR/NR	NR
Stergiou et al., 2004 [17]	138	WCE	62/84/59/86	0.46
Martinez et al., 2006 [29]	225	WCP	50/87/64/79	NR
Nasothimiou et al., 2012 [21•]	252	H	86/94/85/94	0.80
		WCP	74/95/76/95	0.69
		MUH	53/85/47/88	0.69
Nasothimiou et al., 2012 [26]	73[b]	WCP	63/93/83/81	0.59
		MUH	83/85/53/96	0.56
		RH	90/55/71/82	0.46

n number, *Sen* sensitivity, *Sp* specificity, *PPV* positive predictive value, *NPV* negative predictive value, *H* hypertension, *WCE* white-coat effect (office-home blood pressure difference), *WCP* white-coat phenomenon, *MUH* masked uncontrolled hypertension, *NR* not reported, *RH* resistant hypertension

[a] Treated and untreated subjects

[b] Resistant hypertension

Table 3 Randomized trials comparing home blood pressure monitoring for treatment adjustment against office or ambulatory measurements

Study	Comparator	Population (n)	Follow-up (months)	Endpoint and main result
Zarnke et al., 1997 [31]	CBP[b]	33	2	Larger ABP decline in HBP group and more frequent office visits. No difference in compliance and quality of life
Broege et al., 2001[a] [32]	CBP	40	3	Larger ABP decline in HBP group. No difference in quality of life, and drug decrease/discontinuation
Staessen et al., 2004[a] [33]	CBP	400	12	Less ABP decline in HBP group, plus more drug discontinuations, less intensive treatment and marginally lower medical costs. No difference in general well-being and left ventricular mass
Halme et al., 2005 [34]	CBP	269	6	Larger HBP decline in HBP group
Verberk et al., 2007[a] [35]	CBP	384	12	Higher ABP in the HBP group and less medication use. No differences in CBP change or target organ damage
Tobe et al., 2008 [36]	CBP	270	1.5	Larger CBP decline in HBP group
McManus et al., 2010 [37]	CBP[b,c]	480	12	Larger CBP decline in the HBP group
Niiranen et al., 2006 [38]	ABP	98	6	No difference in ABP and HBP
Stergiou et al., 2014 [39•]	ABP & CBP	116	13.4	No difference in ABP/HBP decline, hypertension control rates, and organ damage regression

n number, *CBP* clinic blood pressure, *HBP* home blood pressure, *ABP* ambulatory blood pressure

[a] Inappropriate high HBP goal (same as for CBP)

[b] Patient-adjusted treatment

[c] HBP telemonitoring

The use of HBPM has been shown to improve hypertension control rates. Several randomized controlled trials have shown that treated hypertensives who perform HBPM have improved long-term adherence to drug therapy [40], and thereby higher hypertension control rates [41•]. A systematic review of 72 randomized controlled trials that evaluated the effectiveness of several interventions aiming to improve BP control (HBPM; educational interventions; pharmacist- or nurse-led care; organizational interventions; appointment reminder systems) showed HBPM to be the most efficient method [42]. The MONITOR study showed that in treated uncontrolled hypertensives a two-month HBPM protocol without medication titration led to superior ABPM control than the usual care control group [43]. Another study in 1,350 hypertensive patients attending a BP clinic showed that those using HBPM had higher BP control rates [44].

HBPM is widely available in many countries and is inexpensive (in fact, many patients have decided to cover the cost of the technique themselves), whereas ABPM is not widely available [45] and is rather expensive due to device costs and physician time required for device initialization, download, and interpretation. This difference is expected to decrease as the cost of ambulatory monitors is being reduced and the technique is becoming accessible in pharmacies [46].

Patient preference is always important, particularly for long-term application, and most patients seem to prefer HBPM rather than ABPM, and more so for repeated and long-term use, as it causes less discomfort and restriction of daily activities and sleep [20, 47, 48].

Limitations of HBPM

An important requisite for hypertension management and decision-making based on HBPM is to ensure that a reliable evaluation of BP is made at home using the currently recommended schedule [2]. Several studies have shown that hypertensive patients often misreport (over- or under-report) their HBPM values, which may affect treatment decisions made by physicians on such measurements [49•]. The so-called "HBPM reporting bias" has been described as the "Achilles' heel of HBPM" [49•].

Standardization of HBPM to ensure that the recommended schedule is followed by patients (3–7 days with duplicate morning and evening measurements and discard the first day) [3•, 50] and objective (unbiased) reporting using automated memory or PC link are essential. These requirements can easily be fulfilled by the current technology of HBPM monitors software with minimal increase in the cost [51]. This is a prerequisite for physicians to rely on HBPM in making treatment decisions for hypertension management in clinical practice. ABPM does not have such issues because it obtains prescheduled BP measurements, which are automatically stored in the monitor's memory.

HBPM telemonitoring

Remote telemonitoring of HBPM (tele-HBPM) is a modern solution allowing closer, more regular and unbiased HBPM with the potential to optimize the care of hypertension. The

current evidence suggests that tele-HBPM is associated with lower BP levels and increased patient satisfaction [52–54•]. The increased cost of the method might be offset by more accurate evaluation, more efficient management, and thereby superior BP control. As technology is being improved and the cost is reduced, tele-HBPM might become more cost-effective, particularly in high-risk patients or when combined with monitoring of other vital signs or cardiovascular risk factors (e.g., diabetes) [54•]. Before tele-HBPM is recommended for wide application in clinical practice, additional research is needed that provides direct comparison against usual HBPM and with long-term endpoints including BP reduction, hypertension control, quality of life, and cost-effectiveness [54•, 55].

Conclusion

In the last two decades considerable evidence on HBPM has accumulated and current guidelines recommend its wide application in clinical practice. Benefits from HBPM are its prognostic ability, its contribution in accurate diagnosis, and its usefulness in treatment adjustment and in long-term follow-up leading to improved hypertension control, combined with wide availability, low cost, and good acceptance by patients. Thus, there is no reason anymore for HBPM to have a secondary role in hypertension management and be regarded only as a screening test that requires confirmation by ABPM.

Recent European guidelines recommend HBPM to have a similar role as ABPM for out-of-office BP evaluation, and, more importantly, HBPM to be used by most hypertensive patients, whereas ABPM to be restricted to selected cases [1–3•]. The UK NICE guidelines had the opposite view by recommending ABPM in all subjects with "suspected hypertension", and mentioned HBPM as a suitable alternative in subjects unable to tolerate ABPM [56]. However, the wide adoption of the NICE policy faces several major barriers and at the present time is not feasible for primary care [45]. ABPM is rather expensive, not widely available [45], and less well-accepted by patients particularly for long-term use. Provided that an unbiased assessment is obtained according to current recommendations, HBPM should have primary role in diagnosis, treatment adjustment, and long-term follow-up of most cases with hypertension.

Compliance with Ethics Guidelines

Conflict of Interest Anastasios Kollias, Marilena Zeniodi, Nikos Karpettas, and Angeliki Ntineri declare that they have no conflicts of interest.

George S. Stergiou has received honoraria for educational lectures from Omron and consultation fees from Microlife.

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