Diagnostic Value of Home Blood Pressure

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5.1 Introduction

Recently, new guidelines for the management of hypertension have been released by the European Society of Cardiology/European Society of Hypertension (2018 ESC/ESH guidelines) and American Heart Association/American College of Cardiology (2017 ACC/AHA guidelines) [1, 2]. These guidelines have stressed the importance of out-of-office BPs rather than office BP. There has been a similar emphasis on out-of-office BP-guided management of hypertension in Japan and Asian countries [3–5]. Ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM) are the two standard measurements of out-of-office BPs, and both approaches can detect masked (uncontrolled) hypertension (normotension in office BP and hypertension in out-of-office BP), which carries the highest risk of cardiovascular events, and rule out white-coat hypertension (hypertension in office BP and normotension in out-of-office BP) [1–8].

In current clinical practice, out-of-office BP has been widely accepted as the most accurate modality for the diagnosis and management of hypertension, particularly masked hypertension [6–8]. ABPM is the gold standard, for the diagnosis of masked hypertension. On the other hand, HBPM is also widely used in clinical practice due to its greater practicality, and it can also identify white-coat hypertension and masked hypertension.

5.2 Diagnostic Value of HBPM vs. Office BP Measurement

Previous studies have clearly demonstrated that HBPM has a greater diagnostic value for hypertension than office BP measurement by taking ABPM as reference [9]. HBPM can identify out-of-office hypertension, which is associated with cardiovascular risk, without reference to office BP measurements.

The results of the three measures of BP—i.e., office BP, HBPM, and ABPM—are not always in agreement. For example, Table 5.1 shows the corresponding values of clinic, home, daytime, nighttime, and 24-h BP measurements [2]. The diagnostic BP thresholds of hypertension are 140/90 mmHg for office BP and 135/85 mmHg for home BP. The home BP and daytime ambulatory BP thresholds are comparable, and are 5 mmHg lower than the office BP threshold. At around the 130/80 mmHg level, the office, home, and daytime ambulatory BP levels are correspondent. The difference in BP between the office and out-of-office measures thus becomes more pronounced at the higher BP levels (Table 5.1). This means that the

Table 5.1 Corresponding values of office, home, daytime, nighttime, and 24-h blood pressure measurements

Office	HBPM	Daytime ABPM	Nighttime ABPM	24-h ABPM
120/80	120/80	120/80	100/65	115/75
130/80	130/80	130/80	110/65	125/75
140/90	135/85	135/85	120/70	130/80
160/100	145/90	145/90	140/85	145/90

ABPM ambulatory blood pressure monitoring, *HBPM* home blood pressure monitoring

white-coat effect on BP (office minus out-of-office BP) caused by specific conditions in the office is greater than the difference in the pressor effect between HBPM, measured at rest condition, and ABPM, measured under ambulatory conditions.

The 2017 ACC/AHA guidelines lowered the American diagnostic thresholds for hypertension to 130/80 mmHg both for office and for home BPs [2]. The core concept in these guidelines is the recommendation of earlier and stricter BP control over 24 h, which aims to provide more thorough organ protection and prevent cardiovascular events [10]. This new definition in the 2017 ACC/AHA guidelines markedly changes the prevalence of hypertension subtypes. In the J-HOP (Japan Morning Surge-Home Blood Pressure) study, a general practice-based national home BP registry of outpatients with cardiovascular risk factor (79% medicated with antihypertensive drug) [10], the difference between office and morning home BPs decreases until the two BPs are similar at around a BP threshold of 130/80 mmHg (Fig. 5.1). The prevalence of normotension (well-controlled hypertension), white-coat (uncontrolled) hypertension, masked (uncontrolled) hypertension, and sustained (uncontrolled) hypertension are, respectively, changed from 31%, 15%, 19%, 36% by the ESC/ESH 2018 definition (140/90 mmHg for office BP and 135/85 mmHg for home BP) to 14%, 17%, 10%, 58% by the 2017 ACC/AHA definition (130/80 mmHg for both office and home BPs) (Fig. 5.1) [10]. The population-based Ohasama study also demonstrated the similar change in the distribution of these four classifications [11]. In medicated patients, the prevalence of uncontrolled sustained hypertension is increased, while that of masked uncontrolled hypertension is decreased [10, 11]. The decrease in masked uncontrolled hypertension and the increase in sustained uncontrolled hypertension would give clinicians the opportunity to treat hypertension in this group of patients known to have heightened cardiovascular risk [8].

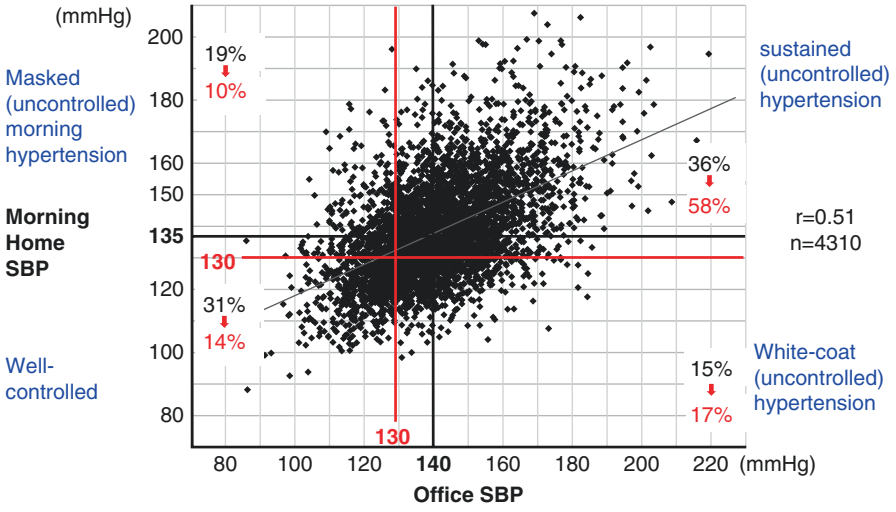

Fig. 5.1 Difference in the prevalence of masked (uncontrolled) hypertension between the 2017 ACC/AHA guidelines (red) and the 2018 ESC/ESH guidelines (black) in subjects in the J-HOP study (Japan Morning Surge-Home Blood Pressure; 4310 medicated hypertensives). *SBP* systolic blood pressure

5.3 Sensitivity and Specificity of HBPM for Diagnosing ABPM-Based Diagnosis of Hypertension

The diagnostic agreement between home and ambulatory BP measurements is a challenging clinical issue. Because the out-of-office BP measurement conditions differ between home BP monitoring and ABPM, the prevalence and characteristics of white-coat hypertension and masked hypertension diagnosed by these two types of monitoring are also different. The main application of HBPM is for the long-term follow-up of treated hypertension. The need for BP assessment out of the office in all treated hypertensive patients is strongly supported by the fact that the white-coat and the masked hypertension phenomena are common in these patients, and the diagnostic value of home BP is as good as in untreated subjects.

Stergiou et al. conducted an extensive systematic review of the use of HBPM for the diagnosis and treatment of hypertension (PubMed, Cochrane Library, 1970–2010) [9, 12, 13]. Sixteen studies of untreated and treated subjects assessed the diagnostic ability of HBPM by taking ABPM as reference. The studies reviewed consistently showed moderate diagnostic agreement between HBPM and ABPM, and superiority of HBPM compared to office measurements in diagnosing uncontrolled hypertension. The diagnostic performance of home BP appeared to be similar across the different populations included in the studies [9, 12, 13]. However, the results on the usefulness of HBPM for the diagnosis of white-coat and masked hypertension were not entirely consistent.

Recently, by using the data of the China Ambulatory and Home BP Registry (N = 1774), which provides the largest number of patients who had undergone ABPM and HBPM within a short period, an accuracy of HBPM in the diagnosis of white-coat and masked hypertension compared to ABPM was tested [14]. This is also the most reliable data using the validated HBPM device, which stores in its BP measurements in memory, and measured by a standardized protocol for 7 consecutive days. In the study, white-coat hypertension is defined as an elevated office BP (≥140/90 mmHg) and a low 24-h ambulatory BP (<130/80 mmHg) or home BPs (<135/85 mmHg), and masked hypertension is defined as a low office BP (<140/90 mmHg) and an elevated 24-h ambulatory BP (≥130/80 mmHg) or home BPs (≥135/85 mmHg). In untreated patients (n = 573), the prevalence of white-coat hypertension (13.1% vs. 19.9%), masked hypertension (17.8% vs. 13.1%), and sustained hypertension (46.4% vs. 39.6%) were significantly ($P < 0.02$) different between 24-h ABPM and HBPM. In treated patients (n = 1201), only the prevalence of masked hypertension differed significantly (18.7% vs. 14.5%; $P < 0.005$) (Table 5.2). Regardless of the treatment status, home BP compared with 24-h ambulatory BP had low sensitivity (range 47–74%), but high specificity (86–94%), and accordingly low positive (41–87%), but high negative predictive values (80–94%), and had moderate diagnostic agreement (82–85%) and Kappa statistic (0.41–0.66). Thus, HBPM has high specificity, but low sensitivity in the diagnosis of white-coat and masked hypertension, and may therefore behave as a complement to, but not a replacement of, ABPM.

Table 5.2 Diagnostic accuracy of home vs. 24-h ambulatory blood pressure monitoring in treated (n = 1201) and untreated patients (n = 573)

Treatment status and hypertension subtype	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Agreement (%)	Kappa statistic
Treated patients						
Uncontrolled clinic pressure and controlled ambulatory or home pressure	52 (46–59)	89 (87–91)	53 (47–60)	88 (86–90)	82	0.41*
Masked uncontrolled hypertension	47 (41–54)	93 (91–95)	61 (54–68)	88 (86–90)	84	0.45*
Sustained uncontrolled hypertension	72 (67–77)	86 (84–88)	71 (67–75)	86 (84–89)	82	0.58*
Untreated patients						
White-coat hypertension	62 (51–73)	86 (83–89)	41 (32–50)	94 (91–96)	83	0.40*
Masked hypertension	47 (37–56)	94 (92–96)	64 (53–74)	89 (86–91)	85	0.46*
Sustained hypertension	74 (69–80)	90 (87–94)	87 (83–92)	80 (76–85)	83	0.66*

Values in the parentheses are 95% confidence interval.
*P < 0.0001.

Kang YY, et al. J Hypertens 2015; 33: 1580–7

A recent cross-sectional study of a multiethnic population of 551 participants (age, 40–75 years; 246 white British, 147 South Asian and 158 African Caribbean subjects) with and without a previous diagnosis of hypertension recruited from 28 primary care practices compared the test performance of clinic BP (using various protocols) and HBPM (1 week) with a reference standard of mean daytime ambulatory measurements using a threshold of 140/90 mmHg for office and 135/85 mmHg for out-of-office measurement [15]. For people without hypertension, office measurement using three different methodologies had high specificity (75–97%) but variable sensitivity (33–65%), whereas HBPM had a sensitivity of 68–88% and specificity of 64–80%, indicating that ABPM remains a better choice for diagnosing hypertension compared to the other modes of BP measurement regardless of ethnicity. For people with hypertension, the use of office measurements for the detection of elevated BP had a sensitivity of 34–69% and specificity of 73–92%, while the use of HBPM had a sensitivity of 81–88% and specificity of 55–65%. Differences in the accuracy of HBPM and office BP measurement (higher sensitivity of the former; higher specificity of the latter) were also not affected by ethnicity.

In the IDH study (Improving the Detection of Hypertension), which examined the overlap between ABPM and HBPM for the detection of masked hypertension in 333 community-dwelling unmedicated adults with office BP <140/90 mmHg, masked hypertension was defined by the presence of daytime (mean daytime BP ≥135/85 mmHg), 24-h (mean 24-h BP ≥130/80 mmHg), or nighttime (mean nighttime BP ≥120/70 mmHg) hypertension, and home masked hypertension was defined as mean BP ≥135/85 mmHg on HBPM [16]. The prevalence of masked hypertension was 25.8% for ambulatory masked hypertension and 11.1% for home masked hypertension. Among participants with masked hypertension on either ABPM or HBPM, 29.5% had masked hypertension on both ABPM and HBPM; 61.1% had masked hypertension only on ABPM; and 9.4% of participants had masked hypertension only on HBPM. After multivariable adjustment and compared with participants without masked hypertension on ABPM and HBPM, those with masked hypertension on both ABPM and HBPM and only on ABPM had a higher left ventricular mass index (mean difference, 12.7 g/m^2, $P < 0.001$; and 4.9 g/m^2, $P = 0.022$, respectively), whereas participants with masked hypertension only on HBPM did not have an increased left ventricular mass index (mean difference [SE], −1.9 [4.8] g/m^2, $P = 0.693$). Thus, ABPM and HBPM will detect many individuals with masked hypertension who have an increased cardiovascular disease risk [17].

When using the BP thresholds recommended in the 2017 ACC/AHA guidelines, the prevalence of ambulatory masked hypertension, daytime masked hypertension, 24-h masked hypertension, nighttime masked hypertension, and home masked hypertension were 40.6%, 21.8%, 25.6%, 32.1%, and 16.2%, respectively [16]. A higher percentage of participants had masked hypertension only on ABPM and masked hypertension on both ABPM and HBPM compared with the percentages when using the BP thresholds from the primary analysis. The prevalence of partial masked hypertension on either HBPM or ABPM and sustained hypertension on both ABPM and HBPM were 10.4% and 22.7%, respectively, in the Ohasama study [11].

These findings on the diagnostic agreement of HBPM with ABPM should take into account the imperfect reproducibility of the two methods, which is responsible for some diagnostic disagreement even if the same method (ABPM or HBPM) is performed twice, and suggest that in fact the diagnostic agreement between the two methods is better than suggested by these studies [13].

5.4 Diagnostic Value for Nocturnal Hypertension

In the past, nighttime BP has been measured by ABPM, but more recently nocturnal HBPM has also been developed for introduction into clinical practice [18–21].

Nocturnal hypertension is frequently found in high-risk patients having diabetes, chronic kidney disease, or sleep apnea, and thus the detection of nocturnal hypertension by ABPM or nocturnal HBPM and the management of uncontrolled nocturnal hypertension might be recommended even in patients with normotension that is well controlled by office and morning home BPs.

Nocturnal hypertension is defined by the threshold of 120/70 mmHg for ABPM. The diagnostic value of HBPM for nocturnal hypertension is not well established. However, several papers have demonstrated that nocturnal HBPM is valuable for the diagnosis of nocturnal hypertension diagnosed by ABPM. In our J-HOP study (N = 854), nighttime home systolic BP (the average of nighttime BPs measured automatically at 2:00, 3:00, and 4:00 am) was slightly higher than nighttime ambulatory systolic BP (difference, 2.6 mmHg; $P < 0.001$) [22]. A two-night home BP schedule (six readings) appears to be the minimum requirement for a reliable assessment of nighttime home BP—i.e., an assessment that shows reasonable agreement with ambulatory BP and reasonable association with the observed preclinical organ damage [23]. In a crossover study using information and communication technology (ICT)-based nocturnal HBPM, the reliability of nocturnal HBPM appeared to be similar whether the HBPM was adapted to the chosen bedtime of participants (measurement at 2, 3, and 4 h after a chosen bedtime) or measured at fixed time points (2:00, 3:00, and 4:00 am) [24].

The standard threshold to diagnose nocturnal hypertension using nighttime ambulatory BP is ≥120/70 mmHg. The 2017 ACC/AHA guidelines defined a threshold of nocturnal BP (110/65 mmHg) corresponding to clinic, home, and daytime BPs (all 130/80 mmHg) (Table 5.1). There are no guidelines on how to measure nocturnal HBPM (how many measurements on how many nights) and what the thresholds for nocturnal home hypertension should be. The J-HOP study, which is the first clinic-based prospective study using nocturnal HBPM, demonstrated that even after controlling morning BP, a risk of uncontrolled nocturnal hypertension remains [25]. The new criteria for nighttime BP threshold from the 2017 ACC/AHA guidelines might not contribute to a reduction in masked uncontrolled hypertension. A morning home systolic BP of 135 mmHg corresponds to a nighttime home systolic BP of 120 mmHg, which is the threshold defined by the Seventh Report of the Joint National Committee on Prevention, while the 110 mmHg threshold of the 2017 ACC/AHA guidelines corresponds to a morning home systolic BP of

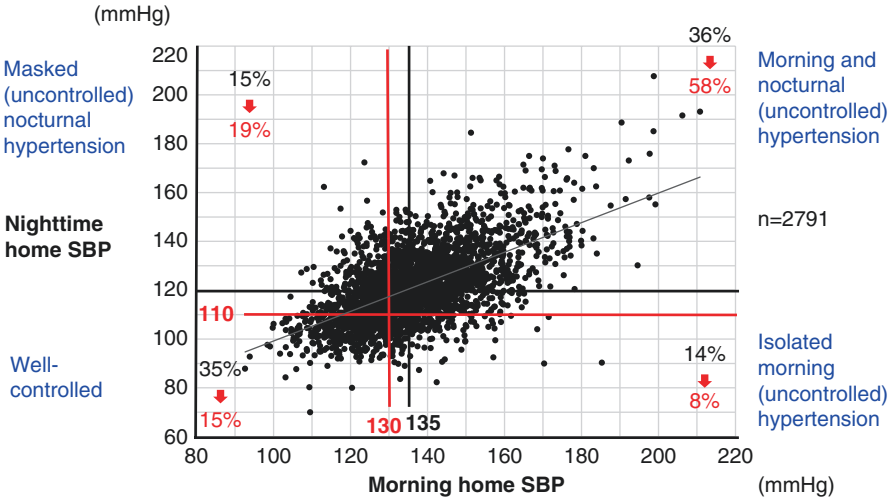

Fig. 5.2 Difference in the prevalence of nocturnal (uncontrolled) hypertension between the 2017 ACC/AHA guidelines (red) and the 2018 ESH/ECC guidelines (black) in subjects in the J-HOP study (Japan Morning Surge-Home Blood Pressure; 2791 medicated hypertensives). SBP, systolic blood pressure

130 mmHg. In those with well-controlled morning home systolic BP, a significant proportion of patients continue to have uncontrolled nocturnal hypertension (30% by the criteria of 135 mmHg for morning home systolic BP and 120 mmHg for nighttime SBP; 56% by the criteria of 130 mmHg for morning home systolic BP and 110 mmHg for nighttime SBP) (Fig. 5.2) [25]. Thus, to detect the residual risk of uncontrolled nocturnal hypertension, nocturnal HBPM would be recommended even in patients with well-controlled normotension based on clinic BP and/or morning home BPs.

5.5 Clinical Benefit of HBPM-Based Diagnosis of Hypertension

The most important diagnostic advantages of HBPM are that it employs a higher number of BP readings by repeated self-measurement compared to an office visit and that these are taken in the usual environment of which individual. To minimize the cardiovascular risk associated with raised blood pressure, uncontrolled hypertension should be controlled to below the target BP levels as soon as possible. Out-of-office BP is not stable, and it changes with various day-by-day personal and environmental conditions such as seasonal variation. By the real-world stress at that time, hypertension may be developed silently before visiting doctor's office. Ideally, self-measured HBPM should support the diagnosis of out-of-office hypertension without the characteristic delay of diagnoses based on the office and/or ABPM.

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