

## Emergence of Home Blood Pressure-Guided Management of Hypertension Based on Global Evidence

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Recent guidelines for the management of hypertension from the 2018 European Society of Cardiology/European Society of Hypertension and the 2017 American College of Cardiology (ACC)/American Heart Association (AHA)<sup>1,2</sup> have stressed the importance of out-of-office blood pressure (BP) measurement for hypertension management. There has been a similar emphasis on out-of-office BP monitoring for the management of hypertension in the United Kingdom, Canada, Japan, and other Asian countries.<sup>3-6</sup> Ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM) are 2 well-validated approaches for measuring out-of-office BP. In the published literature, HBPM is a term that has commonly referred to the self-measurement of BP at home, although in some studies, HBPM has been used to describe a provider or research assistant measuring an individual's BP in his/her home. ABPM and HBPM can identify white coat hypertension (diagnostic disagreement between office and out-of-office BP in untreated subjects) and white coat uncontrolled hypertension (diagnostic disagreement in treated subjects).<sup>1-8</sup> Although ABPM has been the preferred method for out-of-office measurement, the 2017 ACC/AHA BP guideline considered HBPM to be a more practical approach in clinical practice than ABPM, particularly for individuals taking antihypertensive medication. The 2014 Japanese Society of Hypertension Guidelines for the Management of Hypertension proposed HBPM as the most effective and practical for guiding antihypertensive medication initiation and titration in clinical care, while waiting for intervention trials demonstrating better cardiovascular outcomes in patients managed based on out-of-office BP levels.<sup>3,9,10</sup>

### Home BP Threshold of 135/85 mm Hg

A commonly recommended HBPM monitoring schedule consists of performing morning and evening BP measurements twice on each occasion over a minimum of 3 days with a preferred period of 7 days.<sup>1,11</sup> Traditionally, out-of-office BP thresholds have been determined by using the regression and outcome-derived approaches<sup>12</sup> with data from observational studies. The threshold for high out-of-office BP corresponding to an office BP threshold of 140/90 mm Hg has been determined to be 135/85 mm Hg for both home and daytime BP on ABPM.<sup>1,3-8</sup>

### Associations of Home BP With Cardiovascular Disease Outcomes

Previous prospective studies have demonstrated that individuals who have higher home BP levels have an increased risk of cardiovascular disease (CVD) (Table 1). This includes several observational studies conducted among community-based and clinic-based populations.<sup>13-26</sup>

### Community-Based Studies

The Ohasama study was the first to demonstrate that home BP measurement had a stronger predictive value for mortality than screening office BP measurement in a general population (Table 1).<sup>13</sup> Based on initial follow-up data from the Ohasama study in 1997, the outcome-derived reference value for hypertension based on home BP was proposed as 137/84 mm Hg, which supported the aforementioned threshold of 135/85 mm Hg.<sup>27</sup> In another population-based

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Table 1. Prospective Studies of Home BP Monitoring and Cardiovascular Events

|   |  | Measurement Period   | Outcomes  |
|---|--|--|---|
| Community-based study                                 |  |  |   |
| Ohkubo et al <sup>13</sup> ,<br>Ohasama study         | Japan (N=1789; age ≥40 y; mean follow-up, 6.6 y)   | 28-d HBPM (28 readings)  | Relative HR of cardiovascular mortality with a BP increase of 1 mm Hg was 1.021 (95% CI, 1.001–1.041; <i>P</i> <0.05).  |
| Okumiya et al <sup>26</sup> ,<br>Kahoku study         | Japan (N=1186; age, 73.5 y; follow-up, 4 y)  | 5-d HBPM (20 readings)   | Adjusted HRs for cardiovascular mortality of each HSBP ≥135–144 mm Hg, ≥145 mm Hg compared to HSBP 125–134 mm Hg (as reference) were 2.3 (95% CI, 1.0–5.6; <i>P</i> <0.05), 2.1 (0.9–5.0; <i>P</i> <0.1), respectively. |
| Sega et al <sup>14</sup> ,<br>PAMELA study†           | Italy (N=2051; age, 25–74 y; mean follow-up, 131 mo)   | 1-d HBPM (2 readings)  | HR of cardiovascular mortality with a BP increase of 1 mm Hg was 1.05 (95% CI, 1.04–1.06; <i>P</i> <0.0001).*   |
| Hänninen et al <sup>15</sup> ,<br>Finn-Home study     | Finland (N=2046; age, 44–74 y; follow-up, 7.5 y)   | 7-d HBPM (28 readings)   | Adjusted HR of MH for cardiovascular events compared to normotension was 1.62 (95% CI, 0.96–2.71; <i>P</i> =0.07).  |
| Tientcheu et al <sup>16</sup> ,<br>Dallas Heart study | United States (N=3027; age, 18–65 y; median follow-up, 9 y)  | 2 d in-home visit BP measurements (not by the self-measurement, but by trained research personnel; 10 readings)      | Adjusted HR of MH for composite cardiovascular events compared to normotension was 2.03 (95% CI, 1.36–3.03; <i>P</i> =0.0005).  |
| Ntineri et al <sup>17</sup> ,<br>Didima study         | Greece (N=665; mean age, 54 y; follow-up, 19 y)  | 3-d HBPM (12 readings)   | Adjusted HR of cardiovascular morbidity and mortality with an SBP increase of 10 mm Hg was 1.04 (95% CI, 0.94–1.15; <i>P</i> =0.45).  |
| Clinic-based study                                    |  |  |   |
| Bobrie et al <sup>18</sup> ,<br>SHEAF study‡          | France (4939 treated hypertensive patients; mean age, 70 y; mean follow-up, 3.2 y)                                       | 4-d HBPM (baseline HBP; 24 readings)   | Adjusted HR of fatal or nonfatal cardiovascular events with a BP increase of 1 mm Hg was 1.02 (95% CI, 1.01–1.02; <i>P</i> <0.001).   |
| Fagard et al <sup>19</sup>                            | Belgium (391 older outpatients; mean age, 71 y; follow-up, 10.9 y)   | 1-d HBPM (baseline HBP; 3 readings; not by self-measurement, by a physician or assist physician with mercury device) | Adjusted relative HR of cardiovascular events with a home BP increase of 1 SD (22.9 mm Hg) was 1.32 (95% CI, 1.06–1.64; <i>P</i> =0.01).  |
| Asayama et al <sup>20</sup> ,<br>HOMED-BP§            | Japan (3518 hypertensive patients; mean age, 59.6 y; median follow-up, 5.3 y)  | 5-d HBPM (follow-up HBP; 5 readings)   | Adjusted HR of fatal or nonfatal cardiovascular events with a home BP increase of 1 SD (13.2 mm Hg) was 1.47 (95% CI, 1.23–1.75; <i>P</i> <0.0001).   |
| Kario et al <sup>21</sup> ,<br>HONEST study           | Japan (21 591 hypertensive patients; mean age, 64.9 y; mean follow-up, 2.02 y)   | 2-d HBPM (follow-up HBP; 8 readings)   | HR of incidence of cardiovascular events for morning HSBP ≥145 mm Hg and CSBP ≥150 mm Hg compared to morning HSBP 125 mm Hg and OSBP <130 mm Hg was 3.92 (95% CI, 2.22–6.92).   |
| Hoshide et al <sup>23</sup> ,<br>J-HOP study¶         | Japan (4310 patients with a history of and risk factors for cardiovascular disease; mean age, 65 y; mean follow-up, 4 y) | 14-d HBPM (baseline HBP; 84 readings)  | Adjusted HR of stroke events with a home BP increase of 10 mm Hg was 1.36 (95% CI, 1.19–1.56; <i>P</i> <0.001).   |

BP indicates blood pressure; HBPM, home blood pressure monitoring; HR, hazard ratio; HSBP, home systolic BP; MH, masked hypertension; OSBP, office systolic BP and SBP, systolic BP.

\*Calculated from presented data of  $\beta$  coefficient and SE in this study. †Pressioni Arteriose Monitorate e Loro Associazioni (PAMELA) study; ‡Self-Measurement of Blood Pressure at Home in the Elderly: Assessment and Follow-up (SHEAF) study; §Hypertension Objective Treatment Based on Measurement by Electrical Devices of Blood Pressure (HOMED-BP); ||Home Blood Pressure Measurement With Olmesartan Naive Patients to Establish Standard Target Blood Pressure (HONEST) study; ¶Japan Morning Surge-Home Blood Pressure (J-HOP) study.

study of 1186 community-dwelling elderly residents of a rural Japanese town, systolic home BP  $\geq 135$  mm Hg versus 125 to 134 mm Hg was associated with an almost 4 $\times$  higher risk of mortality. Systolic home BP <125 mm Hg was also associated with an increased risk of mortality. The population-based PAMELA study (Pressioni Arteriose Monitorate e Loro Associazioni) demonstrated that the risk of death was progressively higher according to increasing home or ambulatory BP level compared to office BP level, despite only 2 home BP readings being obtained for each participant.<sup>14</sup> In

the Finn-Home Study, masked hypertension, defined as office BP <140/90 mm Hg with home BP  $\geq 135/85$  mm Hg, was associated with a statistically significantly higher age-adjusted risk of CVD events and a higher risk of all-cause mortality after adjustment for age, sex, and office BP compared with normotension (adjusted hazard ratios, 1.64; [95% CI, 1.01–2.67]; and 2.09 [95% CI, 1.17–1.34]).<sup>15</sup> In the Dallas Heart Study, both white coat hypertension (adjusted hazard ratio, 2.09 [95% CI, 1.05–4.05]) and masked hypertension (adjusted hazard ratio, 2.03 [95% CI, 1.36–3.03]), defined using an

office BP threshold of 140/90 mmHg and home BP threshold of 135/85 mmHg, were each associated with higher incidence of CVD events compared with normotension, even after adjustment for traditional cardiovascular risk factors.<sup>16</sup> However, in the Dallas Heart Study, home BP readings were not self-measured but were obtained by research staff on 2 occasions at the individual's home. The Didima study, which had the longest follow-up (mean 19 years), demonstrated that compared to normotension, sustained hypertension (hypertension both in the office and in the out-of-office setting), masked hypertension, and white coat hypertension were each associated with an increased risk of death and CVD. In adjusted models, the risk of death remained statistically significantly higher for sustained hypertension, masked hypertension, and white coat hypertension, whereas the risk for CVD remained statistically significant only for white coat hypertension.<sup>17</sup>

### Clinic-Based Studies Exploring the Role of Office and Out-of-Office BP in Patients Treated for Hypertension

A prospective study conducted among older French adults taking antihypertensive medication reported that those with masked uncontrolled hypertension, defined as office BP <140/90 mmHg and home BP  $\geq$ 135/85 mmHg, had a statistically significantly higher risk of CVD events (hazard ratio, 2.06 [95% CI, 1.22–3.47]) compared to participants who had controlled hypertension, defined as office BP <140/90 mmHg and home BP <135/85 mmHg (Table 1). The risk of CVD events associated with masked uncontrolled hypertension was similar to that of uncontrolled hypertension (hazard ratio, 1.96 [95% CI, 1.27–3.02]), defined as office BP  $\geq$ 140/90 mmHg and home BP  $\geq$ 135/85 mmHg.<sup>18</sup> In a registry consisting of older adults, aged  $\geq$ 60 years, the prognostic value of home BP was superior to that of office BP, and was similar to or better than daytime systolic BP (SBP) and daytime diastolic BP, respectively.<sup>19</sup> The multicenter HOMED BP (Hypertension Objective Treatment Based on Measurement by Electrical Devices of Blood Pressure) demonstrated that the 5-year risk of CVD events was low ( $\leq$ 1%) if on-treatment home SBP was <131.6 mmHg.<sup>20</sup> The HONEST (Home Blood Pressure Measurement With Olmesartan Naive Patients to Establish Standard Target Blood Pressure) Study, the largest prospective study (n=21 591) of home BP conducted to date, demonstrated that higher on-treatment morning home BP was associated with a statistically significant increased risk for CVD events. In this study, cardiovascular risk was increased in participants with morning home SBP  $\geq$ 145 mmHg and office SBP <130 mmHg (hazard ratio, 2.47 [95% CI, 1.20–5.08]) compared with morning home SBP <125 mmHg and office SBP <130 mmHg. Using a spline regression analysis, the morning home SBP level associated with the lowest CVD risk was 124 mmHg.<sup>21</sup> Morning home SBP was more closely associated with the risk of both stroke and coronary artery disease events compared with office SBP.<sup>22</sup> The J-HOP study (Japan Morning Surge-Home Blood Pressure), a nationwide practice-based study, demonstrated that morning home SBP  $\geq$ 135 mmHg was associated with a statistically significant higher stroke risk than morning home SBP <135 mmHg, and morning SBP improved the discrimination of incident stroke (C statistic,

0.802) beyond traditional risk factors including office SBP (C statistic, 0.756). Better discrimination of incident stroke was present for morning versus evening SBP (C statistic, 0.802 versus 0.764).<sup>23</sup> In J-HOP, masked uncontrolled hypertension, defined as office BP <140/90 mmHg and home BP  $\geq$ 135/85 mmHg was associated with increased stroke risk.<sup>24</sup>

Moreover, in a recent post hoc analysis, a home SBP <125 mmHg was associated with the lowest risk of CVD events in high-risk individuals with hypertension and diabetes mellitus or a history of stroke.<sup>25</sup> These data suggest that patients may receive additional CVD risk reduction benefits by achieving a home BP of <125 mmHg, especially among high-risk individuals with hypertension. However, on-treatment home BP targets should be evaluated in large randomized controlled outcome trials.

### Trial Evidence for Improved Hypertension Control With Self-Monitoring of Home BP

There is now a large body of empirical evidence indicating better BP control with HBPM.<sup>28</sup> Uhlig et al<sup>29</sup> conducted a systematic review and meta-analysis of 52 studies that compared HBPM to usual care. The results showed that HBPM alone without co-interventions (ie, one-to-one counseling, remote telemonitoring, and educational classes) to be associated with lower BP at 6 months but not 12 months compared with usual care. However, compared with usual care, HBPM when given with co-interventions was associated with a reduction in BP at 12 months. In a more recent systematic review and meta-analysis, Tucker et al<sup>28</sup> identified 25 trials that compared HBPM to usual care. HBPM was more effective than usual care at lowering BP at 12 months, but this effect was strongly influenced by whether co-interventions were given. There was no difference in BP comparing HBPM alone without co-interventions (web/phone feedback, education, in-person counseling or telecounseling) versus usual care. In contrast, there was a reduction in BP when HBPM was combined with co-interventions, with the reduction increasing with the intensity of co-intervention. The results of both systematic reviews and meta-analyses suggest that the benefits of HBPM on BP control are greatest when given with interventions.

More recent studies using 135/85 mmHg as the home BP target have shown better BP control with HBPM with or without telemonitoring versus usual care.<sup>30,31</sup> Similar or better BP lowering has been observed in individuals titrating their own antihypertensive medication using HBPM under medical supervision.<sup>32,33</sup> Two studies showed that treatment titration aiming at achieving home BP levels <135/85 mmHg improved indices of subclinical organ damage.<sup>34,35</sup> Stergiou et al<sup>36</sup> showed that compared to a strategy combining ABPM and office BP monitoring, HBPM resulted in similar outcomes in terms of end-organ damage regression. Longer-term follow-up of self-BP monitoring trials suggests that these benefits are sustained.<sup>37</sup> The benefits of HBPM may be mediated through the optimization of antihypertensive therapy (eg, reduction of clinical inertia) combined with increased medication adherence.<sup>38</sup>

Taken together, these results provide strong evidence suggesting that the use of HBPM to guide antihypertensive management may lead to better BP control, particularly when



accompanied by co-interventions. Finally, data indicate that HBPM with or without telemonitoring is cost-effective when compared to office BP measurement or usual care in individuals with hypertension.<sup>39-43</sup>

### Home BP Threshold of 130/80 mm Hg

The 2017 ACC/AHA BP Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults<sup>2</sup> suggested lower BP thresholds (ie, office BP goal of 130/80 mmHg) with the aim of preventing organ damage and CVD events.<sup>44</sup> At lower BP levels, the differences between office and home or daytime ambulatory BP values are smaller.<sup>45</sup> Data from observational studies using the regression and outcome-derived approaches suggest that the BP threshold for having high BP corresponding to an office BP of 130/80 mmHg is 130/80 mmHg for home and daytime BP on ABPM.<sup>12</sup>

The 2017 ACC/AHA BP guideline definition for hypertension status (office BP  $\geq$ 130/80 mmHg and home BP  $\geq$ 130/80 mmHg) has markedly changed the prevalence of hypertension subtypes compared to prior thresholds (ie, office BP  $\geq$ 140/90 mmHg and home BP  $\geq$ 135/85 mmHg). In the J-HOP study,<sup>44</sup> a general practice-based national registry of home BP, the prevalence of normotension, white coat uncontrolled hypertension, masked uncontrolled hypertension, and sustained hypertension was 31%, 15%, 19%, and 36%, respectively according to the thresholds (ie, 140/90 mmHg for office BP and 135/85 mmHg for home BP) proposed by the previous Joint National Committee 7 and the 2018 European Society of Cardiology/European Society of Hypertension guidelines. The prevalence of normotension, white coat uncontrolled hypertension, masked uncontrolled hypertension, and sustained hypertension was 14%, 17%, 10%, and 58%, respectively, according to the 2017 ACC/AHA BP guideline threshold definitions (ie, 130/80 mmHg for both office BP and home BP).<sup>44</sup> Thus, the greatest impact of the reclassification of hypertension is an increased prevalence of sustained hypertension and lower prevalence of normotension. The population-based Ohasama study also demonstrated similar changes in the distribution of these 4 hypertension subtypes.<sup>46,47</sup>

A recent analysis of the Ohasama study demonstrated that partial masked hypertension, defined as having masked hypertension on HBPM but not ABPM or alternatively on ABPM but not HBPM, and complete masked hypertension, defined as having masked hypertension on both ABPM and HBPM, were associated with a similar risk for stroke events, when masked hypertension was defined using the BP thresholds of either the 2017 ACC/AHA BP guideline or the 2018 European Society of Cardiology/European Society of Hypertension guideline.<sup>46</sup>

A recent analysis of the Dallas Heart Study (n=5768) and the North Carolina Masked Hypertension study (n=420) used the regression-based approach to determine home BP thresholds corresponding to office BP of 130/80 mmHg. Home BP was measured by research staff visiting the participants' home in the Dallas Heart Study, whereas home BP was self-measured in the North Carolina Masked Hypertension study. In these studies, home BP thresholds were 129/80 mmHg in black participants, 130/80 mmHg in white participants, and

126/78 mmHg in Hispanic participants.<sup>48</sup> According to an outcome-derived approach based on the composite of CVD events or all-cause mortality over 11 years of follow-up of Dallas Heart Study participants, the home SBP thresholds corresponding to office SBP of 130 mmHg were 130 mmHg in black participants, 129 mmHg in white participants, and 131 mmHg in Hispanic participants. Home BP thresholds were identified using the outcomes-based approach for SBP only as home diastolic BP was not associated with outcomes. Both the regression-derived and outcome-derived approaches in these studies support a home BP threshold of 130/80 mmHg for hypertension status in several racial/ethnic groups.<sup>48</sup> As these data are supported primarily by observational studies, randomized controlled trials should examine whether lowering of home BP leads to a reduction in cardiovascular events and also determine the optimal BP thresholds to define hypertension.<sup>49</sup>

There are several ongoing studies based on use of out-of-office BP in hypertension management. The INFINITY (Intensive Versus Standard Blood Pressure Lowering to Prevent Functional Decline in Older People Trial) recently demonstrated that intensive BP reduction to target 24-hour ambulatory SBP to  $<$ 130 mmHg resulted in slower progression of subcortical white matter disease in hypertensive adults of 75 years or older. However, no benefit in the cognitive or functional outcome was observed. The HIPAC trial ([Hypertension, Intracranial Pulsatility, and Brain A-Beta Accumulation in Older Adults], URL: <http://www.clinicaltrials.gov>. Unique identifier: NCT03354143) and MASTER ([Masked-Uncontrolled Hypertension Management Based on Office BP or on Ambulatory Blood Pressure Measurement] study, URL: <http://www.clinicaltrials.gov>. Unique identifier: NCT02804074)<sup>50</sup> will further clarify its role in the management of hypertension and prevention of target organ complications.

The Asia BP@Home study, the first study designed to investigate home BP control status in different Asian countries/regions using standardized home BP measurements taken with the same validated HBPM device, which has data memory capabilities, demonstrated that home BP is relatively well controlled at hypertension specialist centers.<sup>51</sup> However, almost half of all patients had uncontrolled morning BP according to the 2017 ACC/AHA BP guideline, with significant country/regional differences. In a study that enrolled 1443 patients taking antihypertensive medication from 15 Asian specialist centers in 11 countries/regions between April 2017 and March 2018, BP was controlled in 68.2% of patients using a morning home SBP normality cutoff of  $<$ 135 mmHg, and in 55.1% of patients using an office SBP cutoff of  $<$ 140 mmHg. However, when the cutoff values were changed to the 2017 ACC/AHA BP guideline threshold (SBP  $<$ 130 mmHg), only 53.6% of patients had controlled morning home SBP.<sup>51</sup>

### Morning and Nocturnal Home BP

There are 3 subtypes of masked hypertension: morning hypertension, daytime hypertension, and nocturnal hypertension.<sup>44</sup> Although the current reference standard for identifying all 3 types of masked hypertension is ABPM,<sup>52</sup> HBPM can also be used.

Four studies conducted in Asia (Ohasama, J-HOP, HOMED BP, and HONEST) demonstrated that morning

home BP was a predictor of future CVD events.<sup>13,20–23</sup> The measurement of home BP during the morning period has been recommended before taking medications in several guidelines.<sup>1–3</sup> The 2018 European Society of Cardiology/European Society of Hypertension guidelines recommend HBPM being performed during the morning and evening, with the latter being measured before dinner. However, in Asian countries, individuals usually eat dinner before returning home from work, and in Japan, adults usually take an evening bath. For this reason, evening home BP measurement just before bedtime is recommended,<sup>3–6</sup> and in the absence of evening home BP measurement, morning home BP measurement alone may be sufficient for identifying hypertension as a first step toward home BP-guided management and has been successful in self-titration studies.<sup>4,5,32,33</sup> An additional advantage of conducting morning BP measurements before taking medications is the ability to detect through BP levels among individuals taking antihypertensive medications in the morning.<sup>53</sup>

In addition to controlling morning and evening home BP, the control of nocturnal BP should be considered since evidence suggests it is the most important aspect of the 24-hour BP profile for predicting the risk for CVD outcomes.<sup>54,55</sup> In the past, nighttime BP could only be measured with ABPM, but more recently, new HBPM devices have been developed that measure nighttime BP.<sup>56,57</sup> These devices automatically measure and store BP readings at preprogrammed times (eg, 2 AM, 3 AM, and 4 AM) or at a fixed time period after going to bed (eg, 2, 3, and 4 hours after going to bed). The device is removed by the person the next morning, after awakening. The minimum number of readings and the interval for obtaining a reliable estimate of nocturnal home BP have not been determined.<sup>58</sup> Nocturnal hypertension is common among high-risk patients, including those with diabetes mellitus, chronic kidney disease, or sleep apnea. The J-HOP study showed that nocturnal home BP was more closely associated with hypertensive organ damage than office, morning home, and evening home BP. Among individuals with controlled morning home BP (<135/85 mm Hg), uncontrolled nocturnal BP ( $\geq 120/70$  mm Hg) has been associated with increased urinary albumin/creatinine ratio and plasma NT-proBNP (N-terminal pro-B-type natriuretic peptide).<sup>59</sup> In the J-HOP study, nocturnal home SBP was a stronger predictor of CVD events than office and morning home SBP measurements.<sup>60</sup> It has been shown that there is good agreement between HBPM and ABPM for detecting nondippers.<sup>61</sup> A recent meta-analysis showed that ABPM and nocturnal HBPM provide similar BP values and associations with target organ

damage.<sup>62</sup> Thus, either ABPM or nocturnal HBPM may be useful for detecting nocturnal hypertension and nondippers and for the management of uncontrolled nocturnal BP.

In prior studies, an office BP of 140/90 mm Hg has corresponded with a nighttime BP of 120/70 mm Hg and a home BP and daytime BP on ABPM of 135/85 mm Hg (Table 2). Also, for an office BP of 130/80 mm Hg, which corresponds to a 130/80 mm Hg threshold for home BP and daytime BP on ABPM, the 2017 ACC/AHA BP guideline recommends a nighttime BP threshold of 110/65 mm Hg for having nocturnal hypertension (Table 2). A large proportion of patients with controlled morning home SBP have uncontrolled nighttime SBP: 30% using a 120 mm Hg threshold for nighttime SBP; and 56% using a 110 mm Hg threshold for nighttime SBP.<sup>63</sup> Thus, nocturnal HBPM may identify individuals with controlled morning BP who have high nighttime SBP and residual CVD risk, especially among those who at increased risk for having nocturnal hypertension (eg, those with CKD, sleep apnea, or diabetes mellitus).

### Additional Measures on HBPM

Additional information provided by HBPM should also be investigated for possible clinical relevance. In particular, increased day-by-day BP variability on HBPM has been reported to be associated with increased CVD risk, independent of average home BP level in both general and clinical populations.<sup>17,64–66</sup> Further, large seasonal home BP variation and inverse seasonal home BP changes (ie, an increase in home BP during the summer compared to the winter) have been associated with an increased risk of CVD events in individuals taking antihypertensive medication.<sup>67</sup>

### Barriers to HBPM

HBPM requires a long-term commitment from patients in taking their BP over days or weeks. Clinicians are often concerned that some patients may obtain self-home measurements too frequently leading to additional consultations and may self-modify their treatment inappropriately.<sup>68</sup> Furthermore, variation in BP may lead to concerns. Also, HBPM devices without memory function capabilities require reliance on the individual to document their BP readings. Some previous studies have suggested that such documentation may be erroneous although more recent data suggest that 90% or more of readings are accurate.<sup>69</sup> Providers are concerned about the use of nonvalidated HBPM devices, lack of knowledge of where to purchase validated devices, and lack of knowledge of standardized HBPM protocols.<sup>70</sup> An additional barrier is that providers may not have time to properly train patients.<sup>68</sup> Finally, practices may not have the infrastructure to implement co-interventions.

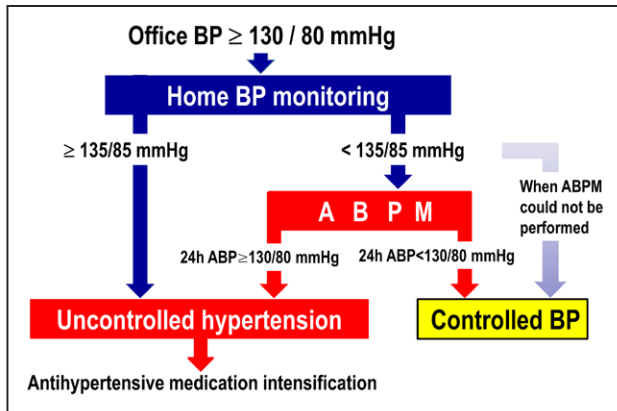
### Follow-Up Strategy for Treated Hypertensive Individuals Using HBPM and ABPM

The Figure shows a strategy for those already on treatment of hypertension based on office BP, HBPM, and ABPM that we recommend. Among individuals with office BP  $\geq 130/80$  mm Hg, HBPM should be conducted to exclude white coat uncontrolled hypertension. Individuals are diagnosed with

**Table 2. Corresponding Values of Clinic, Home, Daytime, Nighttime, and 24-Hour BP Measurements (2017 American College of Cardiology/American Heart Association Guidelines)**

| Clinic  | HBPM   | Daytime ABPM | Nighttime ABPM | 24-Hour 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 indicates ambulatory blood pressure monitoring; BP, blood pressure; and HBPM, home blood pressure monitoring.



**Figure.** Follow-up strategy of treated individuals with uncontrolled office hypertension. This approach is not representative of the 2017 American College of Cardiology/American Heart Association BP guideline. ABPM indicates ambulatory blood pressure monitoring; and BP, blood pressure.

uncontrolled hypertension if home BP  $\geq 135/85$  mmHg. If white coat uncontrolled hypertension is concerned or there is evidence of target organ damage among individuals with home BP  $< 135/85$  mmHg, ABPM should be performed. Individuals are diagnosed with controlled BP if ABPM  $< 130/80$  mmHg in 24 hours. For the detection of masked uncontrolled hypertension, HBPM may also be performed in individuals with treated hypertension who have office BP  $< 130/80$  mmHg if baseline cardiovascular risk is high.

### Conclusions

There is strong evidence that high home BP is associated with increased CVD risk. HBPM can be used to identify specific hypertension phenotypes such as white coat hypertension, masked hypertension, white coat uncontrolled hypertension, and masked uncontrolled hypertension. Morning hypertension, based on the average of morning home BP readings, and nocturnal hypertension, based on the average of nighttime BP readings on nocturnal HBPM can be detected by newer HBPM devices. The proposal of using lower office BP and home BP thresholds by the 2017 ACC/AHA BP guideline (ie, 130/80 mmHg for both office BP and home BP) has raised new perspectives about hypertension diagnosis and management, but has also added some uncertainties in this field. Randomized controlled trials are needed to define the optimal home BP threshold and target goal for the appropriate use of HBPM in routine management of hypertension, including investigations focused on the nocturnal home BP levels.

### Perspectives

In the era of exponential progress in the field of information and communication technology, having home BP values self-measured by patients daily, and remotely sent to electronic health records and providers may increase the accuracy of hypertension diagnosis, and the efficacy of its management, in particular when HBPM is accompanied by co-interventions. In addition, HBPM accompanied by information on patients' living conditions could provide integrated data that might more precisely guide hypertension management, thus helping to reduce CVD risk.<sup>71</sup> Available evidence suggests that HBPM is an important adjunct to office BP measurement for

the diagnosis of hypertension and for monitoring BP control among patients taking antihypertensive medication. In addition, HBPM may itself have a favorable impact on hypertension control, by improving medication adherence. Although office BP remains the standard method for evaluating BP in real-world clinical practice, data from systematic reviews and meta-analyses suggest that HBPM particularly when accompanied by co-interventions reduces BP and is associated with a higher rate of BP control. Therefore, HBPM is an important tool for the management of hypertension.

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