Masked Hypertension Assessed by Ambulatory Blood Pressure Versus Home Blood Pressure Monitoring: Is It the Same Phenomenon?

George S. Stergiou, Eleanna V. Salgami, Dimitris G. Tzamouranis, and Leonidas G. Roussias

Background: Masked hypertension is defined as normal clinic blood pressure (CBP) and elevated out-of-clinic blood pressure assessed using either self-monitoring of blood pressure (BP) by the patients at home (HBP) or ambulatory BP (ABP) monitoring. This study investigated the level of agreement between ABP and HBP in the diagnosis of masked hypertension.

Methods: Participants referred to an outpatient hypertension clinic had measurements of CBP (two visits), HBP (4 days), and ABP (24 h). The diagnosis of masked hypertension based on HBP (CBP <140/90 mm Hg and HBP ≥135/85) versus ABP (CBP <140/90 and awake ABP ≥135/85) was compared.

Results: A total of 438 subjects were included (mean age ± SD, 51.5 ± 11.6 years; 59% men and 41% women, 34% treated and 66% untreated). Similar proportions of subjects with masked hypertension were diagnosed by ABP (14.2%) and HBP (11.9%). In both treated and untreated subjects, the masked hypertension phenomenon was as common as the white coat phenomenon. Among 132 subjects with normal CBP, there was disagreement in the diagnosis of masked hypertension between the HBP and the ABP method in 23% of subjects for systolic and 30% for diastolic BP (κ 0.56). When a 5–mm Hg gray zone for uncertain diagnosis was applied to the diagnostic threshold, the disagreement was reduced to 9% and 6% respectively.

Conclusions: Similar proportions of subjects with masked hypertension are detected by ABP and HBP monitoring. Although disagreement in the diagnosis between the two methods is not uncommon, in the majority of these cases the deviation of the diagnostic BP above the threshold in not clinically important. Both ABP and HBP monitoring appear to be appropriate methods for the detection of masked hypertension. Am J Hypertens 2005;18: 772–778 © 2005 American Journal of Hypertension, Ltd.

Key Words: Masked hypertension, self-monitored home blood pressure, ambulatory blood pressure.

Monitoring of blood pressure (BP) out of the office has found wide application in clinical practice, mainly for the detection of the white coat hypertension.1–3 Masked hypertension has recently attracted great attention as a phenomenon with potential clinical significance.4–6 The term has been proposed to describe subjects with hypertension that remains undetected (normal BP in the clinic) until out-of-office BP is measured.4 The phenomenon is common,7–10 yet its clinical significance only recently has been investigated.11 The Self measurement of blood pressure at home in the Elderly: Assessment and Follow-up (SHEAF) study, which provided prospective data in 4939 treated hypertensive subjects followed for 3.2 years, showed that cardiovascular risk in subjects with masked hypertension is identical to that in subjects with uncontrolled hypertension (ie, those with elevated office BP and out-of-office BP).11

Out-of-office BP can be assessed using either ambulatory BP monitoring (ABP) or self-monitoring of BP by the patients at home (HBP).3,12,13 These methods have important similarities in that they both provide multiple measurements taken away from the clinic.3,12 On the other
hand, they also have important differences in that HBP monitoring provides measurements on multiple days in the sitting posture at home, whereas ABP monitoring provides 24-h measurements in ambulatory conditions, at home, at work, and during sleep.\textsuperscript{3,12}

As it is the case for white coat hypertension, masked hypertension can also be detected using either ABP or HBP monitoring.\textsuperscript{4,5,13} In regard to white coat hypertension, it is generally accepted that ABP monitoring should be the gold standard method for diagnosis and that HBP monitoring should be used as a screening method that requires confirmation by ABP monitoring.\textsuperscript{3,12–16} This is because virtually all of the evidence regarding the clinical significance of white coat hypertension has been based on studies using ABP monitoring, and because ABP has better prognostic data than HBP associated with its use.\textsuperscript{3,17,18}

In contrast to white coat hypertension, the prognostic significance of masked hypertension has been proved by using HBP instead of ABP measurements in the above-mentioned SHEAF study.\textsuperscript{11} In regard to ABP, there are only cross-sectional studies showing that subjects with masked hypertension have increased ventricular mass index and carotid wall thickness compared with those of subjects with true normotension.\textsuperscript{8,19} Thus, it might be argued that HBP rather than ABP monitoring should be the reference method for the diagnosis of masked hypertension.

The objective of this study was to investigate the level of agreement between ABP and HBP monitoring in the diagnosis of masked hypertension.

**Subjects and Methods**

**Subjects**

Study participants were untreated or treated subjects referred to the outpatient hypertension clinic for elevated BP. All participants had their BP assessed by using a standard protocol for clinic BP (CBP), ABP, and HBP monitoring in the context of prospective clinical trials conducted from 1997 to 2003. Criteria for exclusion were repeated systolic CBP $>180$ mm Hg and/or diastolic $>110$ mm Hg, and any change in antihypertensive treatment or in treatment with drugs known to influence BP at least 4 weeks before and during the study.

**Blood Pressure Measurements**

Blood pressure was measured in the clinic, at home, and with ambulatory monitoring, within 4 weeks. The CBP measurements were taken during two study visits, 2 to 4 weeks apart, after at least one pre-study visit. Measurements were taken by physicians who fulfilled the British Hypertension Society Protocol criteria for agreement among observers in BP measurement.\textsuperscript{20} Triplicate CBP measurements were performed at each visit after 5 min sitting rest and with at least 1 min between recordings, using standard mercury sphygmomanometers (bladder size $12 \times 24 \text{ cm or } 15 \times 35 \text{ cm as appropriate}$). The second and the third CBP measurements of the two study visits were averaged to give a single value per individual.

The HBP was measured on 6 routine workdays within 2 weeks using validated fully automated electronic devices, Omron HEM-705CP or OMRON IC\textsuperscript{21} (Omron Healthcare GmbH, Hamburg, Germany), with a bladder size $12 \times 23 \text{ cm or } 14 \times 28 \text{ cm as appropriate}$. Participants were trained in the conditions of HBP measurement and the use of the devices and were instructed to perform duplicate morning (7 to 10 AM; before drug intake for treated subjects) and evening (6 to 9 PM) measurements after 5 min sitting rest and with 1 min between recordings. In addition to the device printout, a form was supplied to the patients to report HBP values. The average of all HBP readings after excluding readings of the initial day was used in the analysis.

The ABP was measured on a routine workday, before or after the HBP monitoring period by using validated oscillometric devices SpaceLabs 90207 or 90217\textsuperscript{21} (SpaceLabs Inc., Redmond, WA). The bladder size was $12 \times 23 \text{ cm or } 14 \times 30 \text{ cm as appropriate}$, and measurements were taken at 20-min intervals for 24 h. The average of awake ABP, calculated using individual patients’ sleeping hours, was used in the analysis.

**Definition of Masked Hypertension**

Two definitions of masked hypertension were used on the basis of CBP and either ABP or HBP measurements. On the basis of ABP monitoring masked hypertension was defined as CBP $<140/90$ mm Hg and awake ABP $\geq 135/85$ mm Hg.\textsuperscript{8,9,19} On the other hand, on the basis of HBP monitoring masked hypertension was defined as CBP $<140/90$ mm Hg and average HBP $\geq 135/85$ mm Hg.\textsuperscript{8,10}

**Statistical Analysis**

Subjects who had fewer than three clinic visits were excluded from the analysis. The ABP data and additional recorded information from the report files generated by the ABP monitor device were batch imported and organized in a relational database (Microsoft Access 2000; Microsoft Corp., Redmond, WA) using a Visual Basic program. This program (designed by L.G.R.) for statistical analysis of ABP-derived data reads the ASCII text files generated by the ABP monitor and performs multiple data procedures and analyses. Any ABP recordings with $<30$ successful awake BP measurements were excluded from the analysis (readings taken during daytime sleep were discarded). Subjects who provided $<12$ valid HBP readings or readings taken on $<3$ days were also excluded. Editing criteria for HBP and ABP readings were as previously described.\textsuperscript{15}

Statistical analysis was performed using the Minitab Statistical Software, release 13.31 (Minitab Inc., PA). The Student $t$ test was used for the comparison of CBP, HBP, and ABP measurements, with Bonferroni correction for multiple comparisons applied where appropriate. The Stu-
dent paired t test was used for the comparison of BP values obtained using different methods in the same subjects. The \( \kappa \) statistic (\( \kappa \)) was used for the assessment of the levels of agreement between the two diagnostic methods. Results are expressed as means \( \pm \) SD. A probability value of \( P < .05 \) was considered statistically significant.

**Results**

Data from 438 subjects were included in the analysis. Mean age was 51.5 \( \pm \) 11.6 years, 260 (59\%) were men and 150 (34.2\%) were on antihypertensive drug treatment.

### Table 1. Characteristics of study participants and blood pressure levels in the clinic (CBP), at home (HBP), and with awake ambulatory monitoring (ABP)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Untreated ( N = 288 )</th>
<th>Treated ( N = 150 )</th>
<th>All ( N = 438 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>48.5 ( \pm ) 11.0</td>
<td>57.3 ( \pm ) 10.4</td>
<td>51.5 ( \pm ) 11.6</td>
</tr>
<tr>
<td>Men/Women</td>
<td>177/111 (61%/39%)</td>
<td>83/67 (55%/45%)</td>
<td>260/178 (59%/41%)</td>
</tr>
<tr>
<td>CBP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>144.7 ( \pm ) 15.7</td>
<td>138.1 ( \pm ) 15.8</td>
<td>142.5 ( \pm ) 16.0</td>
</tr>
<tr>
<td>Diastolic</td>
<td>94.2 ( \pm ) 9.1</td>
<td>85.0 ( \pm ) 8.8</td>
<td>91.0 ( \pm ) 10.0</td>
</tr>
<tr>
<td>HBP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>138.8 ( \pm ) 15.1*</td>
<td>132.6 ( \pm ) 13.9*</td>
<td>136.7 ( \pm ) 15.0*</td>
</tr>
<tr>
<td>Diastolic</td>
<td>88.7 ( \pm ) 9.1*</td>
<td>81.3 ( \pm ) 7.4*</td>
<td>86.2 ( \pm ) 9.3*</td>
</tr>
<tr>
<td>ABP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>140.8 ( \pm ) 13.8*</td>
<td>132.0 ( \pm ) 12.4*</td>
<td>137.8 ( \pm ) 13.9*</td>
</tr>
<tr>
<td>Diastolic</td>
<td>91.3 ( \pm ) 10.6*</td>
<td>81.4 ( \pm ) 9.2*</td>
<td>87.9 ( \pm ) 11.2*</td>
</tr>
</tbody>
</table>

Data are mean \( \pm \) SD (in mm Hg).

* \( P < .001 \) for differences from the corresponding CBP value.

FIG. 1. Plots of clinic blood pressure (CBP) versus daytime ambulatory (ABP) and home blood pressure (HBP) with regression lines. By applying cutoff points of normality (140/90 mm Hg for CBP and 135/85 mm Hg for ABP and HBP, dotted lines) subjects are divided into four groups: group A, normotensive subjects; group B, hypertensive subjects; group C, subjects with the white coat effect phenomenon; group D, subjects with the masked hypertension phenomenon. BP = blood pressure; \( r \) = correlation coefficient.

Demographic characteristics and BP levels of all participants and of treated and untreated subjects are presented in Table 1.

Figure 1 presents plots of CBP versus out-of-clinic BP with correlation coefficients (\( r \)). By using the thresholds of normality for each method, subjects were divided into groups comprising normotensive subjects, hypertensive subjects, and those with white coat or masked phenomenon. The correlation coefficient \( r \) between the CBP–ABP and the CBP–HBP difference was 0.62/0.59 for systolic/diastolic BP (\( P < .0001 \)). The correlation coefficients of these differences with CBP values were 0.58/0.36 and 0.47/0.46 respectively (\( P < .0001 \) for all \( r \) values).

Masked hypertension was detected in 62 subjects (14.2\%) using ABP and in 52 (11.9\%) using HBP monitoring (\( P = \text{NS} \)) (Fig. 2). The proportions of normotensive subjects, hypertensive subjects, and subjects with white coat or masked hypertension, detected by each method in all study participants and in both treated and untreated subjects, are shown in Table 2. Subjects with masked hypertension detected by ABP monitoring had significantly lower HBP and a tendency for higher ABP (significant for 24-h dia-
stolic ABP, data not shown) than those with masked hypertension detected by HBP monitoring (Table 3).

There was disagreement between ABP and HBP monitoring in the diagnosis of masked hypertension (systolic and/or diastolic) in 44 subjects. In all, 27 subjects were classified as having masked hypertension on the basis of elevated ABP only (the HBP being normal), and 17 subjects were classified with the reverse (ie, elevated HBP and normal ABP) (Fig. 3). A total of 35 subjects were classified as subjects with masked hypertension by both ABP and HBP. In the untreated group, disagreement between ABP and HBP in the diagnosis of masked hypertension was found in 19 subjects (51% of untreated subjects with masked hypertension diagnosed by either HBP or ABP) and in the treated group in 25 subjects (59%). There was no difference between treated subjects with discrepant HBP and ABP and the rest of treated subjects in regard to the number of antihypertensive drugs and the type of drug treatment. However, these data are based on small numbers, and therefore definite conclusions cannot be drawn.

The level of agreement between ABP and HBP monitoring in the diagnosis of masked hypertension was further evaluated in 132 subjects, either treated or untreated, who had normal CBP (<140/90 mm Hg) (Fig. 4). There was disagreement in the diagnosis of masked hypertension between ABP and HBP monitoring in 23% of subjects for systolic and 30% for diastolic BP (κ = 0.56, suggesting good agreement between methods). Discordance between the two methods was found in 33% of subjects when both systolic and diastolic BP were taken into account.

When a 5-mm Hg gray zone for uncertain diagnosis was applied to the diagnostic threshold for ambulatory and home hypertension, the proportion of disagreement between methods in the diagnosis of masked hypertension was reduced to 9% and 6% for systolic and diastolic BP respectively (10.6% when both systolic and diastolic BP were considered).

Figure 5 presents individuals with masked hypertension diagnosed only by ABP or only by HBP monitoring. In the majority of these cases (70%), the rise in ABP or HBP above the diagnostic threshold (135 mm Hg for systolic and 85 mm Hg for diastolic BP) was ≤5 mm Hg.

**Discussion**

This study performed a direct comparison of the diagnosis of masked hypertension made on the basis of the two different methods for out-of-office BP measurement (ABP and HBP monitoring) in the same subjects. The major finding is that disagreement in the diagnosis between the

**Table 2.** Proportions of normotensive subjects, hypertensive subjects, and subjects with the white coat or masked hypertension phenomenon detected using awake ambulatory blood pressure (ABP) or home blood pressure (HBP) monitoring in treated and untreated subjects

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Untreated, N = 288</th>
<th>Treated, N = 150</th>
<th>All, N = 438</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABP No. (%)</td>
<td>HBP No. (%)</td>
<td>ABP No. (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normotensive</td>
<td>27 (9)</td>
<td>38 (13)</td>
<td>43 (28)</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>195 (68)</td>
<td>192 (67)</td>
<td>242 (55)</td>
</tr>
<tr>
<td>White coat hypertensive</td>
<td>33 (12)</td>
<td>36 (13)</td>
<td>64 (15)</td>
</tr>
<tr>
<td>Masked hypertensive</td>
<td>33 (12)</td>
<td>22 (8)</td>
<td>62 (14)</td>
</tr>
</tbody>
</table>

**Table 3.** Characteristics of subjects with masked hypertension diagnosed by using home blood pressure (HBP) or awake ambulatory blood pressure (ABP) monitoring

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ABP N = 62</th>
<th>HBP N = 52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>52.9 ± 10.7</td>
<td>54.7 ± 11.4</td>
</tr>
<tr>
<td>Men/Women</td>
<td>37/25 (60%/40%)</td>
<td>36/16 (69%/31%)</td>
</tr>
<tr>
<td>CBP Systolic</td>
<td>128.8 ± 7.4</td>
<td>130.9 ± 5.6</td>
</tr>
<tr>
<td>CBP Diastolic</td>
<td>83.9 ± 5.1</td>
<td>83.4 ± 6.6</td>
</tr>
<tr>
<td>HBP Systolic</td>
<td>131.2 ± 9.6</td>
<td>138.1 ± 9.5*</td>
</tr>
<tr>
<td>HBP Diastolic</td>
<td>83.0 ± 4.9</td>
<td>85.1 ± 5.1†</td>
</tr>
<tr>
<td>ABP Systolic</td>
<td>137.9 ± 7.4</td>
<td>135.1 ± 10.5</td>
</tr>
<tr>
<td>ABP Diastolic</td>
<td>87.9 ± 7.2</td>
<td>85.5 ± 8.4</td>
</tr>
</tbody>
</table>

Data are mean ± SD (in mm Hg).
* P < .001, † P < .05 for differences from subjects with masked ABP.
The prevalence of masked hypertension has been reported to be at 10–20% depending on the definition used. In the Ohasama population study, a 13.4% prevalence has been reported among subjects with normal screening BP, whereas in the PAMELA population study in Italy, a 9% prevalence was found among untreated subjects. In the SHEAF study in France, 11% of participants had masked hypertension. In line with these findings, a 12% to 14% prevalence of masked hypertension was found in the present study in subjects referred to a hypertension clinic. An important practical question regarding masked hypertension concerns what the chance is for a subject who comes to the clinic or office because of elevated BP, and who is found to be normal based on repeated measurements, to have masked hypertension. This issue was addressed in this study by analyzing the subgroup of study participants who had normal CBP. In these subjects normal tension was confirmed by out-of-clinic measurements in only 54% to 61%, whereas an alarming 39% to 46% had elevated ABP and/or HBP despite a normal CBP (Fig. 4).

It should be emphasized, however, that, despite the normal CBP, these subjects should not be regarded as truly normotensive subjects, because they were referred to a hypertension clinic for elevated BP and their BP was found normal after repeated measurements in the clinic. These findings suggest that all subjects with a history of elevated BP are candidates for out-of-office BP monitoring, even if their BP is normalized in repeated clinic measurements.

The major issue addressed in this study is whether ABP or HBP monitoring or both are appropriate methods for the diagnosis of masked hypertension. Similar proportions of subjects with masked hypertension were detected by the two methods in this study (Fig. 2). The PAMELA population study also reported similar prevalence of masked hypertension detected using ABP or HBP monitoring. Interestingly, in both treated and untreated subjects, the masked phenomenon was as common as the white coat phenomenon (Table 2), suggesting that both phenomena are equally important for the practicing physician. Masked hypertension tended to be more common among treated subjects (Table 2). This was also the case for the white coat phenomenon and suggests that disagreement in the diagnoses made by the two methods might be more common in treated subjects. Differences in the effect of treatment on HBP and ABP in different subjects regarding the peak and trough drug effect might have affected the study results. Furthermore, chance phenomena resulting from the small size of the subgroups might account for these findings.

The similarity in the prevalence of masked hypertension detected by ABP and HBP monitoring does not necessarily mean that the same individuals are detected by the two methods. Indeed, in only half of the subjects with masked hypertension in this study was the diagnosis confirmed by both methods, whereas in the rest the diagnosis was not confirmed by the alternative method (masked hypertension diagnosed only by ambulatory blood pressure monitoring [ABP] in panels A and B or only by home [HBP] monitoring in panels C and D). Distribution of deviation of individuals’ ABP or HBP above the diagnostic threshold (135/85 mm Hg). Dotted lines indicate a 5-mm Hg zone above which the deviation is clinically important.
was made by ABP but not by HBP monitoring, or the reverse. These data are in line with the findings of the PAMELA study, in which half of the subjects with masked hypertension diagnosed by ABP monitoring had normal HBP or the reverse.8

In the case of masked hypertension confirmed by both ABP and HBP monitoring, the physician will probably feel confident to ignore CBP measurements and to base decisions on out-of-office measurements. This approach is fully justified, because of the strong evidence showing superior prognostic value of ABP compared with CBP3,17,18 and because of the recent evidence on the prognostic significance of masked hypertension detected by HBP monitoring.11 However, this study showed that disagreement in the diagnosis of masked hypertension between ABP and HBP monitoring is not uncommon (23% to 30%) (Fig. 4).

To investigate cases involving masked hypertension in which the disagreement in the diagnosis was doubtful, a 5–mm Hg zone of uncertainty was applied above the diagnostic threshold for hypertension determined by ABP or HBP (Fig. 4). By using this gray zone for uncertain diagnosis, the proportion of subjects with disagreement between ABP and HBP monitoring was reduced from 23% and 30% for systolic and diastolic BP to 9% and 6% respectively (Fig. 4). Indeed, in 70% of subjects with masked hypertension diagnosed by only one of the two methods, the deviation of the diagnostic out-of-office BP above the threshold (<5 mm Hg) was not clinically important (Fig. 5).

On the basis of the above findings, it can be concluded that clinically important disagreement between ABP and HBP monitoring in the diagnosis of masked hypertension is uncommon. Differences in physical activity and emotional challenges during the day might account for the limited reproducibility of out-of-office BP measurements23 and might explain the large discrepancy between the two methods that was observed in some individuals. In addition, technical differences among the devices used for CBP, HBP, and ABP measurements might account, at least in part, for the differences found among methods. Masked hypertension diagnosed on the basis of a small rise in the diagnostic out-of-office BP above the threshold (<5 mm Hg) should be regarded as questionable. Repeated testing or the use of the alternative technique for out-of-office BP measurement might be required for the reliable diagnosis in these cases. Therefore, the two methods appear to be interchangeable in the diagnosis of the majority of subjects with masked hypertension. It might be argued, however, that for the long-term follow-up of treated subjects with masked hypertension, HBP monitoring is more appropriate than ABP because of its lower cost and greater convenience for repeated measurements.3,13

References


