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Diagnosing Masked Hypertension Using Ambulatory Blood Pressure Monitoring, Home Blood Pressure Monitoring, or Both?

D. Edmund Anstey, MD MPH[a], **Paul Muntner, PhD**[b], **Natalie A. Bello, MD MPH**[a], **Daniel N. Pugliese, MD**[a], **Yuichiro Yano, MD PhD**[c], **Ian M. Kronish, MD MPH**[a], **Kristi Reynolds, PhD MPH**[d], **Joseph E. Schwartz, PhD**[a,e], and **Daichi Shimbo, MD**[a]

[a]Columbia University Medical Center, New York, New York

[b]University of Alabama at Birmingham, Birmingham, Alabama

[c]University of Mississippi Medical Center, Jackson, MS

[d]Kaiser Permanente Southern California, Pasadena, CA

[e]Stony Brook University, Stony Brook, New York

Abstract

Guidelines recommend measuring out-of-clinic blood pressure (BP) to identify masked hypertension (MHT) defined by out-of-clinic BP in the hypertensive range among individuals with clinic-measured BP not in the hypertensive range. The aim of this study was to determine the overlap between ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM) for the detection of MHT. We analyzed data from 333 community-dwelling adults not taking antihypertensive medication with clinic BP<140/90 mmHg in the Improving the Detection of Hypertension Study. Any MHT was defined by the presence of daytime MHT (mean daytime BP≥135/85 mmHg), 24-hour MHT (mean 24-hour BP≥130/80 mmHg), and/or nighttime MHT (mean nighttime BP≥120/70 mmHg). Home MHT was defined as mean BP≥135/85 mmHg on HBPM. The prevalence of MHT was 25.8% for any MHT and 11.1% for home MHT. Among participants with MHT on either ABPM and/or HBPM, 29.5% had MHT on both ABPM and HBPM; 61.1% had MHT only on ABPM; and 9.4% of participants had MHT only on HBPM. After multivariable adjustment and compared to participants without MHT on ABPM and HBPM, those with MHT on both ABPM and HBPM and only on ABPM had a higher left ventricular mass index (mean difference [standard error, SE] 12.7 [2.9] g/m^2, p<0.001; and 4.9 [2.1] g/m^2, p=0.022, respectively), whereas participants with MHT 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). These data suggest that conducting ABPM will detect many individuals with MHT who have an increased cardiovascular disease risk.

Address Correspondence and Reprint Requests: D. Edmund Anstey, MD MPH, Columbia University Medical Center, 622 West 168th Street, PH 9-310, New York, NY 10032, Phone / Fax: (212) 342-4490 / (212) 342-3431, dea2123@cumc.columbia.edu.

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Keywords

Masked hypertension; cardiovascular risk; left ventricular mass; ambulatory blood pressure; ambulatory blood pressure monitoring; home blood pressure monitoring

Some adults with blood pressure (BP) not in the hypertensive range when measured in the clinic have levels in the hypertension range when measurements are obtained outside of the clinic setting, a phenotype known as masked hypertension (MHT).[1] Compared to individuals with sustained normotension, defined by the absence of hypertension both in and outside of the clinic setting, individuals with MHT have an increased risk for cardiovascular disease (CVD) and target organ damage.[2,3]

There are two primary methods of measuring out-of-clinic BP to diagnose MHT: ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM). Currently, there is little evidence to determine whether ABPM, HBPM, or both modalities should be used to detect MHT among individuals not taking antihypertensive medication. A prior study by Stergiou et. al. assessed the prevalence of MHT according to both ABPM and HBPM.[4] In this analysis, only 44% of individuals with MHT had elevated BP outside of the clinic according to both ABPM and HBPM, with the remainder having MHT detected by ABPM only (34%) or HBPM only (22%). However, this study included patients from a hypertension clinic, one-third of whom were taking antihypertensive medication. Further, MHT on ABPM was defined using only daytime BP. More recent guidelines from the European Society of Hypertension / European Society of Cardiology (ESH/ESC) have recommended that MHT be defined by the presence of daytime, 24-hour and/or nighttime hypertension.[5] Despite this recommendation, few published data are available on the overlap between ABPM and HBPM for detecting MHT when daytime, 24-hour, and nighttime BP on ABPM are used to identify MHT.

The primary aim of this study was to compare the prevalence of MHT when out-of-clinic BP is measured by ABPM versus HBPM in individuals not taking antihypertensive medications. A secondary aim of this study was to compare levels of left ventricular mass index (LVMI), a measure of cardiovascular target-organ damage, between participants without MHT on ABPM and HBPM, MHT only on ABPM, MHT only on HBPM, and MHT on both ABPM and HBPM.

Methods

Sample Population

The data that support the findings of this study are available from the corresponding author upon reasonable request. The Improving the Detection of Hypertension (IDH) Study is a community-based study of adults in the metropolitan New York City area designed to compare strategies for diagnosing ambulatory hypertension. Between March 2011 and October 2013, the IDH Study enrolled 408 adults age 18 years or older, without a history of treated hypertension.[6,7] Study exclusion criteria were: clinic systolic BP ≥160 mmHg or diastolic BP ≥105 mmHg during a screening visit; evidence of secondary hypertension; taking antihypertensive medication; taking other medications that affect BP (e.g., steroids,

tricyclic antidepressants, etc.); a self-reported history of CVD, kidney, liver, adrenal, thyroid, rheumatologic, or hematologic diseases; organ transplantation; cancer or dementia; or current pregnancy. The study protocol was approved by the Institutional Review Board at Columbia University and all participants provided written informed consent.

For the current analysis, participants were excluded if they did not have complete clinic BP data (n = 3), did not have complete ABPM data (n = 15) or complete HBPM data (n = 3), or did not have echocardiography data (n = 5). Criteria for defining complete clinic BP, ABPM, and HBPM are provided below. As this study focused on participants with MHT, we further restricted the analysis to those with mean clinic systolic BP <140 mmHg and mean clinic diastolic BP <90 mmHg at Visit 1, leaving a final analytic sample of 333 participants for the primary analysis.

Study Procedures

Demographic information (i.e., age, sex, race/ethnicity) was ascertained at the time of study enrollment using a self-administered questionnaire and information regarding cardiovascular risk factors including smoking status, current use of antihypertensive medication, and self-reported diabetes status was ascertained during a structured interview. Eligible participants attended five visits (Visits 1 to 5) over approximately a four-week period. Clinic BP was measured at Visits 1, 3, and 4, ABPM was performed for 24-hours following Visit 1, and HBPM was conducted by the participants for three weeks, beginning after Visit 2. Echocardiography and laboratory measures were performed at Visit 5.

Laboratory Measures.

Urine and fasting blood samples were obtained from participants. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation based on serum creatinine.[8] Albuminuria was defined as urine albumin-to-creatinine ratio ≥30 mg/g. Chronic kidney disease was defined as having reduced eGFR (defined as <60 mL/min/1.73m^2) or albuminuria.

Clinic BP.

Clinic BP was measured following a standardized protocol. After resting in a seated position for five minutes, BP was measured in triplicate with at least one minute between readings by a trained research nurse/technician using a mercury sphygmomanometer (Baum, Copiague, NY) and an appropriate-sized arm cuff.[9] Complete clinic BP data was defined as having three readings at Visit 1, which were averaged.

ABPM.

After clinic BP was measured at Visit 1, participants were trained in the use of a validated ABPM device (Spacelabs Model 90207[10]; Snoqualmie, WA) and fitted with an appropriate-sized arm cuff and a wrist actigraphy device (ActiWatch; Phillips Respironics, Murrayville, PA). Ambulatory BP measurements were taken at 30-minute intervals throughout the subsequent 24-hour period and the device was returned the next day. The nighttime and daytime periods were defined by the onset of asleep and awake periods, assessed using the wrist actigraphy device supplemented by participant diary reports. Using the International

Database of Ambulatory Blood Pressure in relation to Cardiovascular Outcome (IDACO) criteria,[11] participants with ≥10 daytime and ≥5 nighttime readings were considered to have a complete ABPM recording. The BP readings during the daytime, 24-hour, and nighttime period were averaged to obtain mean daytime BP, mean 24-hour BP, and mean nighttime BP, respectively.

HBPM.

After returning the ABPM device (Visit 2), participants were given a HBPM device, Omron HEM-790IT (HEM-7080-ITZ2)[12] or HEM-791IT (HEM-7222-ITZ),[13] with an appropriate-sized cuff and trained on its use. Participants were instructed to obtain home BP measurements in the seated position after five minutes of rest with one minute between readings, and to measure their BP twice in the morning immediately after awakening and twice before going to bed for three consecutive weeks. BP readings were automatically stored in the memory of the HBPM device with time and date stamps, and directly extracted by study staff. For the current analysis, participants with 16 or more HBPM readings were considered to have complete HBPM data. All of the BP readings were averaged to obtain mean home BP.

2D Echocardiography.

After returning the HBPM device, participants returned for a two-dimensional echocardiogram. Standard images were acquired, and primary measures of left ventricular (LV) dimensions, volumes, and wall thickness were obtained according to recommendations from the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACI).[14] LV mass (LVM, g) was calculated using the ASE formula. LVMI (g/m2) was calculated as LVM divided by body surface area derived by the DuBois method.[15]

Definitions of Hypertension Categories

Clinic hypertension was defined as mean clinic systolic BP ≥140 mmHg or mean clinic diastolic BP ≥90 mmHg. Systolic and diastolic BP thresholds for daytime, 24-hour, and nighttime hypertension, which are based on US and international guidelines,[5,16] are shown in Table S1 As the current analysis only included participants with mean clinic systolic BP <140 mmHg and mean clinic diastolic BP <90 mmHg, those with daytime, 24-hour, nighttime, and home hypertension met criteria for daytime MHT, 24-hour MHT, nighttime MHT, and home MHT, respectively. Any MHT was defined as having MHT for any ABPM period (i.e. daytime MHT, 24-hour MHT, and/or nighttime MHT).

Participants were categorized as having MHT on both ABPM and HBPM, MHT on ABPM but not HBPM (MHT only on ABPM), MHT on HBPM but not ABPM (MHT only on HBPM), and without MHT on ABPM and HBPM. Classifications were done for each type of MHT (any MHT, daytime MHT, 24-hour MHT, and nighttime MHT) on ABPM and Home MHT.

Statistical Analyses

Participant characteristics were calculated for the overall analytic sample and by categories defined by the cross-classification of any MHT and home MHT status. The prevalence of each type of MHT on ABPM (any, daytime, 24-hour, and nighttime MHT) and MHT on HBPM was calculated. Also, we determined the proportion of participants within categories defined by the cross-classification of the status of each type of MHT on ABPM and home MHT.

Next, the difference in mean LVMI between participants with versus without each type of MHT on ABPM was calculated in an unadjusted model using one-way Analysis of Variance (ANOVA), and in a model adjusting for age, sex, race (Black or not), ethnicity (Hispanic or not), and current smoking using Analysis of Covariance (ANCOVA). The adjusted model did not include body mass index, since LVM was indexed to body surface area, and both body mass index and body surface area are derived from height and weight. The analysis was repeated with MHT on HBPM.

Differences in mean LVMI between categories defined by the cross-classification of MHT on ABPM and MHT on HBPM with the reference group being those without MHT on ABPM and HBPM, were determined in an unadjusted one-way ANOVA model, and in an ANCOVA model adjusting for age, sex, race, and ethnicity. Secondary analyses were performed by replacing any MHT with daytime MHT, 24-hour MHT, and nighttime MHT, one at a time.

Four sensitivity analyses were performed. First, the primary analyses were repeated after restricting the sample to participants with mean clinic systolic BP <130 mmHg and mean clinic diastolic BP <80 mmHg (N=234) at Visit 1, which is the threshold for clinic hypertension in the 2017 American College of Cardiology (ACC) / American Heart Association (AHA) BP guideline.[17] Hypertension status on ABPM and HBPM was also defined using BP thresholds from the 2017 ACC/AHA BP guideline (Table S1). Second, the analyses were repeated after the sample was restricted to participants with mean clinic systolic BP <140 mmHg and a mean clinic diastolic BP <90 mmHg (N=309) at each of the 3 study visits at which clinic BP measurement was assessed (Visits 1, 3, and 4). Third, the analyses were repeated after the sample was restricted to participants with a complete ABPM defined according to European Society of Hypertension (ESH) guideline criteria[18] (N=309) instead of IDACO criteria: 20 daytime measurement, 7 nighttime measurements, and 24-hour recording with at least 70% of expected measurements. Finally, the analyses were repeated after using the HBPM data collected during the first 7 days of HBPM recording (N=333).

Results

Baseline Characteristics

In the cohort included in these analyses, the mean (standard deviation [SD]) age was 40.1 (12.9) years, 61.3% of participants were female, and 24.3% and 61.9% were Black and Hispanic, respectively (Table 1). Also, 1.5% of participants had diabetes and 4.8% had chronic kidney disease. The mean (SD) clinic systolic and diastolic BP were 112.2 (11.6)

mmHg and 73.7 (8.0) mmHg, respectively. The mean (SD) number of daytime BP and nighttime BP readings on ABPM were 30 (5) and 13 (3), respectively. The mean (SD) number of HBPM readings was 82 (20).

Prevalence of MHT on ABPM and MHT on HBPM

Among participants without clinic hypertension, the prevalence of any MHT on ABPM was 25.8% and 11.1% for Home MHT. The prevalence of daytime, 24-hour, and nighttime MHT were 17.4%, 17.7% and 19.5%, respectively. When any ABPM period was used to define MHT, 71.5% did not have MHT on ABPM and HBPM, 8.4% of participants had MHT on both ABPM and HBPM, 17.4% had MHT only on ABPM, and 2.7% of participants had MHT only on HBPM (Table 2). Among the participants with MHT on ABPM and/or HBPM, 29.5% had MHT on both ABPM and HBPM, 61.1% had MHT only on ABPM, and only 9.4% had MHT only on HBPM (Figure 1). Among participants with MHT on ABPM and/or HBPM, 18.3%, 19.2%, and 20.7% of participants, respectively, had MHT only on HBPM when the daytime, 24-hour, and nighttime period were examined.

Associations of MHT Defined by ABPM and HBPM with LVMI

Compared to participants without MHT, those with any MHT, daytime MHT, 24-hour MHT, nighttime MHT, and home MHT each had a higher LVMI in unadjusted and adjusted models (Table S2).

Associations of Categories Defined by the Cross-Classification of Each Type of MHT on ABPM and Home MHT Status with LVMI

Compared to those without any MHT on ABPM and HBPM (reference group), LVMI was higher among participants with MHT only on ABPM (adjusted mean difference [standard error (SE)] 4.9 [2.1] g/m^2, p=0.022) and participants with MHT on both ABPM and HBPM (adjusted mean difference [SE] 12.7 [2.9] g/m^2, p<0.001) (Table 3). In contrast, compared to those without MHT on ABPM and HBPM, participants with MHT only on HBPM did not have a higher LVMI (adjusted mean difference [SE] –1.9 [4.8] g/m^2, p=0.693).

Compared to the reference group, LVMI was higher among participants with MHT on both ABPM and HBPM when MHT on ABPM was defined using the daytime period (adjusted mean difference [SE] 11.0 [3.1] g/m^2, p<0.001), and separately, the 24-hour period (adjusted mean difference [SE] 13.2 [3.2], p<0.001). Compared to the reference group, adjusted differences [SE] in LVMI were 4.0 [2.6] g/m^2 for participants with MHT only on ABPM (p=0.126), and 3.7 [4.1] g/m^2 for participants with MHT only on HBPM (p=0.367) when using the daytime period on ABPM. Also, compared to the reference group, adjusted differences [SE] in LVMI were 4.3 [2.6] g/m^2 for participants with MHT only on ABPM (p=0.093), and 1.1 [3.9] g/m^2 for participants with MHT only on HBPM (p=0.788) when using the 24-hour period on ABPM. Further, when MHT on ABPM was examined using the nighttime period, LVMI was higher among participants with MHT only on ABPM (adjusted mean difference [SE] 7.5 [2.3] g/m^2, p=0.001) and MHT on both ABPM and HBPM (adjusted mean difference [SE] 14.7 [3.3] g/m^2, p<0.001). Finally, compared to the reference group, adjusted mean difference [SE] in LVMI was 3.4 [3.6] g/m^2 for participants with MHT only on HBPM (p=0.343).

Sensitivity Analyses Applying the BP Thresholds From the 2017 ACC/AHA BP Guideline

When using the BP thresholds recommended in the 2017 ACC/AHA BP guideline, the prevalence of any MHT, daytime MHT, 24-hour MHT, nighttime MHT, and home MHT were 40.6%, 21.8%, 25.6%, 32.1%, and 16.2% respectively. A higher percentage of participants had MHT only on ABPM, and MHT on both ABPM and HBPM compared to the BP thresholds used in the primary analysis (Table S3). Among participants with MHT on ABPM and/or HBPM, the greatest proportion of participants had MHT only on ABPM (Figure S1). When all ABPM periods were used to define MHT, compared with the participants without MHT on ABPM and HBPM (reference group), adjusted mean difference [SE] in LVMI was 4.0 [2.1] g/m^2 (p=0.053) for participants with MHT only on ABPM, 11.2 [5.0] g/m^2 (p=0.027) for participants with MHT only on HBPM, and 12.5 [2.7] g/m^2 (p<0.001) for those with MHT on both ABPM and HBPM (Table S4).

Sensitivity Analyses Among Participants without Clinic Hypertension at Visits 1, 3, and 4

When the sample size was restricted to participants with a mean clinic systolic BP <140 mmHg and a mean clinic diastolic BP <90 mmHg at Visits 1, 3, and 4, the prevalence of any MHT, daytime MHT, 24-hour MHT, nighttime MHT, and home MHT was 23.0%, 14.2%, 14.6%, 17.2%, and 8.1% respectively. The distribution of participants with MHT on ABPM, HBPM, or both was similar to the primary analysis (Table S5). When all ABPM periods were used to define MHT, compared to participants without MHT on ABPM and HBPM (reference group), the adjusted mean difference [SE] in LVMI was 4.6 [2.2] g/m^2 (p=0.033) for participants with MHT only on ABPM, −0.1 [5.3] g/m^2 (p=0.985) for participants with MHT only on HBPM, and 11.4 [3.5] g/m^2 (p=0.001) for those with MHT on both ABPM and HBPM (Table S6).

Additional Sensitivity Analyses

The prevalence of BP phenotypes and their associations with LVMI did not change when using the ESH[18] versus IDACO[11] criteria for a complete ABPM (data not shown). When repeating the analyses using the HBPM data collected during the first 7 days of HBPM, the findings were also similar to the corresponding analyses using all HBPM recordings (data not shown).

Discussion

In the current study, we examined the overlap between ABPM and HBPM for detecting MHT and the associations of MHT categories, defined by the cross-classification of MHT on ABPM and MHT on HBPM, with LVMI in individuals not taking antihypertensive medications. The majority of participants with MHT had it on ABPM with or without it on HBPM, whereas a small percentage of participants with MHT had it on HBPM but not ABPM.

Consistent with the current results, prior population-based studies of individuals without clinic hypertension have shown that the prevalence of MHT differs when defined using ABPM or HBPM; ranging from 14% to 30% when assessed using daytime and/or 24-hour periods on ABPM and 12% to 18% when assessed using HBPM.[19–22] There is also evidence

to suggest that MHT prevalence differs by the period examined on ABPM.[19,23] In an analysis of individuals in IDACO without clinic hypertension and not taking antihypertensive medication, the prevalence of MHT was 14% when using the 24-hour period, 19% when using the daytime period, and 28% when using any period (daytime, 24-hour, and/or the nighttime period) on ABPM.[21] In the current study, the prevalence of nighttime MHT (19.5%) was slightly higher than the prevalence of daytime MHT (17.4%) or 24-hour MHT (17.7%). These findings are consistent with prior data from the Jackson Heart Study, a cohort of African Americans, where the prevalence of nighttime MHT was also higher than the prevalence of daytime MHT and 24-hour MHT (48.2%, 28.2% and 31.7%, respectively).[23]

In the current study, participants with MHT on ABPM and, separately, participants with MHT on HBPM each had increased LVMI compared to participants without MHT. Although these results suggest that MHT is associated with increased CVD risk regardless of which out-of-clinic BP monitoring approach is performed, there is controversy regarding whether ABPM or HBPM is the best approach in clinical practice to diagnose MHT.[16,24] Compared to HBPM, there are more studies demonstrating an association of ABPM with CVD risk.[16,25] Further, ABPM has been the reference standard for measuring BP during the nighttime period and assessing diurnal patterns. However, in the US, ABPM is not widely available in primary care settings,[16] and reimbursement for ABPM is low.[26] HBPM may also be more practical for routine clinical practice as it more widely available and is associated with greater patient acceptability and tolerability.[16,20] Whether using ABPM or HBPM is the superior approach is further complicated by many individuals having MHT on one modality but not the other. Prior studies found that among those with MHT on ABPM and/or HBPM, only 36% to 45% of participants had MHT detected on both ABPM and HBPM.[4,27,28] These studies only examined the daytime[4,27] or 24-hour[28] periods on ABPM and analyzed participants taking and not taking antihypertensive medication pooled together. In 2013, the ESH/ESC hypertension guidelines recommended using all periods (i.e. daytime, 24-hour, and nighttime) on ABPM to detect MHT, and that the term MHT be used only for those not taking antihypertensive medication.[5] In the current study, which only includes individuals not taking antihypertensive medication, 90.6% of participants with MHT had MHT on ABPM with or without it on HBPM when using all periods to define MHT on ABPM, whereas only 9.4% with MHT had it detected only on HBPM. When the daytime, 24-hour, and nighttime period were examined separately, 18.3% to 20.7% of participants had MHT only on HBPM. These findings suggest that only a small proportion of individuals with MHT would not be detected if ABPM was conducted without HBPM, and all periods were used to define MHT on ABPM.

MHT is associated with poor prognosis, including increased CVD risk and all-cause mortality.[29,30] However, few data exist on the CVD risk associated with MHT when present on ABPM and not HBPM or when present on HBPM but not ABPM.[24] In the primary analysis, participants with MHT detected on ABPM with or without MHT on HBPM, had a higher LVMI compared to participants without MHT on ABPM and HBPM, whereas LVMI was not higher among participants with MHT only on HBPM. In contrast, in a sensitivity analysis using BP thresholds from the 2017 ACC/AHA BP guideline, LVMI was higher among participants with MHT only on HBPM. Therefore, it is unclear whether individuals

with MHT only on HBPM are at increased CVD risk. In a prior study by Satoh et al.,[28] among participants without hypertension based on BP measured in the clinic setting in the Ohasama Study, stroke risk was higher among participants with 24-hour MHT on ABPM but without MHT on HBPM (HR 1.93, 95% CI 1.15 – 3.24) and MHT on HBPM without 24-hour MHT on ABPM (HR 2.26, 95% CI 1.32 – 3.89) compared to individuals with sustained normotension, defined as not having hypertension on 24-hour BP on ABPM and HBPM. One potential explanation for the discrepant results is the outcome was LVMI in the current study and stroke in the Ohasama Study.[28] Additionally, in the Ohasama Study, the sample size of participants with MHT only on HBPM was substantially greater (N=75) than in the current study (N=9). Therefore, our study may be underpowered to examine the relation between LVMI and MHT only on HBPM in both the primary and sensitivity analyses.

If individuals with MHT only on HBPM are at increased CVD risk, HBPM may be warranted if ABPM is initially performed and MHT is not present. However, this approach is unlikely to be cost-effective as individuals would have to undergo both ABPM and HBPM, and the prevalence of having MHT on HBPM among individuals without any MHT on ABPM is very low (9/247 = 3.6%). An alternative approach would be to conduct ABPM if MHT is absent on HBPM. However, many individuals would need to undergo both ABPM and HBPM since a substantial proportion (58/296 = 19.6%) of individuals without MHT on HBPM have any MHT on ABPM. Therefore, despite practical concerns regarding the widespread implementation of ABPM,[7,16,24,31] it may be preferable to HBPM since it will detect the vast majority of participants with MHT.

This study has several strengths. The IDH Study enrolled a community-based sample with a high representation of Hispanics and Blacks. In addition, both ABPM and HBPM were performed under standardized conditions among the same participants. Further, all BP readings on HBPM were automatically recorded in the devices' memory, overcoming potential issues regarding inaccurate reporting of readings by participants.[32,33] Finally, we examined all time periods on ABPM, allowing us to examine how different time periods on ABPM affect the overlap between MHT on ABPM and MHT on HBPM.

There are also possible limitations. As previously mentioned, the sample size was small for some of the groups defined by the cross-classification of MHT on ABPM and HBPM, and we were unable to conduct subgroup analyses by age, sex or race/ethnicity. The analysis was restricted to individuals not taking antihypertensive medication and, therefore, the findings may not be generalizable to those taking antihypertensive medication. Further, although a large proportion of the sample was Black or Hispanic, it is unknown if the findings from the current study are generalizable to other race/ethnic populations. Finally, the IDH Study was cross-sectional and CVD outcomes were not assessed.

Perspectives

Many individuals without clinic hypertension have MHT, which cannot be detected using clinic BP measurements alone. While ABPM and HBPM both measure out-of-clinic BP, some individuals may be diagnosed as having MHT on one modality but not the other. The results of the current study indicate that among those with MHT detected using ABPM

and/or HBPM, the majority had MHT on ABPM with or without it on HBPM, where a minority had MHT only on HBPM. Compared to participants without MHT on ABPM and HBPM, participants with MHT on both modalities and participants with MHT only on ABPM had higher LVMI, whereas those with MHT only on HBPM did not have increased LVMI. MHT only on HBPM was associated with increased LVMI when 2017 ACC/AHA BP guideline-recommended thresholds were used. These findings suggest that using ABPM is essential for detecting most individuals with MHT who are at high CVD risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Novelty and Significance

What is New

- Few studies have previously examined the overlap between masked hypertension (MHT) on ambulatory blood pressure monitoring (ABPM) using different periods on ABPM and MHT on home blood pressure monitoring (HBPM) among individuals not taking antihypertensive medication.
- A large majority of participants with MHT had MHT on ABPM with or without MHT on HBPM, whereas a small minority of participants with MHT had it detected only by HBPM.
- Individuals with MHT detected by ABPM only, or both ABPM and HBPM, had an increased left ventricular mass index (LVMI) compared to those without MHT on ABPM and HBPM. Those with MHT only on HBPM did not have increased LVMI.

What is Relevant

- MHT is associated with an increased risk of target-organ damage and cardiovascular disease (CVD) events.
- This study has direct relevance to whether ABPM or HBPM should be routinely used to detect MHT among individuals not taking antihypertensive medication.

Summary

- ABPM detects many individuals with MHT who have increased CVD risk.

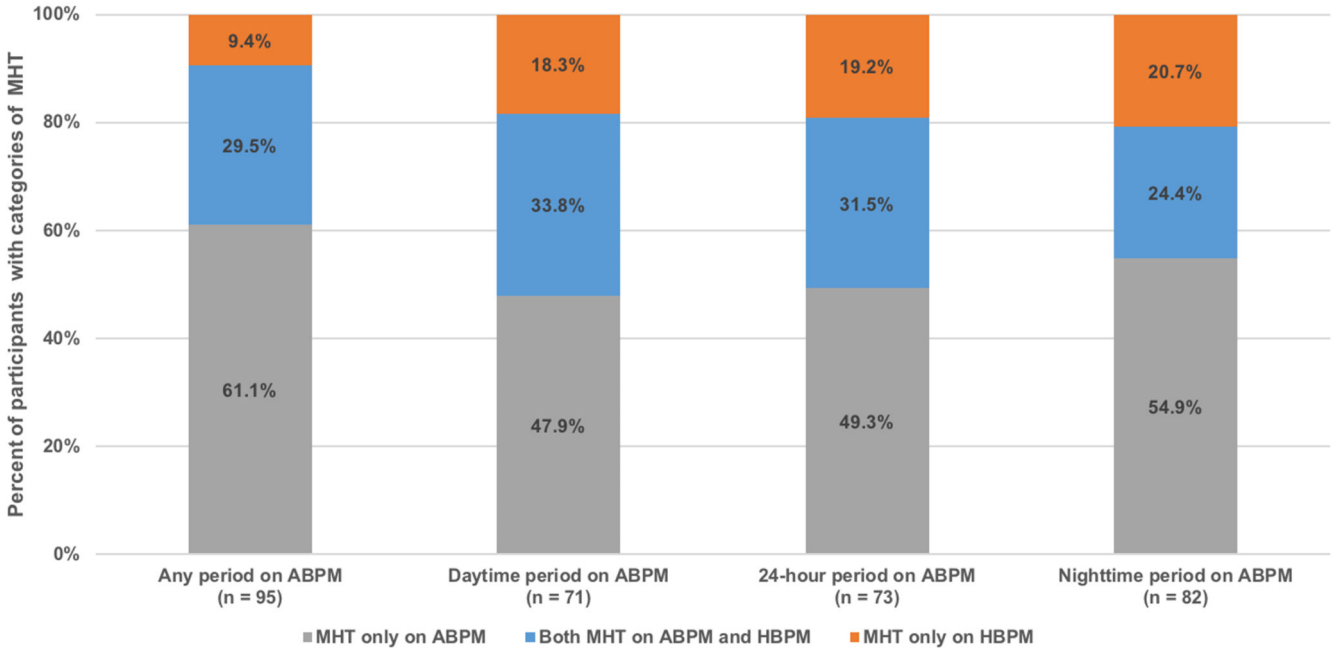

Figure 1:

Distribution of participants into categories based on the absence or presence of masked hypertension on ambulatory blood pressure monitoring and home blood pressure monitoring.

Table 1:

Characteristics of participants in the overall analytical sample and by masked hypertension (MHT) status, defined using ambulatory blood pressure monitoring (ABPM) cross-classified by home blood pressure monitoring (HBPM).

Characteristics	Overall Analytic Sample (N=333)	Neither Any MHT nor Home MHT (N = 238)	Any MHT without Home MHT (N = 58)	Home MHT without Any MHT (N = 9)	Both Any MHT and Home MHT (N = 28)
Age, years	40.1 (12.9)	37.6 (11.8)	45.4 (14.1)	47.6 (11.7)	47.9 (12.9)
Female	204 (61.3)	156 (65.5)	34 (58.6)	4 (44.4)	10 (35.7)
Black race	81 (24.3)	50 (21.0)	21 (36.2)	3 (33.3)	7 (25.0)
Hispanic ethnicity	206 (61.9)	151 (63.4)	33 (56.9)	5 (55.6)	17 (60.7)
Clinical Characteristics					
Diabetes	5 (1.5)	2 (0.8)	1 (1.7)	1 (11.1)	1 (3.6)
Chronic kidney disease	16 (4.8)	11 (4.6)	2 (3.4)	0 (0.0)	3 (10.7)
Current smoker	29 (8.7)	19 (8.0)	5 (8.6)	0 (0.0)	5 (17.9)
Body mass index kg/m^2	27.0 (4.7)	26.3 (4.5)	28.7 (4.7)	30.7 (5.7)	28.0 (5.3)
Blood Pressure Measures					
Clinic SBP, mmHg	112.2 (11.6)	109.1 (10.7)	118.8 (10.0)	118.6 (12.7)	123.1 (8.5)
Clinic DBP, mmHg	73.7 (8.0)	71.6 (7.5)	77.9 (7.2)	77.3 (7.1)	81.9 (4.3)
Daytime SBP, mmHg	122.0 (10.4)	117.6 (7.7)	131.5 (7.4)	127.7 (4.1)	137.5 (8.4)
Daytime DBP, mmHg	76.4 (6.8)	73.8 (5.3)	82.0 (5.8)	79.1 (3.1)	86.5 (4.3)
24-hour SBP, mmHg	117.7 (10.0)	113.3 (7.2)	127.9 (6.6)	121.6 (5.1)	132.1 (8.4)
24-hour DBP, mmHg	72.3 (6.5)	69.6 (4.8)	78.6 (5.3)	73.6 (3.7)	81.9 (4.2)
Nighttime SBP, mmHg	107.1 (10.8)	102.6 (7.5)	119.2 (9.2)	109.0 (8.0)	118.9 (10.0)
Nighttime DBP, mmHg	62.2 (7.4)	59.3 (5.2)	70.2 (6.7)	62.3 (4.6)	70.9 (6.3)
Home SBP, mmHg	113.2 (11.7)	109.0 (9.3)	118.7 (7.7)	126.6 (7.7)	133.7 (8.1)
Home DBP, mmHg	75.2 (7.7)	72.4 (6.4)	79.0 (4.3)	84.8 (1.9)	87.8 (5.4)

The numbers in the table are mean (standard deviation) or n (percentage)

Any MHT was defined as having daytime MHT, 24-hour MHT, and/or nighttime MHT on ABPM

Daytime MHT was defined as mean SBP ≥ 135 mmHg and/or mean DBP ≥ 85 mmHg using BP readings during the daytime period on ABPM

24-hour MHT was defined as mean SBP ≥ 130 mmHg and/or mean DBP ≥ 80 mmHg using all available readings on ABPM

Nighttime MHT was defined as mean SBP ≥ 120 mmHg and/or mean DBP ≥ 70 mmHg during the nighttime period on ABPM

Home MHT was defined as mean home SBP ≥ 135 mmHg and/or mean DBP ≥ 85 mmHg on HBPM

ABPM: Ambulatory blood pressure monitoring

DBP: Diastolic blood pressure

HBPM: Home blood pressure monitoring

MHT: Masked hypertension

SBP: Systolic blood pressure

Table 2:

Cross-classification of masked hypertension (MHT) status defined using ambulatory blood pressure monitoring (ABPM) by MHT status defined using home blood pressure monitoring (HBPM)

Classification	**Any MHT Status**	
Home MHT Status	Without Any MHT	Any MHT
Without Home MHT	238 (71.5%, 66.6% – 76.3%)	58 (17.4%, 13.3% – 21.5%)
Home MHT	9 (2.7%, 1.0% – 4.4%)	28 (8.4%, 5.4% – 11.4%)
	Daytime MHT Status	
Home MHT Status	Without Daytime MHT	Daytime MHT
Without Home MHT	262 (78.7%, 74.3% – 83.1%)	34 (10.2%, 7.0% – 13.5%)
Home MHT	13 (3.9%, 1.8% – 6.0%)	24 (7.2%, 4.4% – 10.0%)
	24-hour MHT Status	
Home MHT Status	Without 24-hour MHT	24-hour MHT
Without Home MHT	260 (78.1%, 73.6% – 82.5%)	36 (10.8%, 7.5% – 14.1%)
Home MHT	14 (4.2%, 2.0% – 6.4%)	23 (6.9%, 4.2% – 9.6%)
	Nighttime MHT Status	
Home MHT Status	Without Nighttime MHT	Nighttime MHT
Without Home MHT	251 (75.4%, 70.7% – 80.0%)	45 (13.5%, 9.8% – 17.2%)
Home MHT	17 (5.1%, 2.7% – 7.5%)	20 (6.0%, 3.5% – 8.6%)

Data are expressed as number (percentage, 95% CI)

Any MHT was defined as having daytime MHT, 24-hour MHT, and/or nighttime MHT on ABPM

Daytime MHT was defined as mean SBP ≥ 135 mmHg and/or mean DBP ≥ 85 mmHg using BP readings during the daytime period on ABPM

24-hour MHT was defined as mean SBP ≥ 130 mmHg and/or mean DBP ≥ 80 mmHg using all available readings on ABPM

Nighttime MHT was defined as mean SBP ≥ 120 mmHg and/or mean DBP ≥ 70 mmHg during the nighttime period on ABPM

Home MHT was defined as mean home SBP ≥ 135 mmHg and/or mean DBP ≥ 85 mmHg on HBPM

ABPM: Ambulatory blood pressure monitoring

CI: confident interval

DBP: Diastolic blood pressure

HBPM: Home blood pressure monitoring

MHT: Masked hypertension

SBP: Systolic blood pressure

Table 3:

Mean and mean differences in left ventricular mass index comparing participants with neither masked hypertension (MHT) on ambulatory blood pressure monitoring (ABPM) nor home blood pressure monitoring (HBPM) versus participants with MHT only on ABPM, MHT only on HBPM, and MHT on both ABPM and HBPM.

Measure	Categories Defined by Any MHT Status and Home MHT Status				
	Neither Any MHT nor Home MHT (N = 238)	Any MHT without Home MHT (N = 58)	Home MHT without Any MHT (N = 9)	Both Any MHT and Home MHT (N = 28)	p-value
LVMI *	76.0 (15.1)	82.1 (14.4)	77.1 (9.2)	92.6 (18.0)	-
Unadjusted difference †	0 (ref)	6.1 (2.2)	1.1 (5.1)	16.6 (3.0)	P1=0.006 P2=0.837 P3<0.001
Adjusted difference †	0 (ref)	4.9 (2.1)	−1.9 (4.8)	12.7 (2.9)	P1=0.022 P2=0.693 P3<0.001
	Categories Defined by Daytime MHT Status and Home MHT Status				
	Neither Daytime MHT nor Home MHT (N = 262)	Daytime MHT without Home MHT (N = 34)	Home MHT without Daytime MHT (N = 13)	Both Daytime MHT and Home MHT (N = 24)	p-value
LVMI *	76.5 (15.1)	82.6 (14.4)	84.0 (17.8)	91.5 (17.2)	-
Unadjusted difference †	0 (ref)	6.2 (2.8)	7.5 (4.4)	15.0 (3.3)	P1=0.028 P2=0.085 P3<0.001
Adjusted difference †	0 (ref)	4.0 (2.6)	3.7 (4.1)	11.0 (3.1)	P1=0.126 P2=0.367 P3<0.001
	Categories Defined by 24-hour MHT Status and Home MHT Status				
	Neither 24-hour MHT nor Home MHT (N = 260)	24-hour MHT without Home MHT (N = 36)	Home MHT without 24-hour MHT (N = 14)	Both 24-hour MHT and Home MHT (N = 23)	p-value
LVMI *	76.4 (15.1)	82.7 (14.6)	81.5 (13.4)	93.3 (18.5)	-
Unadjusted difference †	0 (ref)	6.3 (2.7)	5.1 (4.2)	16.9 (3.3)	P1=0.021 P2=0.223 P3<0.001
Adjusted difference †	0 (ref)	4.3 (2.6)	1.1 (3.9)	13.2 (3.2)	P1=0.093 P2=0.788 P3<0.001
	Categories Defined by Nighttime MHT Status and Home MHT Status				
	Neither Nighttime MHT nor Home MHT (N = 251)	Nighttime MHT without Home MHT (N = 45)	Home MHT without Nighttime MHT (N = 17)	Both Nighttime MHT and Home MHT (N = 20)	p-value

Measure	Categories Defined by Any MHT Status and Home MHT Status				
LVMI *	76.0 (15.1)	84.1 (13.9)	84.1 (13.2)	92.9 (20.0)	-
Unadjusted difference †	0 (ref)	8.1 (2.5)	8.1 (3.8)	16.9 (3.5)	P1=0.001 P2=0.033 P3<0.001
Adjusted difference †	0 (ref)	7.5 (2.3)	3.4 (3.6)	14.7 (3.3)	P1=0.001 P2=0.343 P3<0.001

Adjusted model adjusts for age, sex, race, ethnicity, and current smoking

P1= comparison of Neither MHT on ABPM nor HBPM with MHT on ABPM without MHT on HBPM

P2= comparison of Neither MHT on ABPM nor HBPM with MHT on HBPM without MHT on ABPM

P3= comparison of Neither MHT on ABPM nor HBPM with Both MHT on ABPM and HBPM

Left ventricular mass index (LVMI) defined as left ventricular mass indexed to body surface area in g/m^2

Any MHT was defined as having daytime MHT, 24-hour MHT, and/or nighttime MHT on ABPM

Daytime MHT was defined as mean SBP ≥ 135 mmHg and/or mean DBP ≥ 85 mmHg using BP readings during the daytime period on ABPM

24-hour MHT was defined as mean SBP ≥ 130 mmHg and/or DBP ≥ 80 mmHg using all available readings on ABPM

Nighttime MHT was defined as SBP ≥ 120 mmHg and/or DBP ≥ 70 mmHg during the nighttime period on ABPM

Home MHT was defined as home SBP ≥ 135 mmHg and/or DBP ≥ 85 mmHg on HBPM

* Mean (standard deviation)

† Mean difference (standard error)

ABPM: Ambulatory blood pressure monitoring

DBP: Diastolic blood pressure

HBPM: Home blood pressure monitoring

MHT: Masked hypertension

SBP: Systolic blood pressure