Maximum Value of Home Blood Pressure
A Novel Indicator of Target Organ Damage in Hypertension

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See Editorial Commentary, pp 1041–1042

Abstract—The maximum office systolic blood pressure (SBP) has been shown to be a strong predictor of cardiovascular events, independently of the mean SBP level. However, the clinical implications of maximum home SBP have never been reported. We investigated the association between the maximum home SBP and target organ damage (TOD). We assessed the left ventricular mass index (LVMI) and carotid intima-media thickness (IMT) using ultrasonography and the urinary albumin/creatinine ratio (UACR) as measures of TOD in 356 never-treated hypertensive subjects. Home BP was taken in triplicate in the morning and evening, respectively, for 14 consecutive days with a memory-equipped device. The maximum home SBP was defined as the maximum mean triplicate BP reading in the 14-day period for each individual and was significantly correlated with LVMI ($r=0.51$, $P<0.001$), carotid IMT ($r=0.40$, $P<0.001$), and UACR ($r=0.29$, $P<0.001$). The correlation coefficients with LVMI and carotid IMT were significantly larger for the maximum home SBP than the mean home SBP. In multivariate regression analyses, the maximum home SBP was independently associated with LVMI and carotid IMT, regardless of the mean home BP level. In the prediction of left ventricular hypertrophy and carotid atherosclerosis, the goodness-of-fit of the model was significantly improved when the maximum home SBP was added to the sum of the mean office and home BPs ($P=0.002$ and $P<0.001$, respectively). These findings indicate that assessment of the maximum home SBP, in addition to the mean home SBP, might increase the predictive value of hypertensive TOD in the heart and artery. **(*Hypertension*. 2011;57:1087-1093.) • Online Data Supplement**

Key Words: maximum home systolic blood pressure ■ mean home systolic blood pressure ■ left ventricular mass index ■ carotid intima-media thickness ■ urinary albumin/creatinine ratio ■ aging ■ arterial stiffness

It has been believed that transient increases in blood pressure (BP) might be construed as noise and merely an obstacle to reliable estimation of usual BP (conceived as the true underlying average BP over a period of time). In this case, such increases would result in substantial underestimation of the strength of the real association between usual BP and cardiovascular risk, a so-called "regression dilution bias."[1] Rothwell et al[2] recently showed that the maximum systolic BP (SBP) reached in an office setting was a strong predictor of cardiovascular events, independently of the mean SBP over 12 to 36 months. Ko et al[3] also showed that the maximum SBP during the first 72 hours of acute ischemic stroke was strongly associated with the development of brain hemorrhagic transformation, independently of the mean SBP level. Thus, subjects with episodic high BP might be at a high cardiovascular risk.

One drawback of the use of the maximum SBP in routine clinical management of hypertension is that obtaining it requires several office visits over a period of time. One possible way to solve this is to observe the maximum SBP derived from self-measurement at home, because this self-measurement makes it possible to obtain multiple values for BP in a relatively short period under well-controlled conditions. Furthermore, there is an increasing body of evidence that home BP is correlated better with target organ damage (TOD)[4–9] and that it may predict cardiovascular events[10,11] better than office BP. Therefore, home BP measurement can provide more reliable information on maximum BP in a relatively short period than office BP measurement. However, no studies have investigated the significance of maximum home BP in association with TOD or cardiovascular events.

We hypothesized that the maximum home SBP might reflect more correctly the severity of TOD than the mean home SBP, which has been clearly established as a predictor of TOD and a determinant of cardiovascular prognosis. The aim of the present study was to assess the independent association between the maximum home SBP and TOD in

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subjects with never-treated hypertension and to test whether the maximum home SBP might improve the prediction of the presence of TOD. In this study, we measured the left ventricular mass index (LVMI) as cardiac damage, the carotid intima-media thickness (IMT) as vascular damage, and the urinary albumin/creatinine ratio (UACR) as renal damage. All three have been established markers of subclinical hypertensive TOD[12] and independent predictors of future cardiovascular events.[13–15]

Methods

Study Participants

Never-treated hypertensive subjects were enrolled consecutively from the Department of Internal Medicine for Outpatients in Miwa Municipal Hospital between June 2004 and December 2007. The subjects in this study were recruited from the same population as those in our recent publication.[16] Hypertension was defined as an average office SBP of at least 140 mm Hg and/or diastolic BP (DBP) of at least 90 mm Hg or both at 2 different occasions (with at least a 2-week interval) during the run-in period (4 weeks). Subjects who had secondary hypertension, arrhythmia, a history of heart failure, a history of stroke or coronary artery disease, renal insufficiency (serum creatinine >2 mg/dL), mental disorders, severe noncardiovascular disease, or chronic inflammatory disease were excluded. At baseline, these subjects underwent a medical interview, anthropometric measurements, blood/urine examinations, and ultrasonography. This study was approved by the Institutional Review Board of Miwa Municipal Hospital, and written informed consent was obtained from all participants. See http://hyper.ahajournals.org for further information.

BP Measurements

Office BP was measured during the screening period (twice) and at the end of the home BP measurement term, using the same device as used for home BP. At each office visit, 3 consecutive readings were taken on the nondominant arm with a 15-second interval after a 5-minute rest in a sitting position. Office BP was taken by the study investigators (Y.M. and S.S.) in the morning.

Home BP was measured in a sitting position 3 times each in the morning and evening for 14 consecutive days after the enrollment for this study. The subjects were instructed to place the cuff on the nondominant arm, take a 5-minute rest before the first reading, and take a 15-second interval between the readings. Morning BP was measured within 1 hour after waking, after urination, and before breakfast. Evening BP was measured just before going to bed and at least 60 minutes after taking a bath. These methods are based on Japanese home BP guidelines.[17] The device used for home BP was a validated oscillometric device (HEM-747IC; Omron Healthcare Co, Ltd, Kyoto, Japan) that incorporates an integrated circuit memory and clock to store the BP readings and time of measurement.[18] The arm circumferences of subjects ranged between 22 and 32 cm, so the standard arm cuff could be used for BP measurements in all cases. Patients who conducted home BP measurement for fewer than 5 consecutive days were excluded from the analysis.

Definition of BP Indices

The maximum home BP was calculated as follows. The average triplicate morning BP and average triplicate evening BP were calculated for each day. The highest among these averages for each individual was adopted as the maximum home BP. The mean home BP was defined as the average of all readings for each individual. "Peak size in home SBP" was defined as the difference between the maximum home SBP and the mean home SBP based on a recent report.[19] Day-by-day home BP variability was defined as the SD of home BP (average of morning and evening BPs) for each individual.[20,21] The mean office BP was defined as the mean of the office BPs on 3 occasions.

Table 1. Characteristics of the Subjects

Variable	Total Population (n=356)
General characteristics	
Age, years	66.6±11.0
Male sex, %	47
Body height, cm	154.9±9.4
Body mass index, kg/m^2	23.3±3.2
Waist circumference, cm	82.3±9.2
Hypertension duration, years	3.2±5.9
Smoking, %	16
Habitual drinking, %	28
Diabetes mellitus, %	9
Hyperlipidemia, %	31
Hemodynamic parameters	
Mean office SBP, mm Hg	153.2±17.9
Mean office DBP, mm Hg	84.9±10.5
Mean home SBP, mm Hg	141.4±17.7
Mean home DBP, mm Hg	78.6±10.2
Maximum home SBP, mm Hg	164.3±21.1
Maximum home DBP, mm Hg	91.1±11.7
Day-by-day home SBP variability, mm Hg	8.0±2.7
Day-by-day home DBP variability, mm Hg	4.4±1.6
baPWV, m/sec	18.2±4.2
TOD	
LVMI, g/m^2	115.3±33.4
Prevalence of left ventricular hypertrophy, %	42
Carotid IMT, mm	0.87±0.17
Prevalence of carotid atherosclerosis, %	37
UACR, mg/gCr	22.0 (19.5–25.0)
Prevalence of albuminuria, %	33

Data are shown as the mean±SD, percentage, or geometric mean (95% confidence interval).

SBP indicates systolic blood pressure; DBP, diastolic blood pressure; baPWV, brachial-ankle pulse wave velocity; TOD, target organ damage; LVMI, left ventricular mass index; IMT, intima-media thickness; UACR, urinary albumin/creatinine ratio.

Echocardiography and Carotid Ultrasonography

Ultrasonographic investigations were performed using a high-resolution B-mode ultrasound scanner (EUB 6500; Hitachi, Tokyo, Japan). M-mode echocardiography, guided by 2-dimensional echocardiography, was performed as described previously.[16] End diastolic dimensions were used to calculate LVM using an anatomically validated formula.[22] The LVMI was calculated from LVM divided by body surface area. The presence of left ventricular hypertrophy (LVH) was defined as LVMI ≥125 g/m^2 in men and ≥110 g/m^2 in women.[12]

Carotid IMT was assessed for the right and left common carotid artery and was measured at 3 points proximal to the bilateral carotid bulbus (far wall) in 10-mm segments at the end diastole and always in plaque-free segments. If plaque existed at the IMT measuring point, an appropriate adjacent portion was chosen. The mean of the right and left carotid IMT (totally 6 points) was used in the analyses. Carotid atherosclerosis was diagnosed when there was diffuse common carotid artery thickening defined as an average IMT >0.9 mm.[12] Echocardiography and carotid ultrasonography were performed by 2 cardiologists who were unaware of subjects' clinical

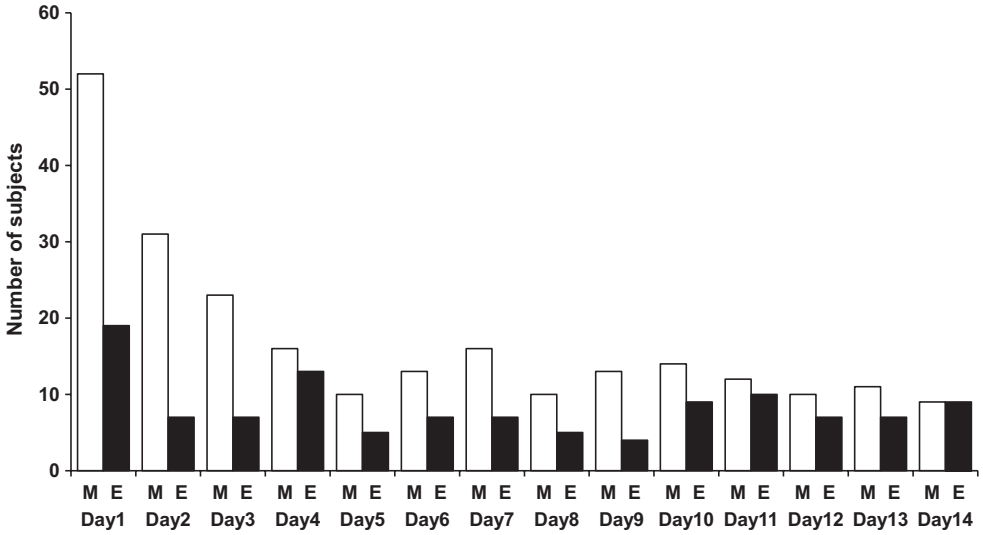

Figure 1. The distribution of the days when the maximum home SBP was observed. M indicates morning; E, evening.

conditions including the results from home BP measurement. The reproducibility of the measurement of LVMI and carotid IMT using this ultrasonography has been described in previous reports.[9,16]

Urinary Albumin Excretion

Blood and urine samples were collected in the morning in a fasting state. The urinary albumin level was determined from a spot urine sample using a turbidimetric immunoassay and expressed as UACR (mg/gCr). Urine creatinine was measured by enzymatic assay. All assays were performed at Mitsubishi Biochemical Laboratory (Tokyo, Japan). The intracoefficients and intercoefficients of variation for the urinary albumin assay were 1.30% and 1.85%, respectively. Albuminuria was defined as UACR ≥22 mg/gCr in men and ≥31 mg/gCr in women.[12] See supplemental material for the other measurements.

Statistical Analyses

All data are expressed as means±SD or a percentage unless otherwise specified. UACR was log-transformed because of its positively skewed distribution. One-way ANOVA was performed to detect differences among groups, and Tukey's honestly significant differences test was also performed for multiple pairwise comparisons of the means among groups. The χ^2 test was used to compare proportions. Analysis of covariance was performed to detect differences among groups after adjustment for covariates, and the Bonferroni test was used for multiple pairwise comparisons. The univariate correlations between the BPs and TODs were assessed using Pearson's correlations. Differences between values of correlation coefficients were compared with Fisher's z tests. The maximum home SBP and mean home SBP could not be included together in the same model, because of their strong correlation ($r=0.92$, $P<0.001$) and high degree of multicollinearity (variance inflation factor [VIF] was 7.49 to 7.97 when both variables were included in the same model). Therefore, we performed multivariate linear regression analyses after dividing subjects into 2 groups with mean home BP cut-off values of 135 mm Hg SBP and 85 mm Hg DBP[23] to explore independent associations between the maximum home SBP and TODs. Variables significantly correlated with each TOD in the univariate analysis were included in the multivariate regression analyses. To estimate the relationship between BP indices and the presence of TOD, logistic regression analyses were performed. In those analyses, the likelihood ratio test was used to assess the goodness-of-fit between models by adding home BP indices. The null hypothesis was rejected when the 2-tailed P value was <0.05. All statistical analyses were performed with SPSS version 16.0 (SPSS Inc, Chicago, IL).

Results

Characteristics of the Subjects

Characteristics of the study subjects are shown in Table 1. The mean age of the total population was 66.6 years, and 44.7% (n=159) was aged 70 years or older. The average number of home BP measurements per subject during the 14-day study period was 79.8±7.9 (mean±SD). Figure 1 shows the distribution of the days on which the maximum home SBP was measured during the 14-day period. As we expected, the largest number of subjects had maximum home SBP on day 1 (n=71, 19.9%).

Univariate Correlations Between BP Levels and TODs

In univariate analyses, all SBP measures were significantly correlated with all TODs (Table 2). As shown in Figure 2, the

Table 2. Univariate Correlations Between BPs and Measures of TOD (n=356)

	LVMI		Carotid IMT		Log UACR	
Variable	*r*	*P*	*r*	*P*	*r*	*P*
Mean office SBP, mm Hg	0.41	<0.001	0.24	<0.001	0.29	<0.001
Mean office DBP, mm Hg	0.05	0.34	0.03	0.56	0.05	0.34
Mean home SBP, mm Hg	0.46	<0.001	0.31	<0.001	0.30	<0.001
Mean home DBP, mm Hg	0.13	0.02	0.09	0.10	0.08	0.15
Maximum home SBP, mm Hg	0.51	<0.001	0.40	<0.001	0.29	<0.001
Maximum home DBP, mm Hg	0.23	<0.001	0.13	0.012	0.08	0.16
Day-by-day home SBP variability, mm Hg	0.31	<0.001	0.23	<0.001	0.20	<0.001
Day-by-day home DBP variability, mm Hg	0.22	<0.001	0.10	0.07	0.06	0.29

BP indicates blood pressure; TOD, target organ damage; LVMI, left ventricular mass index; IMT, intima-media thickness; UACR, urinary albumin/creatinine ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; day-by-day home BP variability, the SD of home BP.

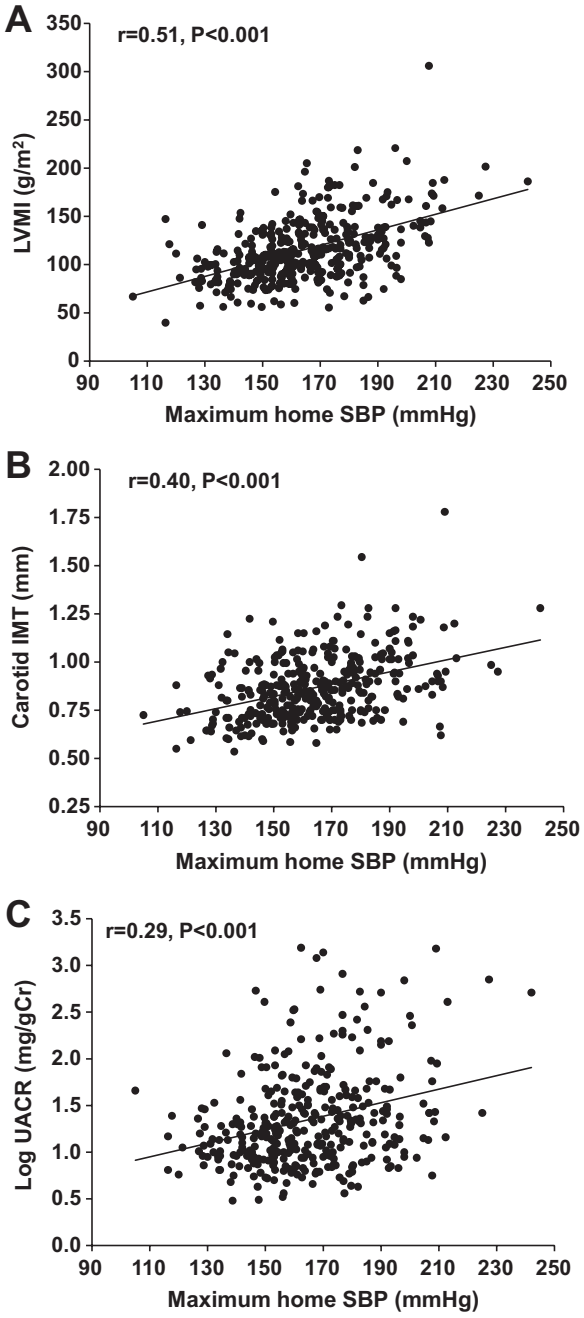

Figure 2. Univariate correlation between the maximum home SBP and left ventricular mass index (**A**), carotid IMT (**B**), and Log UACR (**C**) in 356 hypertensive patients. SBP indicates systolic blood pressure; LVMI, left ventricular mass index; IMT, intima-media thickness; UACR, urinary albumin/creatinine ratio.

maximum home SBP was strongly and linearly correlated with LVMI and carotid IMT. Even after the BP data at day 1 were excluded, the univariate correlations between home BP indices and TODs were similar (see supplemental Table S1). Next, we compared the correlation coefficients between the maximum home SBP and the mean home SBP; the correlation coefficients were significantly different for LVMI (0.51 versus 0.46, $P=0.008$) and carotid IMT (0.40 versus 0.31, $P<0.001$) but not for UACR (0.29 versus 0.30, $P=0.65$). The morning SBP at day 1 was not more closely correlated with LVMI ($r=0.43$), carotid IMT ($r=0.31$), and UACR ($r=0.26$) than was the mean home SBP (probability for the difference was 0.32, 0.90, and 0.18, respectively).

Multivariate Analyses Between Maximum Home SBP and TOD

Table 3 shows the results of the multivariate linear regression analyses that determined the independent association of the maximum home SBP with TODs in the total population and subgroups divided by the mean home BP level of 135/85 mm Hg. We did not observe any multicollinearity in any models; VIF was <1.8 in all models. The maximum home SBP was independently associated with the LVMI and carotid IMT in all groups, even after adjustment for significant covariates including age, sex, and mean office SBP. On the other hand, the maximum home SBP was independently associated with the UACR in the total population, but not in either subgroup. When the BP data at day 1 were excluded, these results were essentially the same (data not shown). As shown in supplemental Table S2, day-by-day home SBP variability was significantly associated with LVMI, but not with carotid IMT or UACR, after adjustments for covariates including the mean home SBP.

Goodness-of-Fit by Adding Home SBP Indices

Table 4 shows the goodness-of-fit of various models. Each prediction model for the presence of LVH, carotid atherosclerosis, and albuminuria was significantly improved when the mean home SBP was added to model 1 based on the mean office SBP, as indicated by the likelihood ratio test ($P<0.001$, $P=0.002$, and $P=0.006$, respectively). Furthermore, in predicting the presence of LVH and carotid atherosclerosis, the model fit was significantly improved when the maximum home SBP was added to model 2 ($P=0.002$ and $P<0.001$, respectively). In models including maximum home SBP, the mean home SBP turned out to be not significant ($P=0.32$) in the prediction of LVH, and the office SBP turned out to be not significant ($P=0.54$) in the prediction of carotid atherosclerosis. On the other hand, in predicting the presence of albuminuria, model improvement was not observed when the maximum home SBP was added to model 2 ($P=0.11$).

Characteristics of the Subjects With Increased Peak Size of Home SBP

We divided all subjects into 3 groups (Q1, Q2, and Q3) according to the peak size in home SBP to clarify the characteristics of subjects with a greater rise of maximum home SBP from mean SBP levels (see supplemental Table S3). The Q2 and Q3 groups, with the highest peaks, were significantly older than the Q1 group, and the Q3 group had a higher proportion of habitual drinkers than the Q1 group. The Q3 group had a higher brachial-ankle pulse-wave velocity (baPWV), LVMI, and carotid IMT than the other groups, and these differences were still significant in relation to the Q1 group after adjusting for age, sex, hypertension duration, habitual drinking, and the mean office SBP ($P=0.005$, $P=0.001$, and $P=0.003$, respectively). In a multivariate regression analysis, age ($\beta=0.109$, SE=0.045, $P=0.01$), habitual drinking ($\beta=2.365$, SE=1.164, $P=0.04$), and

Table 3. Multivariate Regression Analyses Between Maximum Home SBP and TOD in the Total Population and Subgroups Divided by Mean Home BP Levels

			Subgroup Analysis			
	Total Population (n=356)		Mean Home BP <135/85 mm Hg (n=135)		Mean Home BP ≥135/85 mm Hg (n=221)	
Dependent Variable	β (SE)	P	β (SE)	P	β (SE)	P
LVMI*, g/m^2						
Maximum home SBP, mm Hg	0.598 (0.094)	<0.001	0.512 (0.188)	0.007	0.655 (0.145)	<0.001
	Model R^2=0.32		Model R^2=0.21		Model R^2=0.24	
Carotid IMT†, mm						
Maximum home SBP, mm Hg	0.003 (<0.001)	<0.001	0.003 (0.001)	0.006	0.003 (0.001)	<0.001
	Model R^2=0.27		Model R^2=0.26		Model R^2=0.24	
Log UACR‡, mg/gCr						
Maximum home SBP, mm Hg	0.004 (0.002)	0.02	0.001 (0.003)	0.68	0.003 (0.002)	0.18
	Model R^2=0.20		Model R^2=0.15		Model R^2=0.17	

*This model was adjusted by age, sex, habitual drinking, and mean office SBP. †This model was adjusted by age, sex, hypertension duration, smoking, diabetes mellitus, and mean office SBP. ‡This model was adjusted by age, sex, diabetes mellitus, and mean office SBP.

β indicates partial regression coefficient; R^2, multiple coefficient of determination; LVMI, left ventricular mass index; IMT, intima-media thickness; UACR, urinary albumin/creatinine ratio; SBP, systolic blood pressure.

baPWV (β=0.004, SE=0.001, P=0.001) were significant determinants of the peak size in home SBP, whereas sex, hypertension duration, and mean office SBP level were not.

Discussion

The important findings of this study were that (1) the maximum home SBP was better correlated with LVMI and carotid IMT than the mean home SBP; (2) the maximum home SBP was independently associated with LVMI and carotid IMT, even when the mean home BP level was normal; and (3) for the presence of LVH and carotid atherosclerosis, the maximum home SBP provided additional predictive value to the mean levels of office SBP and home SBP. This is the first study to demonstrate the clinical implications of the maximum home SBP in untreated hypertensive patients.

Table 4. Goodness-of-Fit Between the Models by Adding Home SBP Indices

TOD	Model	−2 Log Likelihood	Likelihood Ratio (χ^2 on *df* 1)	P
LVH	Model 1. Mean office SBP	431.2	−	−
	Model 2. Model 1 +mean home SBP	418.6	12.6	<0.001
	Model 3. Model 2 +maximum home SBP	408.8	9.8	0.002
Carotid Atherosclerosis	Model 1. Mean office SBP	453.6	−	−
	Model 2. Model 1 +mean home SBP	443.8	9.8	0.002
	Model 3. Model 2 +maximum home SBP	420.6	23.2	<0.001
Albuminuria	Model 1. Mean office SBP	428.7	−	−
	Model 2. Model 1 +mean home SBP	421.3	7.4	0.006
	Model 3. Model 2 +maximum home SBP	418.7	2.6	0.11

The *P* values indicate improvements of the fit in each model when mean home SBP or maximum home SBP are added to the equations.

SBP indicates systolic blood pressure; TOD, target organ damage; LVH, Left ventricular hypertrophy; −, not applicable.

The present study demonstrated that the maximum home SBP value was more closely associated with LVMI and carotid IMT than the mean home SBP, despite previous reports that the reliability of home BP as a predictor of cardiovascular disease was improved by averaging more measurements.[4,10] In the present study, the maximum home SBP was most commonly reported on the first day. Even after the exclusion of day 1 BP data, the close associations between the maximum home SBP and LVMI/carotid IMT were essentially the same. Although the maximum home SBP differs from BP variability in that it refers specifically to transient changes in BP, these 2 variables often have similar associations with other clinical indices, such as arterial stiffness and baroreceptor dysfunction.[1,24,25] In the present study, age and PWV, both of which may be involved in the impairment of the arterial baroreflex,[26,27] were independent determinants of the size of the maximum home SBP. Thus, a baroreceptor dysfunction could be potentially involved in the mechanisms of larger-value maximum home SBP. Because a baroreceptor dysfunction itself has been reported to be associated with LVH[27] and carotid atherosclerosis,[28] this might underlie the close associations between maximum home SBP and cardiac/vascular damage. Whether the maximum home SBP has a pathogenetic role in the progression of TOD or is just a secondary phenomenon of subclinical vascular damage remains to be determined.

The current results showed that the maximum home SBP did not improve information about potential kidney damage inherent in the mean home SBP level. This finding might indirectly coincide with previous reports that have reported a relatively weak association between awake SBP variability and albuminuria, in contrast to the strong associations between SBP variability and LVMI or carotid IMT.[24,29] Furthermore, Lantelme et al[27] reported that no significant correlation between baroreceptor sensitivity and albuminuria was observed, despite a significant correlation between SBP variability and LVMI. An experimental study using the rat kidney model has demonstrated that renal autoregulation could prevent acute exaggerated BP fluctuations from being transmitted to the glomerular capillary circulation and attenuate glomerular injury.[30] These findings indicate that the kidney might not be affected by a transient increase in BP, as long as autoregulatory mechanisms are normally functioning.

In the present study, subjects with increased peak size of home SBP were characterized by older age and habitual drinking. These results are similar to previous reports, which demonstrated that both older age and excessive use of alcohol were significant determinants of home SBP variability, defined as either the variability between morning and evening SBP values[16,20] or day-by-day SBP values.[20,21] Aging was reported to contribute to decreased baroreceptor sensitivity,[26] and this mechanism can explain transient BP increases observed in the elderly. We have reported that repeated alcohol intake in the evening causes an elevation in morning BP and a reduction in late evening BP.[31] This biphasic effect could increase the maximum home BP level in the morning, but not the mean home BP levels[31]; that is, it could lead to an increased level of peak size in home SBP.

It has been reported that day-by-day home SBP variability[32] and visit-to-visit office SBP variability[2,33] are significant predictors of cardiovascular events, independent of the mean SBP level. In the present study, day-by-day home SBP variability was a significant determinant of LVMI, even after adjustments for covariates including mean home SBP. This is the first study to demonstrate an independent association between day-by-day home SBP variability and TOD. On the other hand, day-by-day home SBP variability was not an independent determinant of carotid IMT. Our results suggest that carotid atherosclerosis might be more strongly associated with transient BP fluctuations (BP instability) than with day-by-day BP variability, which reflects typical fluctuations.

Study Limitations

First, the directional nature of the cause-and-effect relationship between the maximum home SBP and TODs remains to be clarified because the present study was cross-sectional. Second, the reproducibility of the maximum home SBP is unknown, whereas the maximum office SBP was reproducible and not a random phenomenon.[19] Third, the quality of the measurement procedure could have affected the maximum home BP value, although we asked participants to measure BP under controlled conditions. Fourth, whether the maximum BP obtained by 14 days of home BP monitoring is a reflection of short-term BP variability or long-term BP variability remains to be clarified. Finally, although the latest home BP guideline[23] recommends a 1-minute interval between readings, in the present study, we set the interval at 15 seconds[34] to improve the patients' compliance with home BP measurement.

Perspectives

Our study suggests that transiently high BP readings at home are not disregarded as noise, but rather should be taken seriously as meaningful indicators for hypertensive TOD in the heart and artery. These findings also indicate the importance of monitoring the severity of the maximum home SBP, in addition to mean home BP levels, at the first evaluation of hypertension. Further investigation is needed to evaluate the physiological mechanisms of exaggerated fluctuations in home BP and to prospectively assess the clinical implications of this BP phenomenon.

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Disclosures

None.

References

1. Rothwell PM. Limitations of the usual blood-pressure hypothesis and importance of variability, instability, and episodic hypertension. *Lancet*. 2010;375:938–948.
2. Rothwell PM, Howard SC, Dolan E, O'Brien E, Dobson JE, Dahlöf B, Sever PS, Poulter NR. Prognostic significance of visit-to-visit variability, maximum systolic blood pressure, and episodic hypertension. *Lancet*. 2010;375:895–905.
3. Ko Y, Park JH, Yang MH, Ko SB, Han MK, Oh CW, Lee J, Lee J, Bae HJ. The significance of blood pressure variability for the development of hemorrhagic transformation in acute ischemic stroke. *Stroke*. 2010;41:2512–2518.
4. Shimbo D, Pickering TG, Spruill TM, Abraham D, Schwartz JE, Gerin W. Relative utility of home, ambulatory, and office blood pressures in the prediction of end-organ damage. *Am J Hypertens*. 2007;20:476–482.
5. Stergiou GS, Argyraki KK, Moyssakis I, Mastorantonakis SE, Achimastos AD, Karamanos VG, Roussias LG. Home blood pressure is as reliable as ambulatory blood pressure in predicting target-organ damage in hypertension. *Am J Hypertens*. 2007;20:616–621.
6. Niiranen TJ, Jula AM, Kantola IM, Karanko H, Reunanen A. Home-measured blood pressure is more strongly associated with electrocardiographic left ventricular hypertrophy than is clinic blood pressure: the Finn-HOME study. *J Hum Hypertens*. 2007;21:788–794.
7. Niiranen T, Jula A, Kantola I, Moilanen L, Kähönen M, Kesäniemi YA, Nieminen MS, Reunanen A. Home-measured blood pressure is more strongly associated with atherosclerosis than clinic blood pressure: the Finn-HOME Study. *J Hypertens*. 2007;25:1225–1231.
8. Tachibana R, Tabara Y, Kondo I, Miki T, Kohara K. Home blood pressure is a better predictor of carotid atherosclerosis than office blood pressure in community-dwelling subjects. *Hypertens Res*. 2004;27:633–639.
9. Matsui Y, Eguchi K, Ishikawa J, Hoshide S, Shimada K, Kario K. Subclinical arterial damage in untreated masked hypertensive subjects detected by home blood pressure measurement. *Am J Hypertens*. 2007;20:385–391.
10. Ohkubo T, Imai Y, Tsuji I, Nagai K, Kato J, Kikuchi N, Nishiyama A, Aihara A, Sekino M, Kikuya M, Ito S, Satoh H, Hisamichi S. Home blood pressure measurement has a stronger predictive power for mortality than does screening blood pressure measurement: a population-based observation in Ohasama, Japan. *J Hypertens*. 1998;16:971–975.
11. Niiranen TJ, Hänninen MR, Johansson J, Reunanen A, Jula AM. Home-measured blood pressure is a stronger predictor of cardiovascular risk than office blood pressure: the Finn-Home study. *Hypertension*. 2010;55:1346–1351.

12. Mancia G, De Backer G, Dominiczak A, Cifkova R, Fagard R, Germano G, Grassi G, Heagerty AM, Kjeldsen SE, Laurent S, Narkiewicz K, Ruilope L, Rynkiewicz A, Schmieder RE, Boudier HA, Zanchetti A, Vahanian A, Camm J, De Caterina R, Dean V, Dickstein K, Filippatos G, Funck-Brentano C, Hellemans I, Kristensen SD, McGregor K, Sechtem U, Silber S, Tendera M, Widimsky P, Zamorano JL, Erdine S, Kiowski W, Agabiti-Rosei E, Ambrosioni E, Lindholm LH, Viigimaa M, Adamopoulos S, Agabiti-Rosei E, Ambrosioni E, Bertomeu V, Clement D, Erdine S, Farsang C, Gaita D, Lip G, Mallion JM, Manolis AJ, Nilsson PM, O'Brien E, Ponikowski P, Redon J, Ruschitzka F, Tamargo J, van Zwieten P, Waeber B, Williams B; Management of Arterial Hypertension of the European Society of Hypertension; European Society of Cardiology. 2007 Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *J Hypertens.* 2007;25:1105–1187.
13. Schillaci G, Verdecchia P, Porcellati C, Cuccurullo O, Cosco C, Perticone F. Continuous relation between left ventricular mass and cardiovascular risk in essential hypertension. *Hypertension*. 2000;35:580–586.
14. O'Leary DH, Polak JF, Kronmal RA, Manolio TA, Burke GL, Wolfson SK Jr. Carotid-artery intima and media thickness as a risk factor for myocardial infarction and stroke in older adults. Cardiovascular Health Study Collaborative Research Group. *N Engl J Med*. 1999;340:14–22.
15. Wachtell K, Ibsen H, Olsen MH, Borch-Johnsen K, Lindholm LH, Mogensen CE, Dahlöf B, Devereux RB, Beevers G, de Faire U, Fyhrquist F, Julius S, Kjeldsen SE, Kristianson K, Lederballe-Pedersen O, Nieminen MS, Okin PM, Omvik P, Oparil S, Wedel H, Snapinn SM, Aurup P. Albuminuria and cardiovascular risk in hypertensive patients with left ventricular hypertrophy: the LIFE study. *Ann Intern Med*. 2003;139:901–906.
16. Matsui Y, Eguchi K, Shibasaki S, Shimizu M, Ishikawa J, Shimada K, Kario K. Association between the morning-evening difference in home blood pressure and cardiac damage in untreated hypertensive patients. *J Hypertens*. 2009;27:712–720.
17. Imai Y, Otsuka K, Kawano Y, Shimada K, Hayashi H, Tochikubo O, Miyakawa M, Fukiyama K; Japanese Society of Hypertension. Japanese Society of Hypertension (JSH) guidelines for self-monitoring of blood pressure at home. *Hypertens Res.* 2003;26:771–782.
18. Anwar YA, Giacco S, McCabe EJ, Tendler BE, White WB. Evaluation of the efficacy of the Omron HEM-737 IntelliSense device for use on adults according to the recommendations of the Association for the Advancement of Medical Instrumentation. *Blood Press Monit*. 1998;3:261–265.
19. Howard SC, Rothwell PM. Reproducibility of measures of visit-to-visit variability in blood pressure after transient ischaemic attack or minor stroke. *Cerebrovasc Dis*. 2009;28:331–340.
20. Johansson JK, Niiranen TJ, Puukka PJ, Jula AM. Factors affecting the variability of home-measured blood pressure and heart rate: the Finn-home study. *J Hypertens*. 2010;28:1836–1845.
21. Kato T, Kikuya M, Ohkubo T, Satoh M, Hara A, Obara T, Metoki H, Asayama K, Hirose T, Inoue R, Kanno A, Totsune K, Hoshi H, Satoh H, Imai Y. Factors associated with day-by-day variability of self-measured blood pressure at home: the Ohasama study. *Am J Hypertens*. 2010;23:980–986.
22. Devereux RB, Reichek N. Echocardiographic determination of left ventricular mass in man. Anatomic validation of the method. *Circulation*. 1977;55:613–618.
23. Parati G, Stergiou GS, Asmar R, Bilo G, de Leeuw P, Imai Y, Kario K, Lurbe E, Manolis A, Mengden T, O'Brien E, Ohkubo T, Padfield P, Palatini P, Pickering T, Redon J, Revera M, Ruilope LM, Shennan A, Staessen JA, Tisler A, Waeber B, Zanchetti A, Mancia G. ESH Working Group on Blood Pressure Monitoring. European Society of Hypertension guidelines for blood pressure monitoring at home: a summary report of the Second International Consensus Conference on Home Blood Pressure Monitoring. *J Hypertens.* 2008;26:1505–1526.
24. Polónia J, Amado P, Barbosa L, Nazaré J, Silva JA, Bertoquini S, Martins L, Carmona J. Morning rise, morning surge and daytime variability of blood pressure and cardiovascular target organ damage. A cross-sectional study in 743 subjects. *Rev Port Cardiol*. 2005;24:65–78.
25. Eguchi K, Tomizawa H, Ishikawa J, Hoshide S, Pickering TG, Shimada K, Kario K. Factors associated with baroreflex sensitivity: association with morning blood pressure. *Hypertens Res*. 2007;30:723–728.
26. Gobbin B, Pickering TG, Sleight P, Peto R. Effect of age and high blood pressure on baroreflex sensitivity in man. *Circ Res.* 1971;29:424–431.
27. Lantelme P, Khettab F, Custaud MA, Rial MO, Joanny C, Gharib C, Milon H. Spontaneous baroreflex sensitivity: toward an ideal index of cardiovascular risk in hypertension? *J Hypertens*. 2002;20:935–944.
28. Gianaros PJ, Jennings JR, Olafsson GB, Steptoe A, Sutton-Tyrrell K, Muldoon MF, Manuck SB. Greater intima-media thickness in the carotid bulb is associated with reduced baroreflex sensitivity. *Am J Hypertens*. 2002;15:486–491.
29. Tatasciore A, Renda G, Zimarino M, Soccio M, Bilo G, Parati G, Schillaci G, De Caterina R. Awake systolic blood pressure variability correlates with target-organ damage in hypertensive subjects. *Hypertension*. 2007;50:325–332.
30. Griffin KA, Picken MM, Bidani AK. Deleterious effects of calcium channel blockade on pressure transmission and glomerular injury in rat remnant kidneys. *J Clin Invest*. 1995;96:793–800.
31. Ishikawa J, Kario K, Hoshide S, Eguchi K, Morinari M, Kaneda R, Umeda Y, Ishikawa S, Kuroda T, Hojo Y, Shimada K. J-MORE Study Group. Determinants of exaggerated difference in morning and evening blood pressure measured by self-measured blood pressure monitoring in medicated hypertensive patients: Jichi Morning Hypertension Research (J-MORE) Study. *Am J Hypertens.* 2005;18:958–965.
32. Kikuya M, Ohkubo T, Metoki H, Asayama K, Hara A, Obara T, Inoue R, Hoshi H, Hashimoto J, Totsune K, Satoh H, Imai Y. Day-by-day variability of blood pressure and heart rate at home as a novel predictor of prognosis: the Ohasama study. *Hypertension*. 2008;52:1045–1050.
33. Muntner P, Shimbo D, Tonelli M, Reynolds K, Arnett DK, Oparil S. The relationship between visit-to-visit variability in systolic blood pressure and all-cause mortality in the general population: findings from NHANES III, 1988 to 1994. *Hypertension*. 2011;57:160–166.
34. Yarows SA, Patel K, Brook R. Rapid oscillometric blood pressure measurement compared to conventional oscillometric measurement. *Blood Press Monit*. 2001;6:145–147.