What Is the Value of Home (Self) Blood Pressure Monitoring in Patients With Hypertensive Heart Disease?

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The acceptable maximal blood pressure values for patients monitoring their own blood pressure at home have not yet been determined. Risk of cardiovascular disease may be increased at lower blood pressure limits than those suggested by the World Health Organization (WHO) for clinic readings. We have investigated 25 patients with proven hypertensive small-vessel disease and compared self-monitored, ambulatory 24-h (ABPM) and clinic blood pressure measurements. The diagnosis of hypertensive small-vessel disease was based on clinical evidence of myocardial ischemia, angiographic exclusion of coronary heart disease, and abnormal single-photon emission computed tomography (SPECT) thallium-201 myocardial scintigraphy. Mean self-monitored values were 143.4 ± 13.6/84.0 ± 9.4 mm Hg (95% confidence intervals 137.6–149.0 mm Hg for systolic and 80.1–87.9 mm Hg for diastolic blood pressure). Both home and ambulatory daytime readings (141.2 ± 11.8/83.9 ± 10.2 mm Hg) were significantly lower than the clinic readings by the physicians (clinic systolic, 169.2 ± 16.5 mm Hg; clinic diastolic, 95.0 ± 11.6 mm Hg; P < .0001 vs home and ambulatory readings). There was no significant difference between home and ambulatory readings.

Agreement between home and ambulatory values was much closer than for clinic vs ABPM readings. The respective correlation coefficients for systolic values were r = 0.702 (home vs ABPM; P < .0001) and r = 0.32 (clinic vs ABPM; NS). For diastolic values correlation coefficients were r = 0.674 (home vs ABPM; P < .0002) and r = 0.574 (clinic vs ABPM; P < .003) respectively. In conclusion, the reported results suggest that the WHO suggested definition of hypertension (≥ 140/90 mm Hg) may be set too high when blood pressures are measured by the patient at home. A cutoff value of < 135/85 mm Hg, as in ABPM, may be a more realistic upper limit for self-monitoring. Am J Hypertens 1998; 11:813–819 © 1998 American Journal of Hypertension, Ltd.

KEY WORDS: Self-monitoring, ambulatory monitoring, hypertensive heart disease, myocardial scintigraphy, coronary reserve, normal blood pressure, target organ damage.

The use of self-determined blood pressure measurements at home (self-monitoring) has grown dramatically in the past few years. Although the advantages of self-monitoring have been described as early as 1930 by Brown, only recently have general recommendations for the use of self-monitoring been published in this journal. The increasing sales and use of home monitors is mainly patient-driven and electronic devices for self-monitoring are now available in drug stores and mail-order...
Despite the fact that self-measurement of blood pressure is now widely performed by patients with hypertension, no generally accepted guidelines for data analysis are available.

In untreated hypertensive patients self-monitored blood pressures are comparable with daytime readings of ambulatory blood pressure monitoring (ABPM). Correlations with ambulatory 24-h monitoring (ABPM) as well as with left ventricular hypertrophy are closer for self-monitoring than for clinic measurements. Both self-measurement and ABPM are lower than casual measurements and this difference increases with the severity of hypertension. The difference is caused mainly by an interaction between patient and physician during the casual blood pressure measurement in the clinic (clinic blood pressure). Interestingly, this difference between clinic and home blood pressure increases even if self-measurement by the patient is performed in a clinical setting in the presence of the physician. In recent studies comparisons between casual, self-measured, and ambulatory 24-h values in hypertensive patients were not related to target organ damage. We therefore proposed to investigate casual, ABPM, and self-monitoring in patients with proven hypertensive heart disease.

**MATERIALS AND METHODS**

**Patients** Patients were referred to our clinic for cardiac catheterization because of clinical evidence of myocardial ischemia. Clinical diagnosis was based on a history of chest discomfort, complaints thought to be anginal equivalents, an abnormal rest electrocardiogram (ECG), or a stress test suggesting myocardial ischemia. No patient had valvular heart disease, prior myocardial infarction, myocarditis, cardiomyopathy, asymmetric septal hypertrophy, rheologic abnormalities, diabetes mellitus, vasculitis, or poor overall medical condition. Severity of chest pain was classified according to the Canadian Cardiovascular Society. All patients had essential hypertension according to the World Health Organization (WHO) guidelines, defined as repeated casual blood pressure values ≥ 140/90 mm Hg.

Patients included had normal coronary angiograms. A normal angiogram was defined as < 30% luminal diameter narrowing in a major vessel or a major branch. Depressed coronary flow reserve was demonstrated by single-photon emission computed tomography (SPECT) thallium-201 exercise myocardial scintigraphy. Thallium-201 stress perfusion scanning is a noninvasive marker for the detection of myocardial ischemia in patients with hypertensive heart disease in the absence of obstructive epicardial coronary artery disease. We included 25 patients with depressed coronary flow reserve as shown by thallium perfusion defects during exercise thallium scans. These 25 patients with normal coronary angiograms and hypertensive blood pressure values were classified as having hypertensive small-vessel disease. Ten women and 15 men were included (mean age 58.9 ± 9.9 years), with a mean duration of essential hypertension of 7.1 ± 6.7 years (range 1–24 years). Twenty-two of the patients had previous antihypertensive medication. Severity of chest discomfort according to the Canadian Cardiovascular Society was distributed as follows: class I, 13 patients; class II, nine patients, and class III, three patients.

As a control for the self-measured blood pressure values of the patients with hypertensive heart disease we selected 25 healthy, normotensive, age-matched control subjects with repeated casual blood pressure values < 140/90 mm Hg.

The study was approved by the ethical committee of the University of Düsseldorf.

**Blood Pressure Measurement** After cardiac catheterization previous antihypertensive medication was stopped for a period of 2 weeks. After 3 days and after 14 days washout casual BP was determined. Home monitoring of blood pressure was performed during the whole study period, beginning with the first day of washout. However, the statistical analysis of self-measurement included only measurements performed between day 4 and day 14 (last clinic visit) of the washout period. ABPM was performed after 2 weeks without antihypertensive medication (last clinic visit).

Casual blood pressure was measured after 5 min rest in a sitting position with a mercury sphygmomanometer always on the same arm, according to the recommendations of the American Heart Association; we used phase V Korotkoff sounds as diastolic blood pressure. Two readings were taken after 3 days and 14 days washout, and mean values were used for group comparisons.

After sufficient instruction in the correct self-measurement technique by a physician in charge of the trial, patients and controls were directed to measure blood pressure and heart rate at home in the morning (6 AM to 8 AM) and in the evening (6 PM to 8 PM) and to keep a record of all readings. Self-measurement was performed by all patients and healthy controls with a successfully tested and previously calibrated semiautomatic, oscillometric device with automatic deflation and digital display of blood pressure and heart rate values (Mepha-mat, Mepha-Pharm, Germany). To avoid an artificial blood pressure increase due to squeezing the sphygmomanometer bulb, each patient was instructed to place the cuff on the nondominant arm and to use the hand of the opposite arm to inflate the cuff while keeping the cuff arm relaxed. To detect a difference between the self-monitoring device and the conventional mercury sphygmomanometer, a Y-
tube was connected to the device using the same cuff for each patient as that used during the 30-min training period. At least three consecutive measurements were performed within a few minutes to detect a difference between simultaneously measured values of the test device and the standard mercury sphygmomanometer. A difference of >10 mm Hg systolic and 5 mm Hg diastolic was regarded as unacceptable, but this occurred in none of our patients or controls. Self-measured morning (6 AM to 8 AM) and evening (6 PM to 8 PM) blood pressures were averaged for a period of 10 days and the means used for group comparisons.

At the last clinic visit (after 2 weeks without antihypertensive medication) ambulatory 24-h blood pressure monitoring was performed during average working days. For ambulatory monitoring we used the SpaceLabs 90202 noninvasive automatic blood pressure recorder (SpaceLabs, Redmond, WA), whose accuracy has previously been evaluated.10 Blood pressure and heart rate were measured at preset 20-min intervals from 6 AM to 12 PM, and at 60-min intervals at night. Systolic and diastolic blood pressure, mean arterial pressure, and heart rate were stored in the SpaceLabs monitor and screened for artefactual readings by the SpaceLabs computer program, which edits out measurements with obvious technical inconsistencies (slow cuff inflation, measurement aborted because of low batteries, blood pressure not detected, pressure artifacts) and readings below or above given limits (systolic blood pressure <70 or >260 mm Hg, diastolic blood pressure <40 or >150 mm Hg, pulse pressure <20 or >150 mm Hg, heart rate <20 or >200 bpm). The data were analyzed on an IBM computer. We used mean daytime values (6 AM to 12 PM) for statistical comparisons with usual and self-measured (home) blood pressure values.

**SPECT-Thallium 201 Myocardial Scintigraphy** After cardiac catheterization antihypertensive medication was stopped. At least 3 days washout SPECT-thallium-201 scintigraphy (Sopha Camera, Sopha Medical, Germany) was performed under standardized bicycle stress testing. We injected thallium-201 (2.5–3.0 mCi) at peak exercise, and continued it for 30 to 60 sec. Images were interpreted for regional thallium uptake and redistribution (3 h after peak exercise) and considered as abnormal when there was a ≥25% reduction in regional thallium uptake compared with the region of the highest uptake in that image.

**Echocardiographic Assessment of Ventricular Hypertrophy** Satisfactory two-dimensional echocardiography was performed in all 25 patients using a 2.5-MHz transducer linked to an ultrasound system (Toshiba-Sonolayer-SSH-160-A). Measurements were made in accordance with American Society of Echo-cardiography criteria11 and left ventricular mass index (LVMI) was determined according to the formula of Devereux.12 Relative wall thickness (RWT) was calculated as RWT = 2 × PWT/LVID, where PWT = left ventricular posterior wall thickness in cm, and LVID = left ventricular internal dimension at end-diastole in cm.

**Statistical Analysis** All values are given as means ± standard deviation. Unpaired $t$ test was used for the comparison of the respective values of the hypertensive and normotensive controls. For the comparisons of the different blood pressure methods, within-groups paired $t$ test was used.

**RESULTS**

**Home Blood Pressure Measurements** Results of home blood pressure values in the patients with hypertensive heart disease in comparison to normotensive controls are given in Table 1. The home blood pressure values of our normotensive controls were significantly lower than the respective values of the hypertensive patients ($P < .0001$). In comparison to the population mean of the normotensive participants of the Studi delle Pressioni Ambulatoriali delle Loro Associazoni (PAMELA) study we observed very similar home blood pressure values in our normotensive controls.

According to the age- and gender-adjusted upper limits of normality of the PAMELA study, mean home blood pressure values of 23 of the 25 hypertensive patients were abnormally high.8 Only two patients had normal home blood pressure values according to

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<th>TABLE 1. SELF-MONITORED HOME BLOOD PRESSURE VALUES (SYSTOLIC/DIASTOLIC; MM HG) OF PATIENTS WITH HYPERTENSIVE HEART DISEASE (HT; N = 25) AND NORMOTENSIVE CONTROLS (NT; N = 25) IN OUR STUDY, WITH THE RESPECTIVE SELF-MONITORED VALUES OF THE NORMOTENSIVE PARTICIPANTS FROM THE PAMELA STUDY SHOWN FOR COMPARISON (NT-PAMELA)</th>
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SD, standard deviation; CI, confidence interval.

* $P < .001$ (hypertensive v normotensive controls of our study); NS, not significant (normotensive controls of our study v normotensive participants of the PAMELA study).
the PAMELA study criteria. Their respective mean home blood pressure values were 123.2/70.4 mm Hg and 124.7/73.5 mm Hg. The first of these two patients had clearly elevated mean daytime ABPM of 139/83 mm Hg with blood pressure loads of 40% for systolic and 20% for diastolic values, respectively. His clinic blood pressure was 162/96 mm Hg and he showed an exaggerated blood pressure response to stress testing of 240 mm Hg systolic at peak exercise.

The second patient had a clinic blood pressure of 160/100 mm Hg and a maximal systolic blood pressure during stress testing of 210 mm Hg, although ABPM values were quite normal. This second patient with normal home blood pressure values showed echocardiographic signs of ventricular hypertrophy, with an elevated LVMI of 129.8 g/m² and an increased relative wall thickness of 0.4 (normal < 0.35).

Comparison of Home, Ambulatory, and Clinic Blood Pressure Values in Hypertensive Patients  As expected, both home and ambulatory daytime readings were significantly lower than the clinic readings by the physicians (clinical systolic, 169.2 ± 16.5 mg; clinical diastolic, 95.0 ± 11.6 mm Hg; P < .0001, v home and ambulatory readings). As illustrated in Figure 1, however, there was no significant difference between home and ambulatory readings; 95% confidence intervals were 137.6–149.0/80.1–87.9 mm Hg for home readings and 136.3–146.80/79.7–88.1 mm Hg for ambulatory readings.

Furthermore, agreement between home and ABPM values was much closer than for clinic v ABPM readings (Figure 2). Thus the respective correlation coefficients for systolic values were r = 0.702 (home v ABPM; P < .0001) and r = 0.32 (clinical v ABPM; NS).
For diastolic values, correlation coefficients were $r = 0.674$ (home $\nu$ ABPM; $P < 0.0002$) and $r = 0.574$ (clinic $\nu$ ABPM; $P < 0.003$), respectively.

**Blood Pressure Response to Stress Testing** Maximal blood pressure values during bicycle stress testing averaged $210.8 \pm 20.8/101.5 \pm 13.4$ mm Hg at peak exercise. Fourteen of the 25 hypertensive patients had an exaggerated blood pressure response of $\geq 210$ mm Hg for systolic values at peak exercise.

**Echocardiographic Data** Mean LVMI of the hypertensive patients was $129.8 \pm 22.2$ g/m$^2$. According to the recently published upper limits of LVMI for women ($< 108$ g/m$^2$) and men ($< 118$ g/m$^2$), 19 of the 25 patients had echocardiographic signs of left ventricular hypertrophy. Mean relative wall thickness was elevated by 0.46 $\pm$ 0.066.

**DISCUSSION**

The present study confirms the findings of previous investigations, which demonstrated that self-measured blood pressures are consistently lower than casual measurements. There was no significant difference between mean daytime ABPM and home readings for systolic and diastolic values.

Our results imply that the WHO guidelines for the interpretation of casual blood pressures may not be applied to self-monitoring. These findings are in agreement with the results of recent population-based epidemiologic studies that suggest that upper limits of self-measured values may be very similar to the proposed limits of normality for ABPM. The results of these epidemiologic studies provide convincing evidence that considering 140/90 mm Hg as the upper limit of normal for self-monitoring is a logical error (using a value derived from one type of measurement as a standard for another type of measurement). Furthermore it is also a factual error, which may lead to people whose home blood pressures are abnormal being considered as normotensive.

However, up to now it has not yet been shown that such a factual error is associated with greater cardiovascular risk. Target organ damage such as hypertensive heart disease is used to define the cardiovascular risk of hypertensive patients. We therefore investigated self-measured blood pressure in a well-defined patient group with clear evidence of hypertensive target organ damage. The present study is the first comparing self-measured home blood pressure values with the respective clinic and ambulatory readings in patients with hypertensive small-vessel disease.

Hypertensive heart disease is characterized by left ventricular hypertrophy (LVH), impaired coronary flow reserve, or both. Even in the absence of LVH (extravascular factor), coronary flow reserve may be reduced by small-vessel disease (vascular factor) due to an increased media/lumen ratio of coronary resistance arteries. Reduced coronary vasodilator reserve is a common finding in hypertensive patients referred for cardiac catheterization because of suspected atherosclerotic coronary disease but with normal epicardial coronary arteries. Only patients who fulfilled the strict criteria as mentioned above were included in the study; the presence of LVH was not an inclusion criterion. Nevertheless, in 19 of 25 patients increased LVMI could be demonstrated by echocardiography, according to the recently published criteria of Roman et al.

Considering the poor prognosis of patients with hypertensive heart disease, underestimation of blood pressure using self-measured values may have serious prognostic implications. Patients in our study with proven hypertensive heart disease may well not receive antihypertensive therapy if a home blood pressure $\geq 140/90$ mm Hg is considered as an indication for therapy. This is the major finding of the present study.

Furthermore, we observed a closer correlation between home readings and ABPM, compared to clinic readings (Figure 2). This is in agreement with previous studies correlating self-monitored readings with ABPM or LVH. Using 135/85 mm Hg as the cutoff value for ABPM, very similar values for self-monitoring are obtained on the regression line (Figure 2). Although the present study design does not allow us to define normal values for self-measurement, we recommend similar values for upper limits of normal for average home blood pressures, as recently suggested for ambulatory daytime readings, ie, $< 135/85$ mm Hg.

One unsolved problem of self-measurement is the fact that there are still no generally accepted normal values for self-monitoring. In the PAMELA study in-
clearly elevated clinic blood pressures. A definite answer to the important issue of normali-
ty can, however, be expected only from prospective studies that establish the ability of home blood pressure to predict the development of end-organ damage, cardiovascular complications, and death before and during treatment. In a recent long-term prospective study by Imai et al the relative hazard of cardiovascular death during a 5-year follow-up period tended to increase significantly for the highest quintiles of systolic and diastolic home blood pressures, whereas no such tendency was observed for clinic readings. The respective highest quintile of home measurements was > 138 mm Hg for systolic and > 83 mm Hg for diastolic blood pressure values. The same pattern was observed for ABPM. The authors concluded that home as well as ambulatory blood pressure measurements have more reliable prognostic value than clinic measurements. Further prospective studies are necessary to confirm these data.

CONCLUSION

We have demonstrated that patients with hypertensive heart disease monitoring their own blood pressure consistently report lower values than those measured in a clinical setting. As the latter are the basis of the WHO guidelines for treatment of hypertension this may lead to undertreatment and may have serious prognostic implications if the same normal values are used for casual and self-measured blood pressure. Blood pressures < 135/85 mm Hg, as in ABPM, are a more realistic upper limit for self-monitoring patients.

REFERENCES


