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Clinical Significance of Home Blood Pressure and Its Possible Practical Application

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▌ABSTRACT▐

This review represents the clinical significance of home blood pressure (BP) and its possible practical application. Home BP is highly reproducible and its reproducibility is better than ambulatory BP. According to this feature home BP has a greater prognostic value at least than clinic BP and is extremely effective for the evaluation of drug effects and their duration. The introduction of home BP to the diagnosis and treatment of hypertension facilitates long-term BP control. Home BP is particularly important for the diagnosis and treatment of hypertension in diabetes mellitus, pregnancy, children and renal diseases. Home BP measurements improve the adherence to medications and medical consultations, and are indispensable for diagnosis of white coat hypertension and masked hypertension. Such efficiency of home BP improves medical economy. Home BP can detect minimal charge in BP mediated by medication, and intrinsic and extrinsic stimuli and detect long-term change in BP. Thus, home BP is now indispensable for improvement in the management of hypertension in medical practice as well as for the recognition of hypertension in the general population. Standardization of the measurement procedure may elevate the position of home BP in the practice of diagnosing and treating hypertension.

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Key Words: Home blood pressure measurements; Clinical significance; Clinical application; Pharmacology, clinical; Diagnosis; Therapeutics; Hypertension

Introduction

Today, blood pressure (BP) is measured under non-clinical settings by either ambulatory blood pressure monitoring (ABPM) or home BP measurements. These two methods have different characteristics as well as many similarities. One of the similarities is that the procedures provide more information than clinic BP measurements. ABPM provides BP information at many points on a particular day during unrestricted routine daily activities, and the information obtained by ABPM may be compared to serial typhoon information regarding its characteristics in relation to time. On the other hand, home BP measurements provide a lot of BP information obtained under fixed conditions and at nearly fixed hours of the day over a long period of

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Table 1. Characteristics of each type of blood pressure measurement (Modified partly from Imai Y, et al.[9] and Ogihara T, et al.[55])

	Clinic blood pressure	Ambulatory blood pressure	Home blood pressure
Frequency of measurement	Low	High	High
Measurement standardization	Possible (difficult)	Unnecessary	Possible
Evaluation of short-term variability	Impossible	Possible	Impossible
Evaluation of diurnal changes (evaluation of nocturnal blood pressure)*	Impossible	Possible	Partly possible
Drug efficacy assessment	Possible	Appropriate	Appropriate
Evaluation of the duration of drug efficacy	Impossible	Possible	Possible
Evaluation of long-term changes	Partly possible	Impossible	Possible
Reproducibility	Unfavorable	Favorable	Most favorable
White coat phenomenon	Present	Absent	Absent

*Home blood-pressure-measuring devices that can monitor blood pressure during sleep at night are available.

time, which may be compared to fixed-point observations. Whether they are compared to serial typhoon information or fixed-point observations, both methods provide time-related BP information.

Since home BP is measured under fixed conditions and at nearly the same time points during the day over a long period of time, its mean value is stable, and short- and long-term reproducibilities are high.[1-3] On the other hand, as ambulatory blood pressure (ABP) is affected by various internal and external environmental factors on a particular day, the reproducibility of its mean value is inferior to that of home BP,[2-4] and the reproducibility of circadian BP variations based on ABPM is not enough.[5-8] Table 1 summarizes the characteristics of home BP compared with clinic BP and ABP.[9]

Home blood pressure and prognosis

The prognostic significance of home BP has been reported to be comparable to,[10,11] or slightly better than that of ABP. The high prognostic significance of home BP is considered to be derived from the stability of BP information.[12-21] Evidence has also shown that home BP reflects target organ damage with similar or higher reliability than ABP.[22-26]

ABPM provides data on short-term BP variability every 15 to 30 minutes, and these values are reported to have prognostic significance.[27-30] The day-to-day variability of BP detected by home BP measurements has also been reported to predict the risk of cerebrovascular and cardiovascular diseases.[31,32] Heart rate measured simultaneously with home BP also has a prognostic significance.[33]

Home blood pressure and clinical pharmacology of antihypertensive drugs

Since home BP provides a stable mean value and ensures high reproducibility, it is extremely effective for the evaluation of drug effects and their duration. Home BP eliminates the placebo effect[34] and more accurately records the responses to antihypertensive drugs than ABP,[35] and, as such, is considered optimal for evaluating the effects of antihypertensive drugs.[36,37] Consequently, home BP reduces the number of subjects necessary for the evaluation of drug effects compared with ABP, and markedly reduces the number necessary when compared

with clinic BP.[3,35,36)]

Evaluation of the duration of drug effects has been considered possible by the use of the trough/peak (T/P) ratio based on ABP. However, as the reproducibility of ABP is not always adequate, the reproducibility of the T/P ratio is also unsatisfactory.[38,39)] It has recently been reported that the morning/evening or evening/morning ratio obtained from home BP measurements is very effective for evaluating the duration of drug effects.[37,38,40)]

Home blood pressure and telemedicine

With the advance of devices for home BP measurements, BP values have begun to be stored as electronic data. As a result, such data have been transmitted via telephone lines or the internet, and are widely used for decision making[41-45)] and clinical pharmacological evaluations.[45,46)] Improvements in BP control by means of such telemedicine have been reported.[41,44,47-51)]

Home blood pressure and blood pressure control

The Japanese and international guidelines recognize home BP measurements as an optimal tool for long-term BP control.[52-55)]

The introduction of home BP measurements in the diagnosis and treatment of hypertension facilitates the attainment of a goal BP compared with BP management based on clinic BP alone.[50,56-60)] By implementing antihypertensive therapy according to home BP, the goal BP can be achieved sooner.[47,61)]

BP control has been reported to be improved by combining home BP measurements with behavioral therapy.[62)] Home BP measurements also reduce the frequency of clinic consultations[47)] and elevate the participation rate to medical treatment.[63)]

Since home BP is measured and interpreted by the patients themselves, the possibility of self-regulation of antihypertensive medication according to home BP has become relevant in hypertension management.[51,64,65)]

Home blood pressure and adherence

Home BP measurements require an active commitment by the patients themselves in medical care and health management, and results in a marked improvement in the adherence to medication.[66,67)] High adherence to home BP measurements has also been reported to improve BP control.[68)] Patients with high adherence to home BP measurements have also shown high adherence to exercise or dietary intervention.[69)]

Home blood pressure and seasonal changes in blood pressure

Unlike ABP, home BP is effective for evaluating long-term changes in BP. For example, home BP can detect seasonal variations in BP.[70-75)] The monitoring of seasonal changes in home BP facilitates the titration of antihypertensive drugs.

Home blood pressure and physiological and pathophysiological conditions

Home BP can detect slight changes in BP mediated by modifications in lifestyle or by exposure to stress, as well as small changes in BP in response to antihypertensive drugs. For example, home BP can detect the depressor effect caused by the intake of fruits and vegetables in a population[76)] or physical training,[77)] the hypertensive response to passive smoking in a population,[78)] the relationship with the longevity of parents and low BP in children,[79)] the relationship of combinations of hypertension

candidate genes with the incidence of hypertension,[80] and so on. Home BP measurements provide an excellent index for the evaluation of BP changes in individuals and for the comparison of BP among individuals and groups.

In particular, the reliability and precision of BP as a phenotype are determinants of the results of gene-related studies, and home BP is considered to be extremely useful in such studies.[81]

Measurement of home blood pressure under special conditions

Home BP is information obtained under a non-medical setting and essentially by self-measurement. With home BP measurements, time-related BP information can be obtained over a long period. On the basis of these characteristics, home BP has provides information indispensable for the diagnosis of white coat hypertension, masked hypertension, or early morning hypertension. Also, some home BP measuring devices provide BP information during sleep at night. Moreover, home BP measurements are used as a means to average BP over a long period of time and, thus, are used as a means to transform essentially highly variable BP values into stable BP information in the form of averaged BP. This is applied to BP measurements for pregnant women and children. Many studies also reported the usefulness of home BP measurements for the diagnosis and treatment of hypertension in dialysis patients and diabetic patients, in whom daily management of BP mediates critical results on their outcome.

1. White coat hypertension/white coat phenomenon (effect)

White coat hypertension is a condition in which BP measured in a medical setting (outpatient clinic, etc.) is always in the hypertensive range (≥140/90 mm Hg), and that measured in a non-medical setting (home BP, ABP) is always normal. Generally, this condition is diagnosed by home BP measurements. Although the American Heart Association (AHA) recommends the screening of patients for white coat hypertension by home BP measurements with the final diagnosis by ABPM,[82] it is practical to diagnose this condition using home BP in general clinical practice, while ABPM should be considered when necessary. The term "white coat hypertension" is used for untreated patients. Differences between clinic and home BPs are also observed in patients being treated. This condition is called the white coat phenomenon (effect). If a patient being treated exhibits hypertension on BP measurements in a medical setting but normal BP measurements in a non-medical setting, the condition must be specified as "white coat hypertension under treatment". Home BP measurements are indispensable for the diagnosis of white coat hypertension or the white coat phenomenon. While the potential harmfulness of white coat hypertension remains controversial, studies based on home BP have reported that white coat hypertension tends to advance to true hypertension more often than true normotension.[83,84]

The frequency of white coat hypertension based on home BP measurements has been reported to be 38%–58% in cohorts of the general population,[85-87] 15% in untreated patients with hypertension,[88] and 12%–19% in hypertensive patients being treated.[89-91]

The prognosis of white coat hypertension depends on home BP levels. If high normal BP home measurements (125–135/80–85 mm Hg, see 'Home blood pressure measurements in various diseases' section) are regarded as normal, the prognosis of white coat hypertension tends to be poor. However, if optimal BP levels (<120/80 mm Hg, see 'Home blood pressure measurements in various diseases' section) are regarded as normal home BP, the

prognosis of white coat hypertension is generally judged to be favorable.

2. Masked hypertension

In contrast to white coat hypertension, when clinic BP is normal, but the values measured in a non-medical setting are in the hypertensive range, this condition is called masked hypertension. This condition is generally detected by home BP measurements and is observed in both treated and untreated patients. The condition is called masked hypertension because hypertension is masked on measurements taken in the clinic. Masked hypertension detected by home BP measurements in the morning may be related to elevations in BP during this time as part of diurnal BP fluctuations such as those in non-dippers, risers, and the morning surge,[91,92] or as a result of an insufficient duration of the effect of antihypertensive medication, causing an increase in BP to hypertensive levels before the next dosing.[93] The prognosis of masked hypertension is poor.[20,94] Workplace hypertension is also a form of masked hypertension. The frequency of masked hypertension based on home BP is reported to be about 10% in cohorts of the general population[86,87] and 11%–33% in hypertensive patients under treatment.[91,95,96]

3. Morning hypertension and morning and evening home blood pressure

Although there is no precise definition of morning hypertension, a condition with a specifically high BP after waking early in the morning may be referred to as morning hypertension. According to the absolute values of home BP or ABP, 135/85 mm Hg or higher in the morning, for example, may be regarded as morning hypertension, however the value in the morning must be higher than that in the evening to confirm that BP is high specifically in the morning. Morning hypertension may be the result of one of two patterns of diurnal BP changes. One is the morning surge, which is a rapid elevation in BP around awakening from a low nocturnal level. The other is high BP in the morning observed in non-dippers, who show no normal nocturnal decrease in BP, or risers, who show nighttime elevations in BP. Both patterns are considered to be possible risk factors of cardiovascular diseases.[92,97-101]

Home BP is usually measured 2 times a day, i.e., in the morning and evening. According to reports from Japan, home BP is higher in the morning than in the evening.[96,102] Major causes of this difference in BP between the morning and evening are reported to be antihypertensive treatment, alcohol intake, and taking a bath.[103-105] Those who exhibit large morning-evening differences in BP have marked target organ damage such as left ventricular hypertrophy.[106-109] However, home BP measured in the evening also has a high prognostic significance.[100,110]

In contrast, there have been a number of reports from western countries that home BP does not differ between the morning and evening or that home BP is higher in the evening than in the morning.[111,112] This may be partly explained by the difference in evening BP measurement times (mostly early in the evening in western countries, and before going to bed in Japan). Differences in lifestyle between Europeans and Japanese, the latter has the habit of taking a bath in the evening, may also be related.

4. Nighttime blood pressure

During sleep at night, BP is usually measured by ABPM. Recently, home BP measuring devices capable of monitoring BP during sleep at night have been developed, and their performance has been close or equal to that of ABPM.[113-115] Home BP measuring devices with

similar functions to ABPM have also been developed, and the differences between these two methods have been narrowed.[116,117] Generally, the state of sleep is evaluated the next morning according to whether the subject woke up due to operation of the device. However, as BP is measured every 30 minutes to 1 hour by ABPM during the night, i.e., 8 to 16 times during sleep, the relationship between the state of sleep and BP cannot be evaluated using this method. Using a home BP monitoring device, BP during sleep is measured once or twice during the night, although the frequency of measurement can be preset freely, and is therefore able to capture BP in relation to the quality of sleep at the time of the measurement. This is a great advantage of this method.[113]

Recently, midnight BP and diurnal changes in BP, as well as morning BP, are of interest because of their relationships with target organ damage and prognosis. Decreases in nocturnal BP of 10% to 20% compared with daytime BP are classified as a normal pattern of diurnal changes (dipper), decreases of 0% to 10% as a no-nocturnal-dip type (non-dipper), elevations in BP during the nighttime compared with the daytime as a nocturnal elevation type (riser), and 20% or greater decreases in nocturnal BP are classified as an excessive decrease type (extreme dipper). The prognosis has been poor in non-dippers and risers.[97,118-121] In non-dippers and risers, hypertensive target organ damage, such as asymptomatic lacunar infarction, left ventricular hypertrophy, and microalbuminuria, are observed more frequently than in dippers.[119,120,122] Prospective studies have shown that the risk of cardiovascular diseases is higher in non-dippers than in dippers.[97,120-122] According to the results of the Ohasama Study, the risk of cardiovascular diseases is high in non-dippers even if they are normotensive.[121] Therefore, the clinical significance of nocturnal BP is attracting interest. The results of a large-scale intervention study[123] and an international collaborative study of observation studies[124] show that low nighttime, as well as low daytime BP are considered to improve the prognosis of patients. For the future, a wide application of home BP measuring devices is expected to evaluate BP during sleep at night in relation to the quality of sleep and to diurnal changes in BP.

Home blood pressure measurements in various diseases

Home BP, measured by patients themselves over a long period, is widely used for the management of chronic diseases in which BP control has a critical role for the prognosis. The AHA/American Society of Hypertension ASH/Preventive Cardiovascular Nurses Association joint statement[54] and the European Society of Hypertension guidelines for home BP measurements[52] emphasize the importance of home BP measurements in the management of diabetes mellitus, pregnancy, children, and renal diseases.

1. Diabetes mellitus

The International Diabetes Federation has recommended the use of home BP for the management of BP in diabetic patients.[125]

The Japan Home versus Office Blood Pressure Measurement Evaluation Study reported that home BP was 130/80 mm Hg or higher in 7% of diabetic patients in whom clinic BP was controlled under 130/80 mm Hg.[126] Home BP in the morning has been reported to more accurately reflect target organ damage than clinic BP in diabetic patients.[72,99,127] Management of patients on the basis of telemedicine in co-operation with nurses, where home BP is used as an index, has been reported to have led to a more rapid control of BP in diabetic patients.[128]

2. Pregnancy

Long-term and short-term changes in BP occur during pregnancy and after delivery.[75] Home BP monitoring is the optimal method for the early detection of, and early preventive intervention in preeclampsia and eclampsia.[129] White coat hypertension has also been frequently detected by home BP measurements in pregnant women.[130,131] Changes in BP during pregnancy are markedly affected by the season. Seasons are important for the diagnosis of hypertension during pregnancy and preeclampsia.[75,129]

3. Renal diseases (chronic kidney disease, dialysis)

Renal diseases are often accompanied by hypertension, and hypertension is the greatest risk factor for the progression of nephropathy. In the general population, the risk of chronic kidney disease has been reported to be high in patients with masked hypertension, as determined by home BP measurements.[132] In patients undergoing dialysis, the greatest prognostic factor is the presence of cerebro- and cardiovascular complications, and the management of hypertension is extremely important. However, BP measured at the dialysis center fluctuates widely and has been reported to not accurately reflect the outcome. Home BP is known to more closely reflect the usual BP of dialysis patients.[133] In addition, home BP measurements in dialysis patients have been shown to improve the state of BP control.[134,135]

4. Home blood pressure in children

Since white coat hypertension and masked hypertension has also been measured in children, home BP measurements are considered particularly useful for the diagnosis of hypertension.[136] However, unlike adults, home BP in children has been reported to be higher than clinic BP or daytime ABP.[136,137]

Effects of home blood pressure on the medical economy

The introduction of ABPM into the diagnosis and treatment of hypertension has been shown to have a strong effect on the medical economy.[138,139] If home BP provides information comparable to that provided by ABP, it would also be expected to exert a great effect on the medical economy.[140] In fact, in Japan, where home BP measuring devices are already used by most hypertensive patients, the introduction of home BP into the care of hypertension has resulted in a decrease in annual medical expenditure of about 1 trillion yen.[141,142] This decrease has been mediated primarily by screening for white coat hypertension and masked hypertension. As a result of large-scale intervention studies, the introduction of home BP has also been reported to lead to a reduction in medical expenditure via a decrease in the amount of drugs used.[47,61]

Discussion

Home BP measurements are now indispensable for improvements in the management of hypertension in medical practice, as well as for the recognition of hypertension in the general population.

Fortunately, international reference values of home BP are now established. However, the treatment goal for home BP levels has not yet been established. In several guidelines, the normotensive value of home BP is set as 125/80 mm Hg. In the Pressioni Arteriose Monitorate e Loro Associazioni (PAMELA) study,[143,144] the Ohasama study,[145] and results of the International data base,[146] a home BP of 125/80 mm Hg is approximately equivalent to a casual-clinic BP level of 140/90 mm Hg. Therefore,

it seems that a value of less than 125/80 mm Hg has been suggested as the goal for home BP. However, setting of a goal for home BP must be based on the results of large-scale intervention studies. Among such studies, the Treatment of Hypertension according to the Home or Office Blood Pressure (THOP) study[147] and the Hypertension Objective treatment based on Measurement by Electrical Devices (HOMED)-BP study[148] are ongoing. Although such reference values have been proposed in several guidelines, standardization of measurement conditions has not yet been achieved. For example, in the Techmuseh study,[85] the measurement frequency was once in the morning and once in the evening, and the measurement duration was 7 days (14 measurements in total). In the PAMELA study,[143,144] home BP was measured once in the morning and once in the evening on only 1 day (2 measurements in total). In the Ohasama study,[145] home BP was measured once in the morning and once in the evening for 21 days (42 measurements in total). In the THOP study, home BP was measured 3 times in the morning and 3 times in the evening for 7 days,[147] while in the HOMED-BP study, home BP was measured once in the morning and once in the evening for at least 5 days during the run-in-period, and an average of these measurements was used as a control value.[148] Because of the great variety in measurement procedures among studies, it seems impossible to compare results among them. In the future, internationally standardized measurement procedures will be established by consensus, and reference values on the basis of such standardized procedures will be proposed. However, common to all these measurements of home BP values, including those from past databases, is the use of the 1st measurement on each occasion and the mean of these values for a certain period.

Therefore, the common value for home BP, which is available for retrospective analysis, prospective analysis, and even meta-analysis, is the mean of the 1st measurement on each occasion averaged over a certain period. For this reason, the Japanese Society of Hypertension Guidelines for the Management of Hypertension 2009 recommend that home BP should be evaluated by the mean of the 1st measurement in the morning and in the evening, respectively, and these values should be averaged for a certain period.[55]

Standardization of the measurement procedure may elevate the position of home BP measurements in the practice of diagnosing and treating hypertension, and as a result, home BP measurements may bring an improvement in the reliability of screening and diagnosis for hypertension, an improvement in drug adherence, and more accurate assessment of BP control during treatment. Home BP measurements under such controlled conditions are expected to have a beneficial effect on the economics of the diagnosis and management of hypertension.

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