Comparisons of Ambulatory Blood Pressure Monitoring and Repeated Office Measurements in Primary Care

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BACKGROUND. The accuracy of office blood pressure (BP) readings is questionable because of blood pressure variability and measurement errors. The primary aim of this study was to determine the number of office visits required to optimize the estimation of usual blood pressure in older adults in primary care.

METHODS. Ambulatory blood pressure monitoring was used to define usual blood pressure in an observational study of 75 randomly selected family practice patients. Each subject made six visits for office BP measurements and had 24-hour ambulatory BP monitoring done twice. Mean office BP, based on one through six visits, was compared with mean ambulatory BP.

RESULTS. The sample consisted of 29 men and 46 women; 18 were black and 57 were white. Twenty-one subjects were taking antihypertensive medication. The mean age ± 1 /standard deviation (SD) was 60 (±8) years. The correlation between mean office BP and mean ambulatory BP rose with the number of visits averaged, with most of the gain obtained within 3 visits. The maximal correlation for 24-hour ambulatory BP was $r = .85/.75$ (systolic/diastolic) ($P < .01$). However, even when using average office BP over six visits to estimate mean ambulatory BP, a discrepancy of ≥10 mm Hg between estimated and observed ambulatory BP levels persisted in 18% to 20% of subjects.

CONCLUSIONS. Readings from at least three office visits should be averaged to estimate usual blood pressure. It should be noted, however, that important discrepancies between estimated and observed mean ambulatory BP persist even after readings taken over six visits. Ambulatory BP monitoring probably provides unique information about usual blood pressure that cannot be captured by repeated office BP readings.

KEY WORDS. Blood pressure determination; hypertension; blood pressure monitoring, ambulatory; primary health care. (J Fam Pract 1997; 45:426-433)

Among the estimated 43 million Americans with high blood pressure, 75% to 87% have stage 1 hypertension.[1-3] The discriminant ability of blood pressure (BP) measurement to classify anyone as hypertensive is proportional to BP elevation beyond any selected cutpoint, ie, 140/90 mm Hg. This situation puts a large segment of the population at risk for misclassification with respect to the presence or severity of hypertension.

There is considerable evidence that routine office BP measurements produce clinically significant errors. Observer error is 5 mm Hg to 13 mm Hg systolic and 4 mm Hg to 5 mm Hg diastolic.[4-6] Within-person standard deviation in office BP is approximately 9 mm Hg to 13 mm Hg systolic and 7 mm Hg to 8 mm Hg diastolic.[7-9] Normal BP (excluding exercise) can vary by 30 mm Hg to 60 mm Hg systolic and 20 mm Hg to 40 mm Hg diastolic over a 24-hour period.[10-13] In addition, some patients appear to have an "alerting" reaction to office BP measurement. Often referred to as the "white coat response," this reaction results in elevated BPs unique to the medical setting.[14-16]

The National High Blood Pressure Education Program (NHBPEP) has suggested that the diagnosis of hypertension be based on at least two office visits following an initial screening visit, with at least two office BP measurements taken at each visit.[1] How well the average of four to six office BP readings taken over two to three visits characterizes patients' usual BP is not known. It is reasonable to assume that the more BP readings that are taken, the more accurately they will reflect the true underlying mean BP. The point of steeply diminishing returns with repeated office BP measurements is unknown, however.

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Ideally, the optimum number of office BP readings to average would be determined prospectively on the basis of their power to predict hypertensive morbidity. Automatic ambulatory blood pressure monitoring provides an alternative standard against which the accuracy of office BP measurements can be more readily assessed. Ambulatory BP monitoring eliminates examiner error and bias, takes circadian BP variability into account, and minimizes the white coat response.[17,18] Ambulatory BP has been validated against intraarterial-arterial and standard BP measurements,[6,19,20] and cross-sectional and prospective studies have shown mean awake and 24-hour ambulatory BP levels to be robust predictors of hypertensive complications.[21-25] Mean ambulatory BP levels are highly reliable, with test–retest correlation coefficients of .85 to .95.[18,26-28] Intra-person variances in ambulatory BP have been shown to be one third to one sixth of those for office BP.[26] Ambulatory BP monitoring thus provides the most accurate method available for the determination of average or usual BP. Nonetheless, since 1990 four consensus panels have recommended against the routine use of ambulatory BP monitoring for screening or diagnosis of hypertension.[1,29-31] Office BP measurement remains the standard of care for most patients.

The main purpose of our study was to determine the number of routine office visits required to optimize the estimation of usual (mean) BP in older adults in primary care practice, assuming that one or two office BP readings are made at each visit. We also compared strictly standardized office BP readings with those taken in routine clinical practice.

METHODS

We conducted an observational study with 75 randomly selected family practice patients, including both hypertensive and normotensive individuals. No interventions were made; patients taking antihypertensive medications continued their normal regimens. Usual systolic and diastolic BP levels were defined in separate analyses as the mean awake BP or the mean 24-hour BP calculated from two 24-hour periods of ambulatory BP monitoring.

Participants were recruited by mail and telephone. They were drawn from a pool of 4148 persons between the ages of 45 to 75 years who were registered as patients at a university-based family practice center serving the surrounding community. To be eligible, participants had to be ambulatory, able to provide informed consent, not pregnant, and free of any documented cause of nonessential hypertension. Use of antihypertensive medications was recorded and included in the analyses but was not used to determine eligibility.

Each participant made six study visits within a 6-week period between May 1993 and August 1994. Standardized interview and medical record review were used to determine age, sex, race, height, weight, history of hypertension, employment status, medication use, tobacco use, and alcohol use.

Blood Pressure Measurement Protocol

During each study visit, each participant was seen by a nurse and the research assistant. The order in which they were seen by a nurse and the research assistant at the first visit was randomly assigned. The order was reversed for the second visit and alternated for the remaining four visits. Participants were informed that all BP readings would be brought to the attention of their primary care physicians.

Before the study began, all clinic nurses received a refresher course on the measurement of office BP according to NHBPEP guidelines. The nurses were also instructed to take paired BP measurements on all patients and were reminded by memorandum of these guidelines at intervals of about 4 months. To approximate routine clinical practice, nurses were not monitored for compliance with these guidelines.

The research assistant also took paired office BP measurements, which were strictly standardized to comply with NHBPEP guidelines. Accurate calibration of the wall-mounted aneroid sphygmomanometers used by the nurses and the research assistant was assured using a mercury column with a Y-connector at the beginning of the study and every 3 months thereafter. Based on patient arm circumference, the appropriate cuff size was used for all office BP readings made by the research assistant and for all ambulatory BP readings. The nurses were instructed in the use of proper cuff sizes, but they were not monitored for compliance. The nondominant arm was used for all ambulatory and office BP readings.

Each participant underwent two separate 24-hour periods of ambulatory BP monitoring, with BP readings taken every 20 minutes, using SpaceLabs model 90207 monitors. Awake ambulatory BP was determined by awake/asleep times recorded by patients in diaries. Accurate calibration of the ambulatory BP monitors was assured at the beginning of the study and every 4 to 6 weeks thereafter, using a mercury column according to the manufacturer's recommendations. Each monitor remained within the recommended tolerance of ±3 mm Hg throughout the study.

Technical adequacy of the ambulatory BP data was defined as successful recording of at least 70% of the total expected number (three per hour) of BP readings, with no more than a 1-hour gap between readings. Subjects could have technically adequate ambulatory BP readings during waking hours despite inadequate 24-hour data. Individuals with inadequate ambulatory BP data (awake or 24-hour) were dropped from analyses of that particular data.

Statistical Analysis

Mean office BP levels were calculated by first averaging replicate readings within visits and then averaging BP readings across visits. All analyses were performed separately for systolic and diastolic BP, for mean 24-hour ambulatory BP and mean awake ambulatory BP, and for office BP measured by the nurses compared with those of the research assistant. Correlation coefficients for mean office BP and mean ambulatory BP were calculated, with mean office BP based on measurements taken from one through six visits.

We also examined within-subject differences between office and ambulatory BP readings. The percentages of subjects whose mean office BP readings led to either over- or underestimation of mean ambulatory BP by at least 10 mm Hg were calculated by examining the differences between observed mean ambulatory BP level and expected mean ambulatory BP level, based on the regression of mean ambulatory BP on mean office BP. A 10-mm Hg discrepancy was chosen arbitrarily as the minimum required for clinical significance. Any subject whose observed mean office BP led to an estimated mean ambulatory BP level that was ≥10 mm Hg *higher* than observed mean ambulatory BP was categorized as having *falsely high* office BP. Any subject whose observed mean office BP led to an estimated mean ambulatory BP level that was ≥10 mm Hg *lower* than observed mean ambulatory BP was categorized as having *falsely low* office BP. Mean office BP was again based on measurements taken at one to six visits.

The results from these analyses were compared for office BP measured by the nurses with measurements made by the research assistant. We also compared the slope terms for the regression equations relating mean office BP with mean ambulatory BP (with mean ambulatory BP as the dependent variable) using models in which we could test for equality between the regression coefficients for office BP measured by nurses as opposed to measurements made by the research assistant.[32,33]

Multivariate models were used to identify clinical or demographic factors that might affect the relationship between mean ambulatory and office BP, including age, race, sex, height, weight, antihypertensive medication use, alcohol use, tobacco use, employment status (currently employed vs retired or unemployed), and BP cuff size. This analysis was repeated with the *difference* between estimated and observed mean ambulatory BP as the dependent variable.

Finally, the reliability of ambulatory BP levels was examined in terms of correlation coefficients and within-subject differences in mean ambulatory BP levels between the two monitoring sessions.

RESULTS

The study sample was composed of 29 men and 46 women; demographic characteristics are shown in Table 1. The age, race, and sex composition of the sample accurately reflected the clinic population from which it was taken. Average office BP measured by nurses over six visits ranged from 94 mm Hg to 168 mm Hg systolic, and 54 mm Hg to 96 mm Hg diastolic. Twenty-one subjects were taking antihypertensive medication.

All data were complete with the following exceptions: the clinic nurses failed to record *paired* readings on 58% to 66% of participants (depending on the visit). In visits 2 through 6, no BP reading was recorded by the nurse for between one and seven participants. Sixty-eight subjects had technically adequate 24-hour data for the first ambulatory BP monitoring period, 65 for the second period, and 64 for both 24-hour ambulatory BP monitoring periods. Seventy subjects had adequate awake ambulatory BP data during the first session, 69 during the second session, and 67 had adequate awake ambulatory BP during both monitoring sessions.

TABLE 1

Characteristics of Patients in the Study Sample

Characteristic	Study Sample (N=75)
Sex, n (%)	
Male	29 (39)
Female	46 (61)
Race, n (%)	
White	57 (76)
African American	18 (24)
Using antihypertensive medication, n (%)	
Yes	21 (28)
No	54 (72)
Age (years), mean±SD	59.0 ± 8.0
Height (cm), mean±SD	171.5 ± 9.7
Weight (kg), mean±SD	79.6 ± 18.4
No. of cigarettes/day, mean±SD	4.4 ± 11.0
No. of alcoholic drinks/day, mean±SD	0.8 ± 0.8

SD denotes standard deviation; cm, centimeters; kg, kilograms.

Correlations and discrepancies between mean office and ambulatory BP. Table 2 shows the correlation coefficients between mean office BP and mean 24-hour ambulatory BP, with office BP defined by progressively more visits. Focusing on systolic office BP readings made by the nurses, most (76%) of the gain in correlation was made at the second visit, with small incremental gains observed through the fifth visit. For diastolic BP, most (80%) of the increase in correlation was achieved by the third visit, with small incremental gains continuing through the sixth visit. The maximum correlations observed for nurse office BP with mean ambulatory BP were r=.85/.75 (systolic/diastolic). The correlations between mean awake ambulatory BP and mean office BP (data not shown) were almost identical to those between mean 24-hour ambulatory BP and mean office BP.

Correlations between the two ambulatory BP sessions for mean 24-hour BP were high (r=.91/.93, systolic/diastolic), and large discrepancies between sessions were rare. None of the mean 24-hour diastolic BPs differed by ≥5 mm Hg between the two sessions. For mean 24-hour systolic BPs, 12.5% of participants varied by ≥5 mm Hg between the two sessions, and only 1.6% varied by at least 10 mm Hg. Similar

TABLE 2

Correlation Coefficients (*r*) Between Mean Office Blood Pressure (OBP) and Mean 24-Hour Ambulatory Blood Pressure (ABP)

No. of Visits Averaged*	First ABP Session† Nurse *r* (95%CI)	First ABP Session† RA *r* (95%CI)	Both ABP Sessions‡ Nurse *r* (95%CI)	Both ABP Sessions‡ RA *r* (95%CI)
Systolic BP				
1	.63 (.46-.76)	.69 (.54-.80)	.68 (.53-.80)	.73 (.59-.83)
2	.78 (.67-.86)	.79 (.68-.87)	.81 (.70-.88)	.80 (.69-.88)
3	.79 (.68-.87)	.83 (.73-.89)	.82 (.71-.89)	.82 (.73-.89)
4	.81 (.71-.88)	.84 (.75-.90)	.84 (.75-.90)	.84 (.76-.90)
5	.82 (.72-.89)	.85 (.77-.91)	.85 (.77-.91)	.86 (.78-.91)
6	.82 (.72-.89)	.86 (.78-.91)	.85 (.77-.91)	.87 (.79-.92)
Diastolic BP				
1	.62 (.44-.75)	.66 (.49-.78)	.60 (.42-.74)	.66 (.50-.78)
2	.68 (.53-.79)	.69 (.54-.80)	.67 (.51-.79)	.69 (.53-.80)
3	.73 (.59-.83)	.72 (.58-.82)	.72 (.57-.82)	.72 (.57-.82)
4	.72 (.58-.82)	.73 (.60-.83)	.73 (.58-.83)	.74 (.60-.84)
5	.73 (.59-.83)	.75 (.62-.84)	.74 (.60-.84)	.76 (.63-.85)
6	.74 (.60-.83)	.75 (.61-.84)	.75 (.61-.84)	.75 (.62-.84)

*One to two office BP readings per visit.
† No. of patients = 68.
‡ No. of patients = 64.

CI denotes confidence interval; Nurse, office BP was measured by clinic nurses; RA, office BP was measured by research assistant.
NOTE: All correlation coefficients are significantly greater than zero (P<.01).

results were obtained for mean awake ambulatory BP readings.

We also examined the within-person differences between office and ambulatory BP measurements, using mean office BP from all six visits. Because the best-fit regression equation relating mean ambulatory BP to mean office BP over six visits differed significantly ($P < .01$ for both systolic and diastolic) from the line of identity for both 24-hour and awake ambulatory BP, we could not directly compare mean ambulatory with mean office BP. Instead, we compared the observed mean ambulatory BP with the expected mean ambulatory BP based on the regression of mean ambulatory BP on office BP. Interpretation of these data is focused on systolic BP, because it is considered the strongest predictor of risk.[34] Table 3 shows the rates of overestimation, underestimation, and total discrepancy ≥10 mm Hg between observed and estimated mean ambulatory BP values for 24-hour ambulatory BP and awake ambulatory BP. By these criteria, we found a discrepancy rate of 18% to 19% between observed and expected ambulatory BP levels.

Figure 1 shows the impact of varying the number of visits used to estimate usual BP on the prevalence of falsely high office BP and falsely low office BP. Figure 2 illustrates the same analyses for mean awake ambulatory BP. The rate of overestimation of mean ambulatory BP fell as more visits were averaged, but the rate of underestimation remained about the same. Overestimation of mean awake ambulatory BP plateaued after four or five visits.

Effect of office BP observer on the relationship between office and ambulatory BP. Correlations between office and ambulatory BP were essentially the same for office BP readings

TABLE 3

Prevalence of ≥10 mm Hg Error Associated with Using Average Office Blood Pressure (OBP) to Estimate Average Ambulatory Blood Pressure (ABP)

Blood Pressure Reading Variable	Falsely High OBP*	Falsely Low OBP†	Either	Intercept Beta	Intercept SE	Slope Beta	Slope SE
Systolic							
Nurse OBP vs 24-hour ABP	7.8	10.9	18.7	25.50	8.03	0.81	0.06
RA OBP vs 24-hour ABP	12.5	6.3	18.8	28.73	7.40	0.77	0.06
Nurse OBP vs Awake ABP	10.5	7.5	18.0	30.03	7.76	0.81	0.06
RA OBP vs Awake ABP	12.0	7.5	19.5	32.78	6.98	0.77	0.05
Diastolic							
Nurse OBP vs 24-hour ABP	3.2	3.1	6.3	18.19	6.71	0.80	0.09
RA OBP vs 24-hour ABP	3.1	4.7	7.8	25.15	5.85	0.69	0.08
Nurse OBP vs Awake ABP	4.5	4.5	9.0	19.42	6.74	0.83	0.09
RA OBP vs Awake ABP	4.5	6.0	10.5	25.13	5.83	0.74	0.08

*Estimated mean ABP ≥10 mm Hg higher than observed mean ABP.

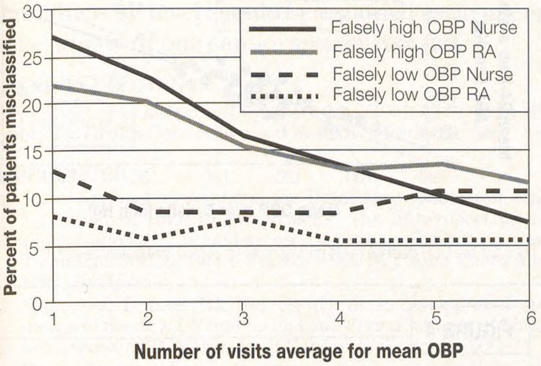
†Estimated mean ABP ≥10 mm Hg lower than observed mean ABP.

SE denotes standard error; Nurse OBP denotes that clinic nurses measured patients' blood pressure in the office; RA OBP denotes that a research assistant measured patients' blood pressure in the office.

Notes: Average OBP was based on 6 visits. Errors refer to discrepancies between observed and expected mean ABP when the expected mean ABP is calculated from a regression equation using mean OBP from data gathered over the period of 6 visits.

FIGURE 1

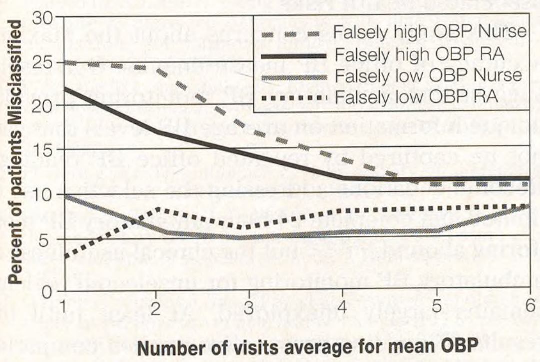
Rates of over- and underestimation of mean 24-hour systolic ambulatory blood pressure (ABP) based on mean systolic office blood pressure (OBP). OBP was measured by clinic nurses (Nurse) and a research assistant (RA).



The estimated 24-hour ABP is based on the observed mean OBP, using a regression equation. A falsely high OBP indicates an estimated mean 24-hour ABP at least 10 mm Hg *higher* than observed 24-hour ABP. A falsely low OBP indicates an estimated mean 24-hour ABP at least 10 mm Hg *lower* than observed 24-

FIGURE 2

Rates of over-and underestimation of mean awake systolic ambulatory blood pressure (ABP) from mean systolic office blood pressure (OBP). OBP was measured by clinic nurses (Nurse) and a research assistant (RA).



The estimated 24-hour ABP is based on the observed mean OBP, using a regression equation. A falsely high OBP indicates an estimated mean 24-hour ABP at least 10 mm Hg *higher* than observed 24-hour ABP. A falsely low OBP indicates an estimated mean 24-hour ABP at least 10 mm Hg *lower* than observed 24-hour ABP.

taken by the nurses compared with those taken by the research assistant (Table 2). Focusing on mean systolic ambulatory BP as predicted by mean office BP, the total discrepancy rate (discrepancy ≥10 mm Hg in either direction between observed and estimated mean ambulatory BP) was nearly identical for measurements taken by the research assistant and nurses (Table 3). Overestimation of mean systolic ambulatory BP was slightly more prevalent for the research assistant than for the nurses.

The relationships between mean office BP measured by the nurses and those by the research assistant and mean 24-hour ambulatory BP are further illustrated in Figures 3 and 4. There was no significant difference between the regression lines for mean office BP as measured by the nurses and measurements made by the research assistant (P >.50). Again, the regression lines differed in slope from the line of identity (P <.03 in both cases), indicating that mean ambulatory BP should not be expected to equal mean office BP on a one-to-one basis.

Potential cofactors in the estimation of mean ambulatory BP from office BP. In stepwise multiple regression analyses, none of the following factors had a significant effect on mean systolic 24-hour ambulatory BP after controlling for mean office BP: age, sex, race, weight, antihypertensive medication use, alcohol use, tobacco use, current employment status, or BP cuff size. Height had a positive correlation with mean ambulatory BP in this model. Two patients with the same mean office BP would be expected to differ in mean systolic ambulatory BP by 0.7 mm Hg for each inch of difference in height; the likelihood of overestimating mean ambulatory BP from mean office BP decreased as height increased. Differences in sex did not account for this relationship. Mean office BP level had no significant association with the absolute value of the difference between mean office BP and mean ambulatory BP (P >.05). Thus, office BP level was not useful in predicting the magnitude of the discrepancy between office BP and usual BP.

DISCUSSION

Precise BP determination is key to the clinical discrimination between hypertensive and normotensive adults. It is also a prerequisite for beneficial changes in antihypertensive therapy when BP readings are near a threshold that would lead to therapeutic adjustments. Taking repeated office BP readings over two or more visits is the most widely suggested method for dealing with BP variability and measurement errors. This is logical since day-to-day variations in resting office BP are much greater than within-day variances.[26]

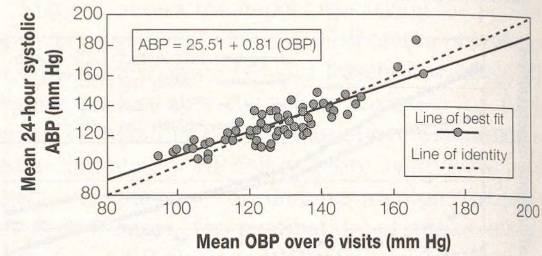
Our study shows that repeated office BP readings improve BP determination in unselected patients by reducing the rate of overestimation of usual BP. This strategy, however, does not reduce the rate of underestimation, and the rate of overestimation appears to plateau. Even when 12 office BP readings taken over six visits were averaged, in 19% of our subjects there was discrepancy of at least 10 mm Hg between estimated and observed usual systolic BP, despite high correlations between mean office BP and mean ambulatory BP. We cannot determine the relative contributions to these discrepancies of circadian BP variability, measurement error, or a white coat response during BP measurement. Regression to the mean would be expected to decrease the rates of both over- and underestimation of usual BP as more office BP readings are averaged.[35] We hypothesize that habituation of a white coat response to office BP measurement is the main reason that the rate of overestimation of usual BP fell with repeated measures, whereas the rate of underestimation did not fall.[8,11,34,36]

Our study was done in a large primary care practice with 16 nurses. Office BP readings taken by our nurses did not differ significantly from standardized readings taken by a single research assistant with respect to mean ambulatory BP, even though the nurses often failed to take paired readings and may have deviated from our recommended standards in other unidentified ways. Smaller practices with fewer nurses, therefore, would probably obtain results similar to these. This study does not address the accuracy of office BP measurements made by any other medical providers, including physicians, nor does it address the utility of BP readings taken by the patient or other lay people.

Previous studies have shown that mean ambulatory BP levels have less day-to-day variability than do mean office BP levels.[26-28] Our study adds to the literature on the reliability of ambulatory BP monitoring but does not address the number of ambulatory BP readings or monitoring sessions needed to optimize the prediction of BP-associated health risks.

FIGURE 3

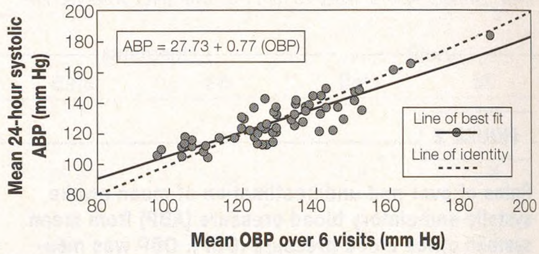
Systolic 24-hour ambulatory blood pressure (ABP) versus office blood pressure (OBP). OBP was measured by clinic *nurses* using a standard sphygmomanometer over six visits.



Includes two OBP readings made per visit and two 24-hour ambulatory sessions.

FIGURE 4

Systolic 24-hour ambulatory blood pressure (ABP) and office blood pressure (OBP). OBP was measured by a *research assistant* using a standard sphygmomanometer over six visits.



Includes two OBP readings made per visit and two 24-hour ambulatory sessions.

This study raises concerns about the maximal accuracy of office BP measurements. Our results suggest that ambulatory BP monitoring provides unique information on average BP levels that cannot be captured by repeated office BP readings. Recommendations addressing the selective use of limited and complete 24-hour ambulatory BP monitoring abound,[1,29-31,37,38] but the clinical usefulness of ambulatory BP monitoring for unselected patients remains largely unexplored. At least until the results of ongoing prospective studies comparing the clinical utility of repeated office BP measurements with ambulatory BP monitoring are available,[39,40] office measurements are likely to remain the standard of care.

Based on our findings, office BP readings averaged over three to six visits should be used to estimate the usual BP level of most patients. The closer the observed BP levels are to a decision threshold, in terms of diagnosis or treatment alterations, the more readings should be averaged. Averaging readings from more than six visits, however, is unlikely to further improve the precision of office BP determination. Office BP level should be regarded as an imperfect estimate of one cardiovascular risk factor.

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REFERENCES

1. Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure. The fifth report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC V). Arch Intern Med 1993; 153:154-83.
2. Stamler J, Prineas RJ, Neaton JD, et al. Background and design of the new US trial on diet and drug treatment of "mild" hypertension (TOMHS). Am J Cardiol 1987; 59:51G-60G.
3. Final Report of the Subcommittee on Definition and Prevalence of the 1984 Joint National Committee. Hypertension prevalence and the status of awareness, treatment, and control in the United States. Hypertension 1985; 7:457-68.
4. Bruce NG, Shaper AG, Walker M, Wannamethee G. Observer bias in blood pressure studies. J Hypertens 1988; 6:375-80.
5. Scherwitz LW, Evans LA, Hennrikus DJ, Vallbona C. Procedures and discrepancies of blood pressure measurements in two community health centers. Med Care 1982; 20:727-38.
6. White WB, Lund-Johansen P, Omvik P. Assessment of four ambulatory blood pressure monitors and measurements by clinicians versus intraarterial blood pressure at rest and during exercise. Am J Cardiol 1990; 65:60-6.
7. Armitage P, Fox W, Rose GA, Tinker CM. The variability of measurement of casual blood pressure. II. Survey experience. Clin Sci 1966; 30:337-44.
8. Gordon T, Sorlie P, Kannel WB. Problems in the assessment of blood pressure: The Framingham Study. Int J Epidemiol 1976; 5:327-34.
9. Watson RDS, Lumb R, Young MA, et al. Variation in cuff blood pressure in untreated out-patients with mild hypertension-implications for initiating antihypertensive treatment. J Hypertens 1987; 5:207-11.
10. Pickering TG, Harshfield GA, Kleinert HD, et al. Blood pressure during normal activities, sleep and exercise: comparison of values in normal and hypertensive subjects. JAMA 1982; 247:992-6.
11. Pickering TG. The influence of daily activity on ambulatory blood pressure. Am Heart J 1988; 116:1141-5.
12. Staessen J, Bulpitt CJ, Fagard R, et al. Reference values for the ambulatory blood pressure and the blood pressure measured at home: a population study. J Hum Hypertens 1991; 5:355-61.
13. O'Brien E, Murphy J, Tyndall A, et al. Twenty-four-hour ambulatory blood pressure in men and women aged 17 to 80 years: the allied Irish bank study. J Hypertens 1991; 9:355-60.
14. Mancia G, Parati G, Pomidossi G, et al. Alerting reaction and rise in blood pressure during measurement by physician and nurse. Hypertension 1987; 9:209-15.
15. Gosse P, Bougaleb M, Egloff P, et al. Clinical significance of white-coat hypertension. J Hypertens 1994; 12(suppl 8):S43-7.
16. Myers MG, Oh PI, Reeves RA, Joyner CD. Prevalence of white coat effect in treated hypertensive patients in the community. Am J Hypertens 1995; 8:591-7.
17. O'Brien E, Staessen J. Normotension and hypertension as defined by 24-hour ambulatory blood pressure monitoring. Blood Pressure 1995; 4:266-82.
18. Prisant LM. Ambulatory blood pressure monitoring in the diagnosis of hypertension. Cardiol Clin 1995; 13:479-90.
19. Graettinger WF, Lipson JL, Cheung WG, Weber MA. Validation of portable noninvasive blood pressure monitor devices: comparisons with intra-arterial and sphygmomanometer measurements. Am Heart J 1988; 116:1155-60.
20. O'Brien E, Mee F, Atkins N, O'Malley K. Accuracy of the Spacelabs 90207 determined by the British hypertension society protocol. J Hypertens 1991; 9:573-4.
21. Devereux RB, Pickering TG. Relationship between ambulatory or exercise blood pressure and left ventricular structure: prognostic implications. J Hypertens 1990; 8(suppl 6):S125-34.
22. Shimada K, Kawamoto A, Matsubayashi K, Ozawa T. Silent cerebrovascular disease in the elderly: correlation with ambulatory pressure. Hypertension 1990; 16:692-9.
23. Giaconi S, Levanti C, Fommei E, et al. Microalbuminuria and casual and ambulatory blood pressure monitoring in normotensives and in patients with borderline and mild essential hypertension. Am J Hypertens 1989; 2:259-61.
24. Perloff D, Sokolow M, Cowan R. The prognostic value of ambulatory blood pressures. JAMA 1983; 249:2792-8.
25. Verdecchia P, Porcellati C, Schillaci G, et al. Ambulatory blood pressure: an independent predictor of prognosis in essential hypertension. Hypertension 1994; 24:793-801.
26. Rao JS. A population-based study of office and ambulatory blood pressure monitoring: variance component estimation and the effects of measurement error [thesis]. Minneapolis, Minn: University of Minnesota, 1991.
27. Mansoor GA, McCabe EJ, White WB. Long-term reproducibility of ambulatory blood pressure. J Hypertens 1994; 12:703-8.
28. Coats AJS. Reproducibility or variability of casual and ambulatory blood pressure data: implications for clinical trials. J Hypertens 1990; 8(suppl 6):S17-20.
29. The National High Blood Pressure Education Program Coordinating Committee. National High Blood Pressure Education Program Working Group report on ambulatory blood pressure monitoring. Arch Intern Med 1990; 150:2270-80.
30. Sheps SG, Pickering TG, White WB, et al. Ambulatory blood pressure monitoring. J Am Coll Cardiol 1994; 23:1511-3.
31. American College of Physicians. Automated ambulatory blood pressure and self-measured blood pressure monitoring devices: their role in the diagnosis and management of hypertension. Ann Intern Med 1993; 118:889-92.
32. Hotelling H. The selection of variates for use in prediction with some comments on the problem of nuisance parameters. Ann Math Stat 1940; 11:271-83.
33. Dunn OJ, Clark V. Correlation coefficients measured on the same individuals. J Am Stat Assoc 1969; 64:366-77.
34. Stamler J, Stamler R, Neaton JD. Blood pressure, systolic and diastolic, and cardiovascular risks. US population data. Arch Intern Med 1993; 153:598-615.
35. Davis CE. The effect of regression to the mean in epidemiologic and clinical studies. J Epidemiol 1976; 104:493-8.
36. Australian National Blood Pressure Study Management Committee: untreated mild hypertension. Lancet 1982; 1:185-91.
37. Pickering T. Recommendations for the use of home (self) and ambulatory blood pressure monitoring. Am J Hypertens 1996; 9:1-11.
38. Sheps SG, Bailey KR, Zachariah PK. Short-term (six-hour), ambulatory blood pressure monitoring. J Hum Hypertens 1994; 8:873-8.
39. Clement DL. Office versus ambulatory recordings of blood pressure (OvA): a European multicenter study. J Hypertens 1990; 8(suppl 6):S39-41.
40. Clement DL, De Buyzere M, Duprez D. Prognostic value of ambulatory blood pressure monitoring. J Hypertens 1994; 12:857-64.