

Misclassification of Blood Pressure by Usual Measurement in Ambulatory Physician Practices

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Background: Standardized measurement of blood pressure (BP) is widely recommended but rarely followed in usual clinical practice.

Methods: We compared the classification of hypertension status of 107 patients referred by family physicians for ambulatory BP monitoring (ABPM) and with elevated clinic BP when assessed by usual clinical office measurement, a trained hypertension research nurse using a standardized measurement protocol, or an ambulatory BP monitor.

Results: Usual clinic readings resulted in higher BP readings than those obtained by the research nurse: mean (95% confidence interval [CI]), 10.8 (8.0 to 13.6)/4.9 (2.9 to 6.9) mm Hg, the daytime ambulatory BP 7.7 (5.1 to 10.3)/5.1 (3.0 to 7.1), and the 24-h ambulatory BP 12.1 (9.6 to 14.6)/8.9 (6.9 to 10.9). The interpretation of whether the patient

had a hypertensive versus normotensive reading in the usual clinic setting differed in 42% of patients relative to standardized nurse readings.

Conclusions: Following standardized technique is important for correct classification of the BP status of patients. Use of usual or casual technique results in higher readings than standardized or ambulatory BP readings. This study indicates that significant improvement in the assessment of BP is required for diagnosis and optimal management of hypertension. Consideration strongly needs to be given to the development of alternative methods of assessing BP in clinical practice. Am J Hypertens 2005;18:1522-1527 © 2005 American Journal of Hypertension, Ltd.

Key Words: Blood pressure, blood pressure measurement, hypertension.

In westernized countries, high blood pressure (BP) is estimated by the World Health Organization to be the leading risk factor for mortality in women and the second leading risk factor in men.¹ About 40% of Americans or Canadians have hypertension by age 55 years² and for those who do not have hypertension by this age, the residual lifetime risk of developing hypertension is 90%.³ Reflecting the importance of high BP, measurement of BP is recommended at each health care encounter,^{4,5} and hypertension is the most common reason for an adult to visit a physician.

The diagnosis and management of hypertension relies on office measurement of BP using the auscultatory method. However, several studies have demonstrated wide variation in the accuracy of equipment and the use of non-standardized technique in assessing BP in clinical practice.⁶⁻¹⁰ When assessed in isolation, variation in a BP

measurement technique and inaccurate equipment can result in marked variations in BP with changes of up to 40 mm Hg or more.^{11,12} For example, crossing the legs during measurement increases BP by 8.1/4.5 mm Hg¹³ and approximately 10% of aneroid devices are out of calibration by ≥ 10 mm Hg.⁶ Nonetheless there are few data on the accuracy of BP assessed in usual clinical practice relative to that measured by trained nurses or ambulatory devices.¹⁴⁻¹⁷ To our knowledge, there are only two prior studies that have directly compared usual office BP measurement to a standardized measurement that also had ambulatory BP monitoring data as a comparator.^{15,18} Although large differences in BP were noted in those studies, there was an interval of up to 3 months between the usual clinic reading and the standardized readings in one study. In this study, we examine the accuracy and potential misclassification of usual clinic BP measurement, relative

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to a trained research nurse using standardized technique, and to readings using an ambulatory BP monitor.

Methods

The study was approved by the Conjoint Bioethics Committee of the University of Calgary and the Calgary Health Region. Written informed consent was obtained from all patients enrolled in the study.

Study Population

Family physicians were recruited for this study in two ways. First, 20 family physicians were randomly selected from the Yellow Pages of the Calgary telephone book and asked to participate. Physicians were also recruited who routinely referred patients to the Calgary Health Region Hypertension and Lipid center. Physicians were asked to refer adult hypertensive patients for the study for whom they would usually request ambulatory BP monitoring. Patients with usual clinic BP readings on referral to the study that were <140 mm Hg systolic and <90 mm Hg diastolic were excluded. Antihypertensive therapy was not altered during the study.

The patients underwent 24-h ambulatory BP monitoring using a SpaceLabs model 90207 device (SpaceLabs, Redmond, WA). After removal of the device, a research nurse who was trained in recommended BP measuring technique assessed each patient's BP using a mercury sphygmomanometer. The same nurse measured two BP in all patients and the average was used. Within 3 h, patients returned to their family doctors' offices for a usual clinic BP measurement. The BP reading and the profession (ie, a physician or nurse) of the person performing the readings in the clinic were recorded.

The research nurse was specifically trained to follow the Canadian Hypertension Education Program protocol for BP measurement.⁴ A mercury sphygmomanometer, a cuff of appropriate size, and a 5-min rest in a quiet comfortable room was used before measurement. The calibration of the ambulatory monitors was assessed when the devices were applied and before removal. The ambulatory monitoring occurred during weekdays and the patients were requested to follow their usual daily routines. Apart

from the editing performed by the manufacturer's software, the readings were not otherwise altered. Ambulatory BP results were excluded from analysis if calibration testing showed that the ambulatory device deviated >5 mm Hg of simultaneous nurse readings or if there were >15% "errors" recorded by the ambulatory monitor. Patients with daytime ambulatory BP \geq 135/85 mm Hg or with 24-h ambulatory BP \geq 130/80 mm Hg were considered to be hypertensive.

Statistical Analysis

The database was entered on a Microsoft Excel version 7.0a Spreadsheet (Microsoft Corp., Redmond, WA). Standard functions were used to determine means, minima, maxima, absolute values, and 95% confidence intervals. Nurse- or physician-recorded systolic BP of \geq 140 mm Hg or diastolic BP of \geq 90 mm Hg were labeled as hypertensive values. The *F* test was used for comparison between two variances. A *Z* test for proportions was used to assess terminal digit preference. The Pearson product-moment correlation was calculated to determine the relationship of usual readings BP readings to those taken by the research nurses or via daytime ambulatory monitoring. A one-way analysis of variance (ANOVA), followed by a Student-Newman-Keuls all pairs comparison using SPSS version 13 software (SPSS Inc., Chicago, IL), was used to determine differences in mean systolic and diastolic BP among methods.

Results

A total of 121 patients participated in the study. Two subjects did not meet the hypertension inclusion criteria and five were excluded for absence of usual clinic BP reading. Ambulatory BP readings of seven subjects met exclusion criteria. Of the 107 patients (57 women and 50 men) included in the analyses, the average age was 57 ± 12 years. In all, 47% of the patients were taking antihypertensive pharmacotherapy. Fifteen family physicians referred patients for the study. Blood pressures were measured by nurses in six clinics and by physicians in nine clinics.

The average BP values are shown in Table 1. The average (95% CI) clinic BP values were 10.8 (8.0 to 13.6)/4.9

Table 1. Average blood pressures (BP) and percentage of subjects classified as hypertensive when assessed in the physicians' clinics, a specifically trained nurse using standardized technique, or ambulatory blood pressure monitoring

Measurement	Systolic BP (mm Hg)		Diastolic BP (mm Hg)	
	Average	SD	Average	SD
Clinic	149.5	16.4	90.4	11.3
Trained Nurse	138.7*	15.8	85.5*	7.9
Daytime Ambulatory	141.8*	13.0	85.3*	9.1
24h Ambulatory	137.4*	12.7	81.5*	8.6

* Blood pressure readings are lower than the clinic BP readings, $P < .001$.

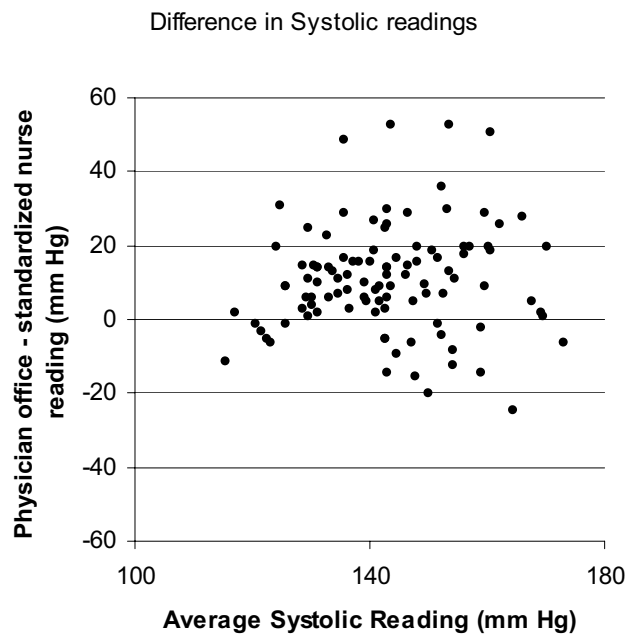


FIG. 1. Casual and standardized systolic blood pressure measurements in 107 patients. The **values outside the solid lines** indicate differences of >20 mm Hg between the two readings.

(2.9 to 6.9) mm Hg higher than the readings using standardized technique. The differences ranged from -24 to 53 mm Hg systolic and -16 to 57 mm Hg diastolic. Figures 1 and 2 show the differences in BP between the usual clinic readings and standardized measurement. Figures 3 and 4 depict the differences in BP between the usual clinic readings and ambulatory BP readings (Bland-Altman plots). When comparing usual clinic readings with standardized measurement, several patients' readings differed by 20 mm Hg and some showed differences >40 mm Hg. Reporting only the arithmetic mean differences between methods may obscure the real magnitude of how BP

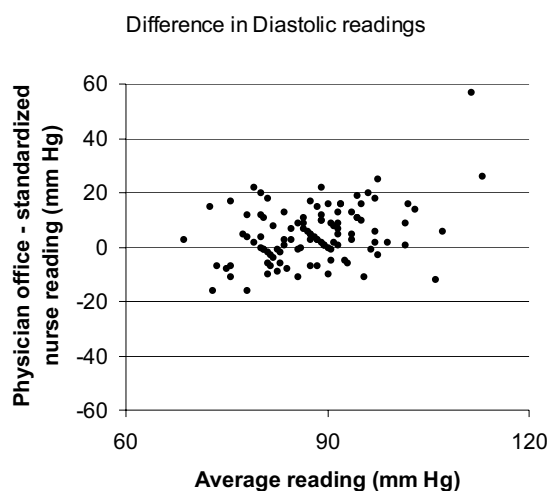


FIG. 2. Casual and standardized diastolic blood pressure measurements in 107 patients. The **values outside the solid lines** indicate differences of >20 mm Hg between the readings.

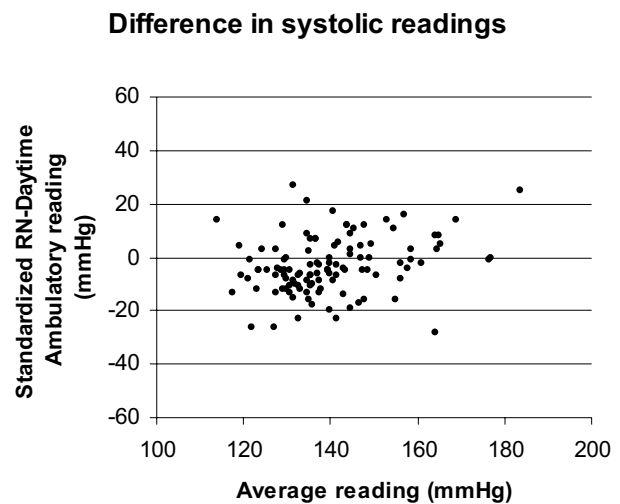


FIG. 3. Standardized and daytime ambulatory systolic blood pressure measurements in 107 patients. The **values outside the solid lines** indicate differences of >20 mm Hg between the two readings.

measurements differ among methods. By reporting absolute differences, for which the averages are calculated without consideration of positive or negative values, the average absolute difference in BP between the usual clinic reading and standardized measurement was 14.5 (12.4 to 16.6)/ 8.7 (7.3 to 10.2) mm Hg.

The correlation between the usual clinic BP readings and the standardized measurement was 0.58 for systolic ($P < .0001$) and 0.44 for diastolic pressure ($P < .0001$). The correlation between the usual clinic BP readings and ambulatory daytime BP readings was 0.59 for systolic ($P < .0001$) and 0.47 for diastolic BP ($P < .0001$). The correlation of BP readings between those obtained by the trained nurse and the daytime ABPM was 0.74 for systolic ($P < .0001$) and 0.65 for diastolic BP ($P < .0001$).

The tendency to round BP readings to zero at a fre-

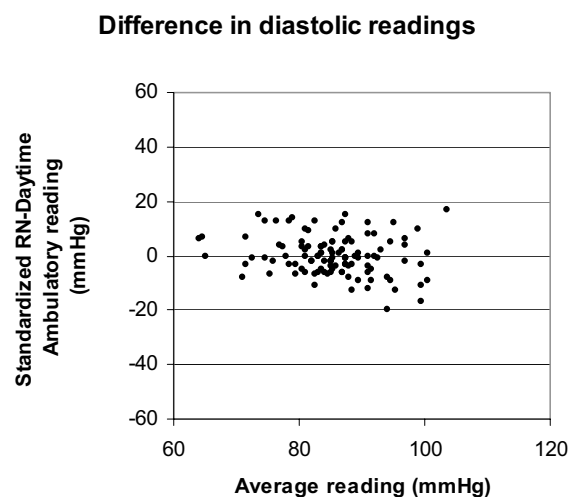


FIG. 4. Standardized blood pressure and daytime ambulatory diastolic measurements in 107 patients. The **values outside the solid lines** indicate differences of >20 mm Hg between the two readings.

quency greater than that predicted by chance is a marker of the quality of a BP assessment. Following current recommendations to round BP readings to the closest 2 mm Hg should result in 20% of readings ending in zero. When physicians took the BP reading in usual clinical office, more than half of all readings ended in 0 (average 52.3% v 20% expected, range 0% to 75%, $P < .0001$). Zero was also the most common terminal digit in BP readings taken by nurses in the usual clinic setting (average 39.2% v 20% expected, range 0% to 50%, $P = .002$). When readings were taken by standardized methodology, zero accounted for 23% of the readings (v 20% expected, $P = .62$).

Overall, a substantial number of the patients assessed as hypertensive in the usual clinic office were normotensive by the other techniques (Table 2). In some clinics physicians routinely measure BP; in others, BP is measured by a clinic nurse. When physicians assessed BP as hypertensive, 44.1% of the patients had normal BP when measured by the trained study nurse. When clinic nurses found BP values in the hypertensive range, 55.9% of subjects had normotensive readings when assessed by the trained study nurse who used standardized technique.

Discussion

The diagnosis and management of hypertension requires accurate measurement of BP; however, this study has found a large potential for misclassification of patients' BP when assessed by usual clinical practice compared with either a standardized readings taken by well-trained research technician or 24-h ambulatory BP. The BP readings were 10.8/4.9 mm Hg higher in usual clinical practice compared with standardized readings resulting in overclassification of hypertension and the perception of poorly controlled BP. This could result in over-treatment of patients with antihypertensive drugs. Although major national recommendations advocate for standardized measurement of BP,^{4,19} the recommendations have not been implemented in clinical practice.

Our study confirms previous results indicating that usual office readings are higher and that hypertensive

readings are often not confirmed by standardized BP readings or ambulatory BP readings.¹⁴ Previous studies have found that few of the recommendations for measuring BP are followed in usual clinic offices and that inaccurate equipment is frequently used in clinical practice.²⁰ The BP values obtained in usual clinical practice are not as well correlated with left ventricular mass index as standardized measures.²¹ Blood pressure readings taken with standardized methodology are more highly correlated with the ambulatory BP than are measurements made with usual techniques as performed in routine clinical practice.²¹⁻²³ Serial measurements using standardized technique can be as predictive as ambulatory BP for left ventricular hypertrophy.²¹⁻²³

There are likely several components that explain the discrepancies between usual clinic pressures and those taken by a trained nurse or by ambulatory BP. Mancina et al have eloquently documented that physicians cause a more marked pressor response in patients than nurses when encountering patients.²⁴ Others have confirmed that when well-trained physicians and nurses measure BP, the physician-measured BP values are higher by 2 to 3 mm Hg²⁵ and suggests that physicians should not routinely assess BP for the purpose of evaluating hypertensive patients. In our study, a physician took many of the usual clinic BP measures. Much larger differences in BP (5.5 to 13.7/4.8 to 9 mm Hg) have been found between BP assessed by either a nurse or a doctor not specifically trained to measure BP and a nurse trained in standardized technique.¹⁴⁻¹⁶ Because neither clinical nurses nor clinical physicians are accurate, training in the assessment of BP is important regardless of medical profession. In our study neither the usual physician readings nor the nurse readings were accurate relative to either the reading by the nurse trained in standardized technique or the ambulatory BP monitoring readings.

Our study included only patients who were being referred for ambulatory BP monitoring and specifically excluded patients referred with normal BP. This design resulted in few patients having normal BP when subsequently assessed using usual clinic readings and likely resulted in referral of patients suspected of having the white coat response. Nonetheless the inaccuracies in this study are unlikely to be explained by white coat hypertension because the largest differences in BP were between usual clinical BP and the standardized measures by a nurse rather than between usual clinic BP and ambulatory BP monitoring results. The design is the probable explanation as to why none of the patients were classified as normotensive by usual technique but hypertensive by standardized readings or ambulatory BP monitoring. Despite different designs and limitations, the percentage of patients classified as hypertensive by usual technique and normotensive by standardized technique is similar in this study and our previous study¹⁵ (42% v 42%). Some of the differences in BP and classification of BP between techniques will relate to the inherent variability of BP. How-

Table 2. Percentage of patients classified as hypertensive by usual clinic, trained nurse, daytime ambulatory, or 24-h ambulatory blood pressure (BP) readings*

Method	Systolic BP	Diastolic BP	Combined
Clinic	75.7	59.8	86.9
Trained nurse	42.1	26.2	44.9
Daytime ambulatory	72.9	57.0	82.2
24-h ambulatory	73.8	58.9	81.3

* All patients ($n = 107$) had hypertensive readings when initially assessed in their usual clinic.

ever, variability of BP would not result in higher average usual clinic BP. In fact, the standardized measurement occurred in an unfamiliar setting for most of the patients, and this would be expected to result in higher rather than lower BP readings and would reduce the difference between the standardized reading and two usual clinic readings. The sequence of the different methods for assessing BP in this study was not random and this could bias the results. The sequence selected had the usual clinic measures last, and this would be likely to result in lower usual clinic pressures. Finally, single BP readings are not recommended for diagnostic purposes, and serial readings done in clinical offices could more accurately assess patients' BP.

National guidelines and experts continue to advocate the use of standardized BP technique in usual clinical practice. However the use of standardized technique requires specific retraining, and there is loss of accuracy over time even in clinical trials or surveys in which the practitioners measuring BP are highly trained and are aware that the readings are being scrutinized.²⁶ Mercury-containing manometers are banned in several states and countries, and more extensive international bans are expected. Aneroid devices used in clinical practice are often inaccurate, and quality assurance programs are required to ensure their accuracy.²⁰ Furthermore, a standardized assessment of BP takes approximately 8 to 12 min, whereas the average length of time for a family physician visit is about 8 min. This suggests that the recommendations are impractical and unlikely to be adopted in clinical practices.

Improved methods of assessing BP are required. Some BP assessment programs rely on highly trained laypersons with reporting to physicians,²⁷ and assessment of BP in pharmacies or by patients is also common. However, these programs require close attention to quality control.²⁸ Many hypertension experts advocate 24-h ambulatory monitoring as a potential solution. This technique is expensive, uncomfortable, must be repeated to assess the effect of time or interventions, and requires expertise for use and interpretation. In hypertension research centers the reproducibility of the key prognostic indicators of ambulatory BP monitoring (ie, white coat hypertension and nocturnal dipping) are poor, and there are no studies examining the quality of 24-h ambulatory monitoring in usual clinical practice. Finally, automated monitors for use in the clinic have been developed that remove many of the technical and time consuming aspects of BP measurement and produce less white coat effect.²⁹ Although there may be no perfect solutions at present, the adoption of newer technology and assessment by specifically trained persons in the community are positive steps to improve to the monitoring of BP and hypertension.

With the increased recognition that hypertension is a leading risk factor for death and extensive efforts to improve the management of hypertension, there is a strong need to use new technologies and quality assurance pro-

grams for BP measurement to ensure that hypertension is properly diagnosed.

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