Ambulatory Blood Pressure Monitoring: A Review of Its Clinical and Prognostic Relevance

Irfan S. Chughtai, MD
Aldo J. Peixoto, MD

It has been known for more than half a century that blood pressure (BP) is higher in the physician's office than at home.[1] Despite this observation, office values continue to be used as the standard for diagnosis and treatment of hypertension (HTN). The high prevalence of HTN and the high costs associated with its treatment have led to a search for methods to eliminate the discrepancy between office and home BP readings, because clarification of this difference might result in a lesser need for antihypertensive drug use.

Two possible strategies to achieve such a goal are home BP monitoring and ambulatory BP monitoring (ABPM). Home BP monitoring has great value in the evaluation and management of hypertension, because it provides a large number of readings in an ambulatory setting. Unfortunately, the evidence supporting its improved ability to predict outcomes is scarce. On the other hand, ABPM not only provides information on BP in the ambulatory setting, but also differentiates itself from simple home self-monitoring by allowing for automated BP measurements during sleep. This feature is relevant in view of strong evidence showing the importance of diurnal BP profiles in predicting clinical outcomes. Thus, ABPM has gained increased prominence as a diagnostic tool over the past few years. For example, there is now a substantial body of literature supporting the contention that target-organ damage (TOD) in HTN is better predicted by BP measured in the ambulatory setting than by BP measured in the physician's office.[2]

This article reviews the clinical uses of ABPM and provides a critical assessment of its value in predicting cardiovascular outcomes. For the sake of brevity, the extremely relevant use of ABPM in hypertension research will not be addressed.

METHODS OF AMBULATORY BLOOD PRESSURE MONITORING

The technique of placement of ambulatory blood pressure monitors is quite simple. Modern monitors are easy to use, lightweight, and fully computerized for operation and data analysis. Because available monitors are quite expensive ($3,000–$5,000 for a single monitoring unit with software), it is advisable to purchase only an appropriately validated instrument. A list of independently validated devices (validation procedures are published in peer-reviewed journals) is published periodically and should be used as a guide.[3]

There are 2 basic types of monitors (oscillometric and auscultatory) that differ in the method used for BP recording. Auscultatory devices use a microphone to detect Korotkoff sounds and register BP values. Oscillometric devices analyze oscillations at the cuff, detecting the mean arterial pressure at the point of peak oscillations; systolic and diastolic BPs are then derived by means of validated proprietary algorithms.[4] There is controversy about which method is better, but the monitors using either method probably do not differ significantly, as long as they are properly validated.[3,5] Some have argued in favor of instruments with capabilities for both methods, and such devices are already on the market.

We have used oscillometric devices for most of our clinical and research endeavors with good results.[6] However, if both instrument types are available, certain patient characteristics may help dictate the choice; specifically, the auscultatory method loses accuracy in patients with congestive heart failure, aortic regurgitation, pregnancy, other high-output states, and obesity, whereas the oscillometric devices are less accurate in children as well as in elderly persons.[7] Both techniques are less accurate in patients with cardiac arrhythmias,

Dr. Chughtai is a nephrologist in private practice in Richmond, KY; when this article was written, he was a Fellow, Division of Nephrology, University of Connecticut School of Medicine, Farmington, CT. Dr. Peixoto is an Assistant Professor of Medicine, Section of Nephrology, Yale University School of Medicine, New Haven, CT; and an attending nephrologist, VA Connecticut Healthcare System, West Haven, CT.

Table 1. Clinical Indications for Ambulatory Blood Pressure Monitoring

To rule out suspected office hypertension (ie, white-coat hypertension)
To evaluate borderline hypertension with end-organ damage
To investigate labile/paroxysmal hypertension
To evaluate symptoms possibly related to blood pressure fluctuations (especially orthostasis)
To evaluate orthostatic hypotension, autonomic neuropathy, and carotid sinus syncope
To follow up adequacy of antihypertensive therapy

Table 2. Accepted Normal Range for Different Ambulatory Blood Pressure Monitoring Parameters

Parameter	BP Range
24-hour BP	130–135/80–85 mm Hg
Awake BP	135–140/85–90 mm Hg
Sleep BP	120–125/75–85 mm Hg
Awake BP load	< 30%
Sleep BP load	< 30%
Night-to-day BP ratio	0.75–0.90

Data from Pickering.[16]

BP = blood pressure.

especially atrial fibrillation, so such patients should not be monitored in order to avoid biased results.

CLINICAL USE OF AMBULATORY BLOOD PRESSURE MONITORING

The principal advantages of ABPM are the number of readings obtained and the fact that monitoring occurs throughout a 24-hour period. Frequent readings in the outpatient setting lead to a closer estimate of "true BP" (also obtained by self-monitoring of home BP), and automated readings during wakefulness and sleep allow for the analysis of the circadian rhythm of BP, which may have significant prognostic relevance, as discussed later. This latter property is what sets ABPM apart from home self-monitoring of BP. In combination, these features of ABPM enable physicians to obtain a more precise estimate of a patient's BP, to assess BP levels out of the office setting—thereby ruling out disparities between office and home readings, and to study BP variability, including the circadian BP profile.

Table 1 lists the most common indications for ABPM in clinical practice. In a study conducted at the University of Connecticut, 90% of 237 consecutive patients referred for ABPM fell into 4 major categories of indications: (1) determination of the ambulatory BP profile in patients with borderline HTN, (2) evaluation of BP control in patients receiving antihypertensive therapy, (3) diagnosis of "white-coat HTN", or (4) investigation of refractory HTN.[8] In this series, ABPM resulted in a change in diagnosis or therapy of HTN in as many as 46% of studied subjects.

INTERPRETATION OF AMBULATORY BLOOD PRESSURE MONITORING RESULTS

Three quantitative types of information are derived from an ABPM study: (1) estimates of average systolic and diastolic BP, pulse pressure, and heart rate; (2) quantification of circadian fluctuations of these same variables; and (3) estimation of short-term BP variability. Average BPs are established after the data are edited for aberrant readings. The software automatically performs this editing, although most investigators visually inspect the raw data in each study. Averages are calculated for a 24-hour period, as well as for periods of sleep and wakefulness (established by review of a patient-kept diary of activity and times of waking and going to bed). The actual times of sleep and wakefulness must be used, because the use of other arbitrarily determined times may lead to substantial errors in the estimation of BP averages, especially the circadian fluctuations of BP.[9–11]

The interpretation of these averages is obviously dependent on the accepted parameters of normalcy. There has been substantial debate in the literature about what represents normal ambulatory BP. The controversy exists because of limited data relating levels of 24-hour BP to morbidity and mortality. Unfortunately, as discussed later, this complete analysis is not yet available. Consequently, BP normalcy is currently determined on the basis of data from several population-based data banks on normotensive persons.[12–16] **Table 2** summarizes currently accepted limits of normalcy for different ABPM parameters.

Blood pressure load is a concept developed to evaluate how often a patient's blood pressure remains above a particular threshold. It has been established that when more than 50% of readings lie above the accepted thresholds (> 140/90 mm Hg during the day and > 120/80 mm Hg during the night in the classic study analyzing this issue), there is a marked increase in the prevalence of left ventricular hypertrophy (LVH).[17] This finding has justified the more conservative approach of accepting BP loads greater than 30% as

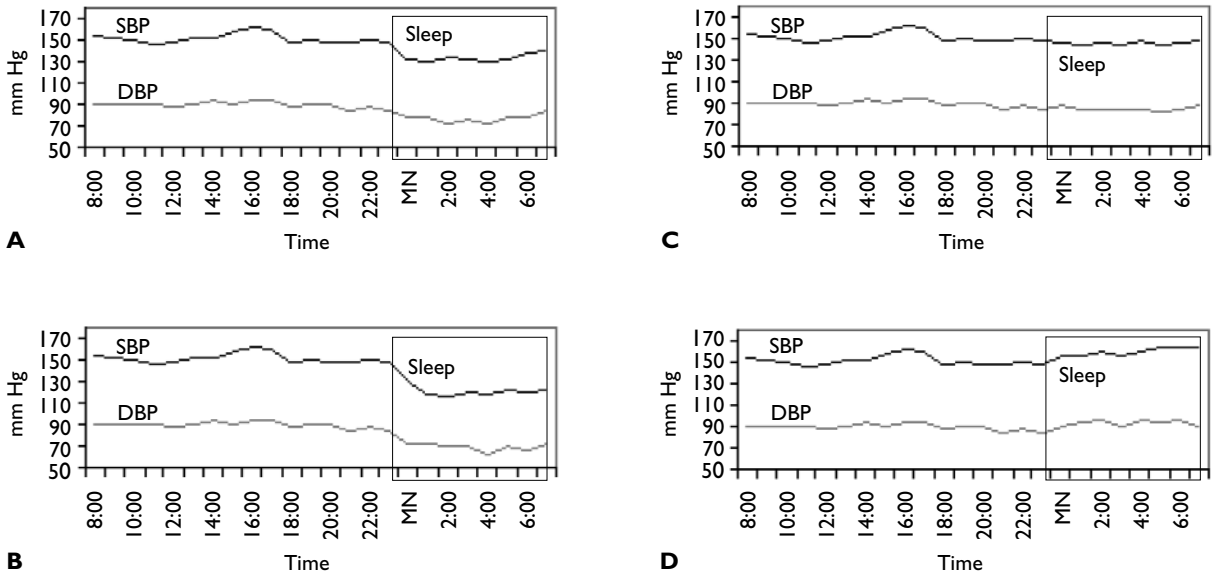

Figure 1. Circadian blood pressure (BP) profiles. All profiles have the same awake ambulatory BP (152/90 mm Hg). However, the behavior of BP at night will alter the 24-hour BP average, as shown for each tracing. (**A**) BP profile of a hypertensive dipper with an awake BP of 152/90 mm Hg, a sleep BP of 133/78 mm Hg, and a 24-hour BP of 146/86 mm Hg. (**B**) BP profile of a hypertensive extreme dipper with an awake BP of 152/90 mm Hg, a sleep BP of 121/70 mm Hg, and a 24-hour BP of 141/83 mm Hg. (**C**) BP profile of a hypertensive nondipper with an awake BP of 152/90 mm Hg, a sleep BP of 145/85 mm Hg, and a 24-hour BP of 150/88 mm Hg. (**D**) BP profile of a hypertensive reverse dipper with an awake BP of 152/90 mm Hg, a sleep BP of 160/94 mm Hg, and a 24-hour BP of 154/91 mm Hg. DBP = diastolic blood pressure; SBP = systolic blood pressure.

being too high, therefore justifying more aggressive therapeutic interventions.[18]

Once the daytime and nighttime BP averages are established, the percentage change in BP during sleep is established. Typically, there is a fall in both systolic and diastolic BP during sleep, and the magnitude of this BP "dip" is approximately 13% for systolic BP and 17% for diastolic BP.[12] **Figure 1** depicts the different BP profiles delineated by ABPM. A substantial amount of data has established that persons who lack a normal BP dip (referred to as *nondippers*) are at increased risk for TOD in essential HTN.[2] Most studies have used an arbitrary definition of a decrease in BP (systolic or diastolic) of less than 10% as being abnormal. However, current data have shown the importance of looking at the BP dip as a continuous variable, because it seems that the less one dips, the greater the cardiovascular risk. Risk is greatest in those subjects whose BP averages are higher during sleep than during wakefulness; these persons are referred to as *reverse dippers*.[19]

Lastly, data on BP variability can be obtained from ABPM. These estimates are established based on the standard deviation of the BP averages. Earlier data using intra-arterial ABPM had demonstrated increased morbidity in patients with increased BP variability.[4] However, the analysis of a large database with information about persons who had undergone noninvasive ABPM did not confirm the previous findings.[20]

CLINICAL IMPLICATIONS OF AMBULATORY BLOOD PRESSURE MONITORING

The last few years have provided an extensive body of literature on the prognostic value of ABPM. Understanding these data leads to optimal use of ABPM from a clinical perspective.

It is established that subclinical and less dramatic cardiovascular events precede overt cardiovascular manifestations, such as stroke, myocardial infarction and renal insufficiency. The correlation of these events of TOD with ambulatory BP has been explored extensively, in both a cross-sectional and a prospective observational fashion. Studies have mostly investigated the issue either as the relationship between ambulatory BP and TOD or as the prevalence of TOD characteristics such as LVH among subjects with isolated clinic HTN (or white-coat hypertension [WCH]), normotension, and sustained hypertension.

Most of the data presented herein relates to patients

with essential HTN. However, the prognostic role of ABPM has also been addressed in the general population in a large observational study, namely the Ohasama Study.[21] The correlation between ambulatory BP and mortality was studied in ambulatory subjects older than 20 years in a rural Japanese community. Results showed that mortality was increased in the highest quintile of the ambulatory BP distribution, and ambulatory BP emerged overall as a much stronger predictor than clinic BP. A limitation of this study was the lack of statistical adjustment for presence of diabetes mellitus and level of serum cholesterol and its possible limited applicability to Western populations.

In 1983, Perloff and colleagues published their seminal report on awake ambulatory blood pressure as a predictor of cardiovascular outcomes.[22] In subsequent years, several additional prospective ambulatory blood pressure studies have been completed worldwide[23,24]; almost invariably, ambulatory BP has been shown to have better correlation with TOD. More recently, further analysis of the prospective study conducted by Verdecchia and colleagues[23] has shown that not only does baseline ABPM predict outcomes better than does clinic BP, but also achieved ambulatory BP is a better predictor of future events than is achieved clinic BP.[25] These findings raise the possibility that ABPM may be valuable in patient follow-up during therapy; however, only a prospective intervention trial would be able to confirm this possibility appropriately.

AMBULATORY BLOOD PRESSURE AND CARDIAC COMPLICATIONS

Echocardiographic LVH has been studied most extensively in association with ABPM, because its prognostic importance has been documented by epidemiologic studies in hypertensive patients[26] and in the general population.[27] LVH occurs in persons with HTN because of the increased pressure load and wall tension. At least since the early 1980s, ambulatory BP has been shown to have a better correlation with LVH in hypertensive subjects than does than clinic BP,[28–30] a correlation confirmed by later studies.[31–35] Despite these encouraging data, however, a definitive conclusion about the advantage of ambulatory BP over clinic BP in predicting TOD could not be made, given the lack of a study with a controlled experimental design. This lack was the basis for the Study on Ambulatory Monitoring of Blood Pressure and Lisinopril Evaluation, which prospectively examined the role of ambulatory BP versus clinic BP in predicting regression of echocardiographic LVH with antihypertensive treatment.[36] In the final results, LVH regression had a strong correlation with 24-hour average systolic BP but not with clinic BP, thus providing the first longitudinal evidence of the greater significance of systolic ambulatory BP compared with systolic clinic BP.

Further evidence about the importance of ambulatory BP as a prognostic marker appeared in the Systolic Hypertension in Europe (Syst-Eur) trial,[19] a randomized study of isolated systolic HTN in elderly subjects. Results from the placebo group showed that the hazard ratio for events increased with the ambulatory systolic BP but not with clinic systolic BP, thus making ambulatory systolic BP emerge as a better predictor of cardiovascular events in this study. More interestingly, the night-to-day ratio was found to be an independent predictor of the incidence of cardiovascular end points, so that the cardiovascular risk increased by 41% for each 10% increment in the night-to-day ratio. The explanation suggested by the authors was that both nighttime BP and cardiovascular risk were linked to an increased overall sympathetic tone[37] or renal dysfunction that necessitated a higher nighttime BP to achieve natriuresis.[38] None of these hypotheses has been formally tested.

The aforementioned studies have relied on noninvasive ambulatory BP monitoring. Intra-arterial BP is used mainly for research but also represents the most accurate measure of diurnal BP variation and daily hemodynamic load. The study by Khattar and colleagues[24] provided the longest follow-up (average, 9.2 years) in the evaluation of the prognostic significance of ambulatory BP using intra-arterial ABPM. Once again, ambulatory BP emerged as the better tool for assessment of cardiovascular risk (ie, risk for coronary artery and cerebrovascular disease).

DIURNAL VARIATION AND DIPPING STATUS

Controversy exists as to which component of the 24-hour ambulatory BP has better prognostic value in predicting TOD; both daytime[28,29] and nighttime BP[39] have been purported to have a better correlation with LVH. Furthermore, controversy also exists about the prognostic importance of systolic versus diastolic ambulatory BP. Recent longitudinal evidence suggests the greater importance of systolic ambulatory BP over diastolic ambulatory BP.[40]

More important and controversial, however, has been the correlation between nocturnal dipping and TOD. Some earlier reports did not find a difference in LVH between dippers and nondippers,[41,42] whereas in other studies, the correlation with LVH was found to hold only in female nondippers.[23,32,43] A meta-analysis of 19 cross-sectional studies involving 1223 participants concluded that an association between cardiac structure and

nocturnal dipping status was not well established and that the day-night BP difference accounts for no more than 15% of the observed variance in left ventricular mass.[44]

In contradistinction to the latter study, recent reports from independent centers have shown greater prevalence of LVH[32,35,45] and other surrogate markers (eg, silent cerebrovascular disease,[46,47] peripheral arterial changes, microalbuminuria,[48,49] progression of renal disease[50]) in nondippers. Especially noteworthy is the aforementioned Syst-Eur trial,[19] in which the ratio of night-to-day systolic ambulatory BP was an independent strong predictor of cardiovascular events in the control group.

AMBULATORY BLOOD PRESSURE AND CEREBROVASCULAR COMPLICATIONS

Few studies have used ambulatory BP in studies of subjects with neurologic disease. From a population standpoint, the Ohasama cohort has shown that ABPM predicts the occurrence of stroke better than does clinic BP.[51] Regarding ABPM data, perhaps the most interesting early report is the one by Shimada and colleagues, in which clinic BP and ambulatory BP were measured in 54 normotensive and 34 hypertensive subjects, all of whom also underwent cerebral magnetic resonance imaging (MRI) to look for lacunae and periventricular white matter changes, both well-known markers of ischemic cerebrovascular disease.[46] Such lesions were found to have better correlation with ambulatory BP than clinic BP, and nighttime BP had a stronger correlation than did daytime BP; moreover, nondippers showed significantly more ischemic changes on MRI than did dippers.

Intriguing data were provided by Kario and colleagues to expand on this knowledge.[47] These authors found a J-shaped relationship between nocturnal dipping status and MRI changes of ischemic cerebrovascular disease, such that subjects with both nondipping and extreme dipping profiles had more cerebral changes. In a recently published study by some of the same authors, stroke events were studied in 575 older Japanese patients with sustained hypertension, as determined by ABPM.[52] The study group was subclassified by the decrease in their nocturnal systolic blood pressure (extreme dippers, 17%; dippers, 40%; nondippers, 32%; reverse dippers, 11%). Again, a significant J-shaped relationship was noted between the incidence of stroke and dipping status, such that the reverse dippers had the worst stroke prognosis and extreme dippers had the second worst prognosis, whereas there was no significant difference between dippers and nondippers. It was proposed that cerebral hypoperfusion resulting from the nocturnal BP decrease might trigger ischemic strokes during the night in extreme dippers. However, it should be noted that in this study, 55% of strokes in extreme dippers occurred in the morning period, suggesting that an exaggerated morning increase in BP in extreme dippers might also contribute to stroke events. The other interesting finding of the study was that reverse dippers were more prone to have hemorrhagic strokes.

AMBULATORY BLOOD PRESSURE AND RENAL COMPLICATIONS

A strong, graded relationship exists between both systolic and diastolic blood pressure and end-stage renal disease.[53] It is known that even patients with high-normal BP or Stage I HTN may progress to end-stage renal disease over time. Given this fact, one can appreciate the potential prognostic value of ambulatory BP monitoring. This area remains less thoroughly investigated, and prospective data are even more scarce. Urine albumin excretion has been observed to have a linear relationship with BP in normotensive,[54] white-coat hypertensive,[54] and hypertensive[54,55] subjects when ambulatory BP has been used instead of clinic BP. In these studies, the strength of the association between clinic BP and microalbuminuria was much weaker and often not statistically significant. Interestingly, in one study, the urine albumin excretion was found to be worse in the subset of microalbuminuric persons who were nondippers.[49]

A nondipping BP profile tends to be very prevalent in persons with chronic kidney disease (as many as 75% of cases) and is seen across its spectrum of etiologies and degrees of renal dysfunction. The prevalence of nondipping BP profiles increases as glomerular filtration rate decreases, peaks in dialysis patients (hemodialysis as well as peritoneal dialysis), and is seen in patients with recent organ transplants. Besides the aforementioned correlation between nondipping and microalbuminuria, nondipping BP profiles have also been shown to have an association with more rapid progression of renal disease in IgA nephropathy,[56] HTN,[50] and diabetes mellitus.[57] Additionally, the development of an abnormal nocturnal BP on longitudinal follow-up of patients with type 1 diabetes mellitus confers a 4-fold higher risk for development of microalbuminuria after a mean follow-up period of 63 months.[58] In the absence of prospective intervention trials, however, it is difficult to be certain that the observed relation is causal.

WHITE-COAT HYPERTENSION

Perhaps no other ambulatory BP issue generates as much controversy as WCH. The finding of WCH has

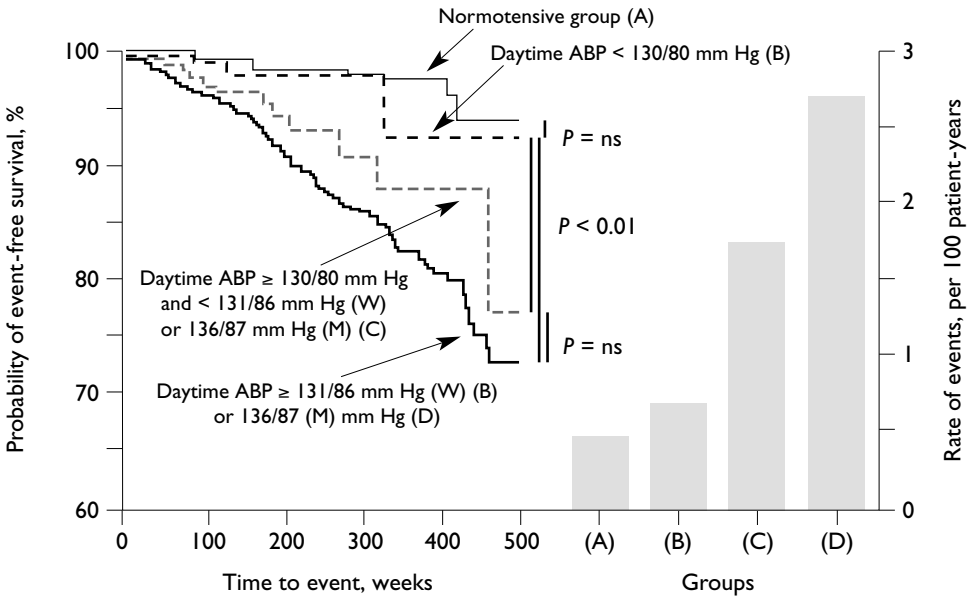

Figure 2. Rate of major cardiovascular morbid events in a normotensive group (A), 2 groups with white-coat hypertension defined with a restrictive (B) or liberal (C) criterion, and a group with ambulatory hypertension (D). (Reprinted with permission from Verdecchia P. Prognostic value of ambulatory blood pressure: current evidence and clinical implications. Hypertension 2000;35:844–51.) ABP = ambulatory blood pressure; M = men; ns = not significant; W = women.

been variously reported as being benign or having some correlation with TOD. Unfortunately, cross comparison among the various studies is cumbersome because of the lack of a standard cutoff. WCH has been differently defined, therefore, as an elevation above either 24-hour average ambulatory BP, average systolic BP, average diastolic BP, both systolic and diastolic BP averages, average daytime BP, and even BP–ambulatory BP differences. This lack of a uniform standard has also led to the well-known discrepancy in the reported prevalence of the condition. It is worth noting that the prevalence of WCH increases sharply as one liberalizes the ambulatory BP defining it, making it as high as 25% of hypertensive subjects in some studies.[59]

WCH has always been viewed with concern but was previously considered not to have an association with TOD in longitudinal studies.[23,60] Khattar and colleagues found a significantly lower long-term prevalence of LVH and carotid artery hypertrophy in persons with WCH compared with persons with sustained HTN.[60] Significantly, this study had a 10-year follow-up, ambulatory BP was measured intra-arterially, and the cutoff used for dichotomizing WCH and sustained HTN was relatively liberal at 140/90 mm Hg. The higher cutoff is expected, if anything, to amplify the studied effect. However, this study lacked a normotensive control group.

In contrast to these findings, recent evidence argues against the benign verdict previously given to WCH.[23,61,62] Besides providing support to the significant prognostic role of ambulatory BP, Verdecchia and colleagues reported that the cardiovascular event rate had a graded nature.[23] Thus, patients with sustained HTN had more events than did those with WCH, which in turn had a higher event rate than did normotension. The difference, however, became insignificant after multivariate analysis. A subsequent analysis of the same study dichotomized the WCH subset of patients in this study into 2 further groups, one with patients whose ambulatory BP was less than 130/80 mm Hg and the other with patients whose ambulatory BP was higher.[63] The former group was identified as having a low cardiovascular risk, not different from normotensive patients, whereas the latter group that had higher cardiovascular risk (**Figure 2**). Additionally, the PAMELA study (Pressione Arteriose Monitorate E Loro Associazioni study) examined the prevalence of WCH and its association with LVH in the general population.[64] Results showed that WCH was accompanied by structural cardiac changes. Once again, TOD had a graded nature, so that patients with WCH had a left ventricular mass index and wall thickness that were less than they were in hypertensive patients but greater than they were in normotensive patients.

In conclusion, although controversy about WCH abounds, robust evidence suggests that WCH may not be an entirely harmless phenomenon. However, this statement does not automatically translate into treatment initiation. Rather, the decision about pharmacologic treatment of WCH should be individualized after meticulous review of concomitant cardiovascular risk factors. It has been proposed that in persons with WCH, assessment of left ventricular structure and perhaps other markers of TOD is necessary. Furthermore, the Tecumseh Blood Pressure Study[65,66] indicated that persons with WCH have a metabolic profile that is similar to those with sustained HTN. Hence, as a group, these persons have elevated serum levels of cholesterol, triglycerides, and insulin and low serum levels of high-density lipoproteins, placing them at higher risk for coronary artery disease. Persons with WCH should, therefore, be followed closely, and lifestyle changes should be implemented rigorously.[67]

The phenomenon of "white-coat normotension" (ie, normal BP in the office but high ambulatory BP levels) also exists, although it is encountered less frequently than is WCH in clinical practice. Cross-sectional observational data suggest that this phenomenon is associated with LVH and carotid wall thickness, in a manner similar to what occurs in persons with sustained HTN.[68] This association also helps explain the ability of a high-normal left ventricular mass and high-normal clinic BP to predict future HTN and cardiovascular events in patients with clinical normotension.

AMBULATORY BLOOD PRESSURE AND REFRACTORY HYPERTENSION

Refractory HTN is persistently high clinic BP, despite treatment with multiple antihypertensive agents. It is common and may be classified etiologically as idiopathic or secondary to other disorders. It may be a consequence of an exaggerated white-coat effect, which means that it can be deciphered by ambulatory BP monitoring. To investigate this issue, Redon and colleagues examined the correlation between ambulatory BP and cardiovascular events in 86 patients with refractory HTN (diastolic BP ≥ 100 mm Hg on an adequate combination of 3 or more antihypertensive medications).[69] Cardiovascular risk increased linearly with an increase in the ambulatory BP, thereby suggesting that ambulatory BP had superior predictive capability than did clinic BP in these subjects. The study, however, had the limitations of a relatively small sample size and the possibly confounding effect of plasma lipid levels. Nevertheless, the study demonstrates a very relevant prognostic value of ambulatory BP in refractory HTN, which has led to the formal recommendation that ABPM be obtained in patients with refractory HTN.[70] More prospective studies are needed to better assess this issue.

AMBULATORY BLOOD PRESSURE AND PREGNANCY

Hypertensive disorders of pregnancy remain a major cause of maternal as well as perinatal morbidity and mortality.[71,72] Traditionally HTN in pregnancy has been diagnosed and managed based on the clinic BP, a technique fraught with observer error. Ambulatory BP has emerged as a valuable tool, especially since monitors have been validated for use in pregnancy.[73] Studies have been done in normotensive, white-coat hypertensive, and hypertensive pregnant subjects.

The pattern of ambulatory BP in normal pregnancy was first studied in a cross-sectional manner in 11 hospitalized pregnant subjects in their third trimester by Margulies and colleagues[74]; the ambulatory BP pattern was described as being similar to that seen in nonpregnant female subjects. In a subsequent prospective study, Halligan and colleagues measured ambulatory BP in all 3 trimesters of pregnancy, as well as 6 weeks postpartum (as a control) in 106 primigravid white female subjects.[75] Nocturnal dipping was found to be preserved, and both systolic and diastolic BP increased in the third trimester. Interestingly, differences were observed between daytime ambulatory BP (systolic and diastolic) and clinic BP in all trimesters but were significant only up to 33 weeks. A subsequent cross-sectional study effectively used ambulatory BP to assess normalcy of BP during pregnancy and found that mean 24-hour BP, daytime BP, and nighttime BP all were significantly elevated during the third trimester.[76]

The value of ambulatory BP as a screening test for pre-eclampsia in normotensive persons was first studied in 162 nulliparous subjects by Kyle and colleagues[77]; a correlation between an elevated mean ambulatory BP at 18 weeks and pre-eclampsia was observed. However, a subsequent prospective study concluded that second trimester ambulatory BP was not helpful in predicting pre-eclampsia because of small absolute differences.[78] Ambulatory BP has similarly been used as a predictive tool for fetal growth retardation. In their study, Churchill and colleagues found a continuous inverse relationship between maternal ambulatory BP and fetal growth.[79] The ability of ambulatory BP to identify normotensive patients at high risk for poor obstetrical outcome has been reproduced subsequently.[80,81] Furthermore, the results of a prospective cohort study by Bellomo and colleagues suggest that 24-hour BP is superior to clinic BP for prediction of pregnancy outcomes.[82] The authors

propose that this is most likely secondary to the ability of ambulatory BP to distinguish true HTN from WCH.

ABPM has emerged as an even more promising prognostic tool in pregnant women with pre-existing hypertension. Specifically, ambulatory BP has therefore been shown to have a better correlation with 24-hour urine protein levels[83] and preterm delivery compared with clinic BP.[80]

TREATMENT BASED ON AMBULATORY BLOOD PRESSURE MONITORING

The clinician's interest in a modality like ambulatory BP eventually boils down to treatment decisions, an issue that has been addressed in a randomized controlled trial.[67] The investigators were able to show that antihypertensive treatment decisions based on ambulatory BP instead of clinic BP led to a lesser use of antihypertensive drugs without adversely affecting BP control or LVH over a 6-month follow-up period. They also observed that by using ambulatory BP, drug treatment could be postponed in a quarter of hypertensive patients and multidrug treatment could be avoided in another 15%.[67]

A related issue is that of the chronopharmacologic approach to antihypertensive therapy. This concept refers both to the use of antihypertensive drug formulations that mimic the normal circadian patterns of BP fluctuation and to the use of alternative dosing schedules of conventional vasoactive drugs in an attempt to change the diurnal BP profile (eg, in nondipper hypertensive patients). Several drug classes have been shown to effectively turn nondippers into dippers in a sizable number of patients.[84] There have, as yet, been no data showing an improvement in outcomes related to this intervention, although ongoing trials are expected to provide information on this issue soon. It must be remembered that actual harm may be associated with the induction of a larger decrease in nocturnal BP if one extrapolates from the observational data on increased ischemic cerebrovascular lesions in extreme dippers.[46,52]

ADVERSE EFFECTS OF AMBULATORY BLOOD PRESSURE MONITORING

ABPM is an extremely safe technique. Other than the inconvenience of wearing the monitor for 24 hours, most of the complications are local and infrequent.[85] Some patients have difficulty sleeping; although this outcome does not occur as a rule, studies have demonstrated a change in the polysomnographic patterns of sleep during ABPM.[5] Isolated reports have mentioned upper extremity edema, petechiae/ecchymoses, contact dermatitis, olecranon bursitis, superficial thrombophlebitis, and neuralgia in association with ABPM.[86–88]

CONCLUSION

In addition to being a valuable research tool, ambulatory BP is superior to office BP in predicting cardiovascular morbidity and mortality in essential HTN and, therefore, is a valuable prognostic tool.

Available evidence supports the use of 24-hour ABPM in the management of hypertensive patients in clinical practice, especially those at increased risk for cardiovascular disease and those with refractory HTN. Referral of such patients to a hypertension clinical specialist may be helpful in sorting out difficult issues in patient management, including questions about interpretation of ABPM results. Although routine use of ABPM cannot yet be recommended, upcoming studies will soon resolve key issues related to prognosis and impact on therapy. **HP**

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