Automated Ambulatory Blood Pressure Monitoring: Clinical Utility in the Family Practice Setting

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Although the percentage of patients who are treated for hypertension has increased, the percentage of those who demonstrate control of blood pressure has declined. As a result of this trend, clinicians may increasingly rely on ambulatory blood pressure monitoring to improve the diagnosis and treatment of hypertension. Studies confirm that ambulatory blood pressure monitoring devices more accurately reflect a patient's blood pressure and correlate more closely with end-organ complications than blood pressure levels measured in the physician's office. Discriminate use of this technology in specific clinical circumstances assists in identifying patients at risk for hypertension and may result in improved outcomes in this subset of patients. Ambulatory blood pressure monitoring may be particularly helpful in clinical situations such as borderline hypertension, white-coat hypertension, apparent drug resistance, hypotensive symptoms from medications or autonomic dysfunction, episodic hypertension, and evaluation of antihypertensive efficacy. (Am Fam Physician 2003;67:2343-50,2353-4. Copyright© 2003 American Academy of Family Physicians.)

A patient information handout on blood pressure monitoring, written by the authors of this article, is provided on page 2353.

See page 2241 for definitions of strength-of-evidence levels.

See editorial on page 2262.

Ambulatory blood pressure monitoring (ABPM), although previously considered only a research instrument, may be useful in the management of some of the nearly 50 million adults in the United States with hypertension.[1] With ABPM, multiple automatic measurements of blood pressure are obtained at specific intervals throughout a 24- to 48-hour period, enabling the clinician to assess the level of blood pressure control under conditions of a normally active day.[2] Although ABPM is not applicable to all hypertensive patients, it is particularly useful in patients with borderline hypertension, white-coat hypertension, suspected autonomic dysfunction, and episodic hypertension. It also is useful in the evaluation of drug resistance and medication compliance.[3]

Indications for use of ambulatory blood pressure monitoring include white-coat hypertension, borderline hypertension, and resistant hypertension.

Accurate in-office blood pressure readings, obtained in compliance with the American Heart Association guidelines, remain the gold standard for decision-making in the diagnosis and treatment of hypertension.[1,4] Recent studies, however, indicate that ABPM data may more accurately reflect a patient's actual blood pressure than casual or in-office blood pressure measurements and may improve the physician's ability to predict cardiovascular risk.[2,5] The best possible use for ABPM data, then, is to further evaluate and fine-tune treatment in conjunction with in-office pressure assessment.

Ambulatory Blood Pressure Monitoring Techniques

Since the introduction of ABPM, increasingly automated, lightweight, and accurate measurement devices have emerged. They are typically battery-powered, belt-worn, and of a size and shape similar to that of a Sony Walkman radio *(Figure 1)*. ABPM units indirectly measure blood pressure through auscultation (of Korotkoff's sounds) with piezoelectric microphones, through oscillometric measure-

FIGURE 1. Ambulatory blood pressure monitor and cuff (Model 90207, SpaceLabs Medical, Inc., Issaquah, Wash.).

ment of the vibratory signals associated with blood flow in the brachial artery, or through the combined use of both technologies.[3,6] Auscultatory devices record both systolic and diastolic pressures, whereas the oscillatory units record systolic and mean pressure and then calculate diastolic pressure through a variety of algorithms. Validation testing against mercury sphygmomanometry and intra-arterial measurement has confirmed the accuracy of these technologies. Studies indicate that there is a discrepancy of less than 5 mm Hg between ambulatory devices and readings taken by trained human observers.[2]

The process of selecting a monitoring device for the office includes an assessment of the validation of the equipment performed by an independent laboratory or association, as shown in *Table 1*.[7] Data are collected at 15- to 30-minute intervals (and when triggered at the patient's request) throughout the monitoring period and are stored in the unit's memory chip. The clinician downloads the system's memory to a personal computer for organization and interpretation. The simultaneous advantage and challenge of ABPM interpretation lies in coping with the volume of data. However, software simplifies this interpretation and, when combined with review of the patient's diary of daily activities, allows interpretation of the results.

TABLE 1
Selection of Monitors Validated by the U.S. Association for the Advancement of Medical Instrumentation

Manufacturer	*Model and validation information*
A & D Engineering, Inc. 1555 McCandless Dr. Milpitas, CA 95035 408-263-5333	TM-2420 and TM-2421; validated at rest
SpaceLabs Medical, Inc. 15220 N.E. 40th St. P.O. Box 97013 Redmond, WA 98073 800-251-9910	SpaceLabs 90207; validated at rest,* in pregnancy, in elderly patients with postural effect SpaceLabs 90217; validated at rest
Sun Tech Medical Instruments 8917 Glenwood Ave. Raleigh, NC 27617 919-782-3005	Accutracker II; validated at rest

**—Validated for high, medium, and low pressure ranges.*

Adapted with permission from O'Brien E, Coats A, Owens P, Petrie J, Padfield PL, Littler WA, et al. Use and interpretation of ambulatory blood pressure monitoring: recommendations of the British hypertension society. BMJ 2000;320:1129.

Daily Blood Pressure Variability

The literature describes a normal diurnal variation in blood pressure readings, an effect frequently chronicled by ambulatory pressure records. Peak pressures are typically encountered around 6 a.m. and herald the characteristic higher daytime blood pressures. In the normotensive patient, daytime pressures taper to lower levels during the evening hours and fall even further at night. The pressure nadir ("dip") typically occurs between 2 and 4 a.m.[2] *(Figure 2)*. This dip in nocturnal pressure may have prognostic implications. The absence of this decline may place patients at an increased risk of cardiovascular disease, particularly elderly patients, and has been identified as an early marker of microalbuminuria in diabetic patients[8-10] *(Figure 3)*. Diurnal variation in blood pressure has been attributed to changes in physical activity, changes in environmental conditions, and variations in the hormonal milieu.[2,11]

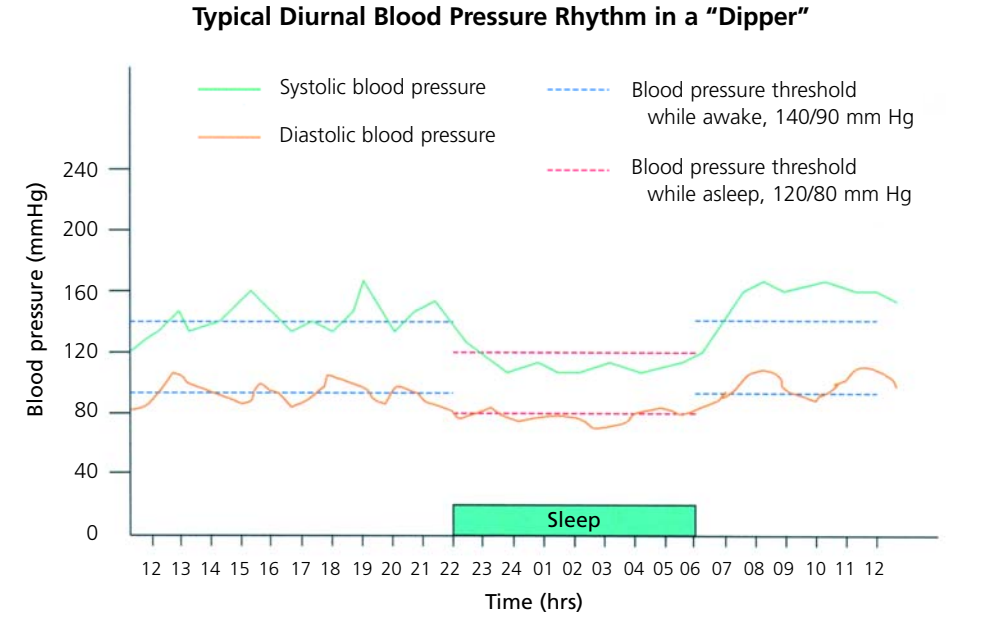

FIGURE 2. Ambulatory blood pressure report of a hypertensive patient who is a "dipper."

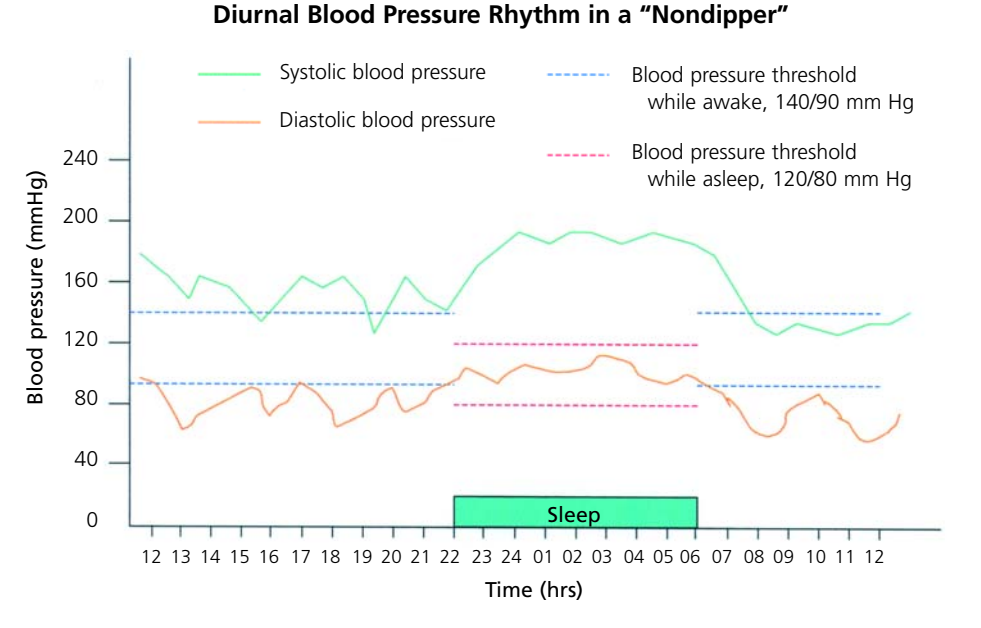

FIGURE 3. Ambulatory blood pressure report of a hypertensive patient who is not a "dipper."

TABLE 2

Situations in Which Ambulatory Blood Pressure Monitoring Might Be Useful

Evaluation of newly diagnosed hypertensive patients with or without target-organ damage
White-coat hypertension
Evaluation of drug-resistance or resistant hypertension
Evaluation of pregnancy-induced hypertension
Evaluation of treatment
Episodic hypertension associated with symptoms
Autonomic neuropathy
Orthostatic hypotension

Information from references 1, 3, and 12.

Indications for ABPM

Research indicates that clinical management may be simplified by using ABPM in certain situations *(Table 2)*.[1,3,12]

WHITE-COAT HYPERTENSION

Hypertensive patients frequently demonstrate their highest recorded levels in a clinical setting, with subsets of patients who demonstrate hypertensive blood pressures only in the physician's office.[13] To manage these white-coat hypertensive patients, it is first necessary to identify them and then to stratify their cardiovascular risk status.[12,14] Historical appraisal and review of self-recorded blood pressures can aid in the identification of these patients, but stratifying their risk solely on the basis of office measurement of blood pressure is more difficult.

Recent studies suggest that ABPM data can clarify the clinical situation, since 20 to 30 percent of patients who are hypertensive in the office are normotensive at other times[2] *(Figure 4)*. Recognition and proper management of this subgroup allows a reduction in antihypertensive medication use and a decrease in related side effects.[12] Accumulat-

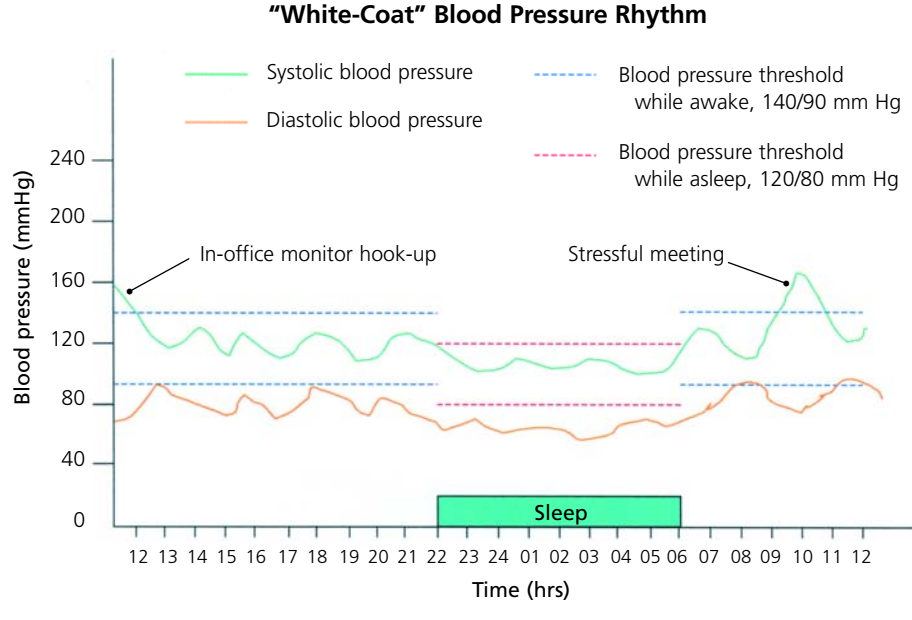

FIGURE 4. Ambulatory blood pressure report of a patient with white-coat hypertension.

ing ABPM data suggest that patients with white-coat hypertension who maintain low ambulatory blood pressures (less than 130 to 135/80 mm Hg) have a low cardiovascular risk status and no demonstrable end-organ damage.[14]

Armed with ABPM control data, the clinician can make rational recommendations about continued or expanded lifestyle modifications or progressive use of antihypertensive medications.

BORDERLINE HYPERTENSION WITHOUT END-ORGAN DAMAGE

The decision to initiate pharmacotherapy in patients with stage 1 (mild) hypertension can be difficult, particularly in patients without identified end-organ damage, a family history of hypertension, or a secondary etiology. Pharmacotherapy decisions traditionally depend on sequential office blood pressure readings and review of patient-supplied home recordings.

Accuracy of at-home recordings can be improved by calibration of the home instrument with a known standard, but even so, a lower threshold for treatment is recommended (i.e., less than 135/85 mm Hg), because of inaccuracies in home measurements and the tendency for home readings to be lower than office readings *(Table 3)*.[1,12] ABPM data may help refine decision-making by rectifying discrepancies between in-office and home measurements and by quantifying the patient's overall level of control. Armed with this control data, the clinician can make rational recommendations about continued or expanded lifestyle modifications or progressive use of antihypertensive medications.

RESISTANT HYPERTENSION

Resistant hypertension is the term applied when adequate blood pressure control cannot be achieved despite the use of appropriately combined antihypertensive therapies in proper dosages for a sufficient duration.[3] This clinical dilemma arises in true drug-resistant hypertension, cases of patient noncompliance, white-coat hypertension, and cases of pseudohypertension (where brachial artery calcification precludes collapse by the pressure cuff, leading to spuriously high readings). These patients typically have persistently elevated clinic pressures and normal or equivocal home or ABPM readings but fail to demonstrate any evidence of target-organ damage.[12]

Sleep apnea and other sleep disorders are noteworthy etiologies of resistant hypertension. It is critical to identify an underlying disorder, given the cardiovascular risks associated with failure to diagnose and treat such disorders.[15] Patients with sleep apnea and other sleep disorders demonstrate sporadic hypertensive episodes, coincident with apneic spells, and often fail to demonstrate the nocturnal physiologic dip in blood pressure. ABPM data may help the clinician determine whether inadequate therapy or true drug resistance underlies the failure to control hypertension. Of course, excluding noncompliance as the cause requires skilled interpretation by the clinician.

TABLE 3
Ambulatory Blood Pressure vs. Clinic Blood Pressure—Thresholds for Treatment

Hypertension	*Clinic blood pressure (mm Hg)*	*Ambulatory blood pressure (mm Hg)*
Daily[1]	140/90	135/85
Nighttime[12]	125/80	120/75
With diabetes[1]	130/85	†
With renal disease[1]	130/85 125/75*	†

**—Blood pressure goal in patients with renal disease who have proteinuria in excess of 1 g per 24 hours.[1]*

†—Although daytime and nighttime hypertensive blood pressure thresholds have been established for clinic and ambulatory readings, thresholds for specific disease states (e.g., diabetes, renal disease) have not been established.

Information from references 1 and 12.

Excluding noncompliance as the cause of failure to control hypertension requires skilled interpretation by the clinician.

HYPERTENSION IN PREGNANCY

Research supports the use of ABPM for the evaluation of hypertension during pregnancy. Reference values have been established for this clinical setting.[16] Hypertensive disease complicates nearly 10 percent of pregnancies in the United States, with white-coat hypertension affecting an additional 30 percent of patients.[7] Because ABPM can more accurately identify hypertensive risk in these subgroups than office readings, it may be particularly helpful in reducing unwarranted hospitalizations or medication use in pregnancy.[17] [Evidence level B, nonrandomized clinical trial]

EVALUATION OF HYPOTENSIVE SYMPTOMS

Transient hypotensive episodes, whether related to antihypertensive therapy or to autonomic dysfunction, are difficult to assess with standard clinic blood pressure measurements but are readily recorded on ABPM monitoring. Identification of these episodes can clarify diagnostic strategies and medication management. This step may be particularly important in elderly or debilitated patients.[3,12]

EVALUATION OF TREATMENT EFFICACY

Previous reluctance to use ABPM devices in the routine management of patients with hypertension may change following the results of a comparative study of conventional and ABPM measurements.[18] This study compared cost, symptoms, left ventricular hypertrophy (LVH), and intensity of pharmacotherapy in patients followed by conventional clinic monitoring and by ABPM. The results failed to demonstrate any differences in cost, incidence of LVH, or level of reported symptoms between the two study groups. Antihypertensive therapy could be discontinued in 26 percent of the ABPM patients, compared with 7.3 percent ($P < 0.001$) of the patients in the clinic-monitoring group. In addition, hypertension was controlled with single-drug therapy in 27.2 percent of the ABPM patients. Multiple-drug therapy was required in 42.7 percent ($P < 0.007$) of the clinic-monitoring patients.[17] Despite the simplification or elimination of drug therapy and the reduction in the number of physician visits in the ABPM group, the study showed that cost savings were offset by the costs of ABPM equipment.

Interpretation of ABPM Results

Hypertension (defined as 140/90 mm Hg or higher) is difficult to apply to ABPM data because studies indicate that ambulatory pressures tend to be lower than clinic pressures, even in patients with hypertension.[1,19] The challenge is complicated further by the attempted application of treatment guidelines designed for clinic monitoring to the ABPM setting. Revised definitions of hypertension for the ambulatory setting have simplified diagnosis, and careful data interpretation and software manipulation appear to simplify treatment recommendations.

Mean systolic and diastolic pressures over the monitoring period are assessed to determine elevation above normal limits (140/90 mm Hg

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awake, 120/80 mm Hg during sleep) and the total duration that the patient's pressure remains above acceptable limits.[3] Combined use of these parameters defines the concept of "blood pressure load" (correlated with cardiac changes secondary to hypertension) and enables the clinician to assess the quality and quantity of overall blood pressure control.[2]

A Look at the Evidence

Epidemiologic and clinical studies correlate office-based blood pressure management with reductions in cardiovascular end points and surrogate markers of target-organ damage (e.g., LVH, proteinuria).[8] The identification and subsequent regression of these markers allows clinicians to better gauge long-term risks and monitor influences afforded by antihypertensive therapy.[20] An extensive and consistent body of evidence demonstrates that managing hypertension with ABPM rather than office-based readings significantly reduces these risks.[10,20] [Reference 10—Evidence level B, uncontrolled clinical trial]

Cost Issues

Ambulatory blood pressure technology does not come cheaply, with monitoring equipment and software estimated to cost approximately $4,500 to $5,500 for a fully equipped office. Clinician cost for a single-patient study ranges from $60 to $100, including staff time and supplies. The patient's cost ranges from $100 to $300 (with the addition of patient education, equipment hook-up, and data interpretation costs).[12] Although third-party reimbursement is variable, as would be expected for emerging technology, the Centers for Medicare and Medicaid Services has recently approved reimbursement for ABPM in patients with suspected white-coat hypertension.[21]

Opponents to the use of ABPM for routine clinical management cite an overall increase in cost, but proponents are quick to point out that careful patient selection is key to successful application of this technology.[22] Within carefully selected populations, ABPM may simplify or eliminate drug therapy, reducing medication consumption and its attendant potential complications, resulting in an overall cost savings.

The estimated cost of monitoring equipment and software to fully equip a physician's office for ambulatory blood pressure monitoring is $4,500 to $5,500.

Reduction in or simplification of pharmacotherapeutic regimens and increased use of lifestyle modifications to treat hypertension offer a potential for cost-effective use of this technology. Further research is warranted to link this promising tool to an overall improvement in morbidity and mortality in hypertensive patients.

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