REVIEW

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Ambulatory Blood Pressure Monitoring in Clinical Practice: A Review

J. Rick Turner, PhD,[a] Anthony J. Viera, MD, MPH,[b] Daichi Shimbo, MD[c]

[a]Quintiles, Durham, NC; [b]University of North Carolina at Chapel Hill School of Medicine, Chapel Hill; [c]Columbia University Medical Center, New York, NY.

ABSTRACT

Ambulatory blood pressure monitoring offers the ability to collect blood pressure readings several times an hour across a 24-hour period. Ambulatory blood pressure monitoring facilitates the identification of white-coat hypertension, the phenomenon whereby certain individuals who are not taking antihypertensive medication show elevated blood pressure in a clinical setting but show nonelevated blood pressure averages when assessed by ambulatory blood pressure monitoring. In addition, readings can be segmented into time windows of particular interest, for example, mean daytime and nighttime values. During sleep, blood pressure typically decreases, or dips, such that mean sleep blood pressure is lower than mean awake blood pressure. A nondipping pattern and nocturnal hypertension are strongly associated with increased cardiovascular morbidity and mortality. Approximately 70% of individuals have blood pressure dips of ≥10% at night, whereas 30% have nondipping patterns, when blood pressure remains similar to daytime average or occasionally increases above daytime average. The various blood pressure categorizations afforded by ambulatory blood pressure monitoring are valuable for clinical management of high blood pressure because they increase the accuracy for diagnosis and the prediction of cardiovascular risk.
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KEYWORDS: Ambulatory blood pressure monitoring; High blood pressure; Masked hypertension; Nocturnal blood pressure; White-coat hypertension

High blood pressure is currently the greatest threat to the global burden of disease.[1-3] Hypertension continues to be the most common diagnosis in adult primary care practice and the most salient cardiovascular disease risk factor. Recent figures published by the American Heart Association's Statistics Committee and Stroke Statistics Subcommittee, based on 2007-2010 data, revealed that 33% of adults aged ≥20 years in the United States have hypertension, that is, approximately 80 million people. The prevalence is similar for both sexes.[4] Fortunately, antihypertensive treatment substantially reduces the risk of heart failure, myocardial infarction, and stroke.[5]

Blood pressure measurements are essential for clinicians in the diagnosis and treatment of hypertension.[6] Therefore, choosing the most informative blood pressure assessment methodology is a topic of fundamental importance. Pickering et al[7] observed that: "Any clinical measurement of blood pressure may be regarded as a surrogate measure for the 'true' blood pressure of the patient, which may be defined as the mean level over prolonged periods."

Compared with the traditional method of taking a small number of readings in a clinical setting, ambulatory blood pressure monitoring offers the ability to collect blood pressure readings several times an hour across a 24-hour period. These readings can be aggregated to yield 24-hour means and grouped into time windows (eg, mean daytime and nighttime values). The various blood pressure categorizations facilitated by ambulatory blood pressure monitoring are valuable for clinical management of

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Requests for reprints should be addressed to J. Rick Turner, PhD, Quintiles, 4820 Emperor Blvd, Durham, NC 27703.

E-mail address: rick.turner@quintiles.com

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high blood pressure because they increase the accuracy for diagnosis and the prediction of cardiovascular risk.[8] Several recent guidelines discuss the use of ambulatory blood pressure monitoring in clinical practice (Table 1).[9-16]

Given the rapidly expanding and diverse literature on ambulatory blood pressure monitoring, this article provides a narrative review of the underlying rationale for its use in clinical practice, its strengths and limitations, and the directions it may take in clinical practice in the coming years.

CLINICAL SIGNIFICANCE

- Ambulatory blood pressure monitoring allows blood pressure readings to be taken across a 24-hour period.
- Several guidelines exist for the use of ambulatory blood pressure monitoring in clinical practice.
- Using ambulatory blood pressure monitoring to rule out white-coat hypertension prevents patients from being prescribed unnecessary antihypertensive medications.
- Ambulatory blood pressure monitoring also allows measurement of nocturnal blood pressure, an increasingly important prognostic parameter for cardiovascular disease risk.

FUNDAMENTALS OF AMBULATORY BLOOD PRESSURE MONITORING

As noted earlier, ambulatory blood pressure monitoring generates more information than the single (typically daytime) "snapshot in time" reading yielded by clinic measurement by providing a profile of blood pressure behavior over a 24-hour (or longer[17]) period and, therefore, how blood pressure throughout this period can be beneficially influenced by antihypertensive therapy. The challenges, limitations, and questionable veracity of (office) blood pressure measurement have been discussed extensively.[7,18,19] It is now well documented that ambulatory blood pressure monitoring provides superior prediction of cardiovascular outcomes, as discussed shortly.

As well as facilitating blood pressure assessment aggregated over the entire 24-hour period, ambulatory blood pressure monitoring also allows more fine-tuned assessments during specific windows of this time cycle. The circadian cycle can be divided into various periods: Assessments at different times permit evaluation of circadian variation in blood pressure (Figure 1). Nighttime blood pressure is one of the most important measures of this circadian variation. Normally during sleep, blood pressure decreases (dips) such that average sleep blood pressure is lower than average awake blood pressure. The normal dip is considered 10% to 20%. Individuals with a dip <10% are said be nondippers. Nocturnal hypertension and nondipping pattern are strongly associated with increased cardiovascular morbidity and mortality. Approximately 70% of individuals show reduced blood pressure at night (ie, show dipping ≥10%), and approximately 30% have nondipping patterns, when blood pressure remains similar to daytime average, or occasionally increases above daytime average (reverse dippers). Other important parameters of blood pressure assessment facilitated by ambulatory blood pressure monitoring are the morning surge, when blood pressure increases rapidly from nighttime levels to daytime levels, and blood pressure variability.

Both hardware and software considerations are important for successful and optimally informative implementation of ambulatory blood pressure monitoring. First, monitors should be validated according to internationally accepted protocols. The International Protocol of the European Society of Hypertension[20,21] is now the protocol that is used most commonly for the independent validation of devices.[22] Second, although it is essential that appropriate hardware be used, it is equally, and arguably more, important that appropriately informative software be used.[23]

Several articles provide informative summaries of ambulatory blood pressure monitoring techniques.[7,23-25] Considerably more detailed discussion can be found in the European Society of Hypertension's 2013 position paper on ambulatory blood pressure monitoring.[14]

PREDICTION OF CLINICAL OUTCOMES

In a seminal study, Perloff et al[26] examined follow-up data for more than 1000 hypertensive individuals who initially had been evaluated with both office measurements and ambulatory blood pressure monitoring. Both sexes were equally represented. The mean (± standard deviation) initial office blood pressures were 161.2 ± 22.6 mm Hg/100.7 ± 12.1 mm Hg, and the mean ambulatory blood pressures were 145.6 ± 22.3 mm Hg/91.5 ± 13.7 mm Hg. Ambulatory blood pressure monitoring was found to be an independent prognostic indicator when assessing the overall risk profile of individual patients. Those patients whose ambulatory blood pressure monitoring values were higher than predicted via regression analysis from their office blood pressure measurements (systolic blood pressure ≥10 mm Hg higher or diastolic blood pressure ≥6 mm Hg higher) had statistically significantly higher cumulative mortality and morbidity over 10 years than those whose ambulatory blood pressure monitoring values were lower than predicted (systolic blood pressure ≥10 mm Hg lower or diastolic blood pressure ≥6 mm Hg lower). These findings extended research by the same group demonstrating that among patients with similar office blood pressure measurements, those with relatively higher ambulatory blood pressure monitoring values had a greater prevalence of target organ damage, including retinopathy and left ventricular hypertrophy. Therefore, ambulatory blood pressure monitoring was considered superior to traditional