Ambulatory Blood Pressure Monitoring: Techniques, Advantages, Drawbacks and Follow Up

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Abstract

Background: Blood pressure is one of the most common global health problems. The risks imposed by hypertension are indisputable and have been proven by large-scale observational studies. Conventional office BP readings provide a snapshot evaluation of the patient's BP, which might not reflect the patient’s actual BP, with the possibility of being falsely increased or falsely decreased. In addition, office BP measurement does not give any idea about BP variation throughout the day or the effect of the antihypertensive on the variation. Ambulatory BP measurement (ABPM) helps in decreasing the number of possible inaccurate readings, along with the added benefit of understanding the dynamic variability of BP.

Keywords: Ambulatory blood Pressure

Background

Systemic Hypertension

Overview of Hypertension:

Affecting more than 1 billion people worldwide, hypertension remains the most common, recognizable, and reversible risk factor for myocardial infarction (MI), heart failure, stroke, aortic dissection, atrial fibrillation, peripheral arterial disease, and cognitive decline (1).

The global burden of hypertension is rising due to escalating obesity and population aging and is expected to affect 1.5 billion persons—one-third of the world’s population—by 2025(2).

Hypertension is rapidly increasing in developing countries (80% of the world), where inadequate hypertension treatment and control contribute to the rising epidemic of cardiovascular disease (CVD). High blood pressure (BP) continues to be the largest contributor to the global burden of disease, causing two-thirds of all cerebrovascular accidents (strokes) and half of all ischemic heart disease worldwide (2).

Hypertension levels have shifted during the past four decades from high-income countries to low-income countries in south Asia and sub-Saharan Africa, while BP remained persistently high in central and eastern Europe (3).
Ambulatory blood pressure monitoring

Introduction:
Hypertension is one of the major risk factors for coronary artery disease (CAD), myocardial infarction, heart failure, stroke, and chronic kidney disease (CKD); however, it is a modifiable risk factor, with non-pharmacological and pharmacological measures providing substantial risk reduction of these conditions (4).
Hence, BP measurements are very important for physicians in the diagnosis and management of hypertension (4).
Conventional office BP readings provide a snapshot evaluation of the patient's BP, which might not reflect the patient’s actual BP, with the possibility of being falsely increased or falsely decreased. In addition, office BP measurement does not give any idea about BP variation throughout the day or the effect of the antihypertensive on the variation. Ambulatory BP measurement (ABPM) helps in decreasing the number of possible inaccurate readings, along with the added benefit of understanding the dynamic variability of BP (5).

Ambulatory blood pressure monitoring
ABPM refers to BP recording, usually over 24 h, and average BP values are usually provided for daytime, nighttime, and 24 h, which is very helpful to assess the pressure variability patterns. It provides a better and more precise assessment of true BP than the one-time measurement.
ABPM provides a good understanding of circadian changes (diurnal rhythmic changes, including nocturnal dipping and morning surge) and also BP variation with different environmental and emotional changes. ABPM is a better predictor of Hypertensive-mediated organ damage than office BP (6).
In addition, mean 24 h ambulatory BP has repeatedly been shown to have more a stronger connection to morbid or fatal events. and is a more effective risk predictor of CV outcomes such as cardiovascular events than conventional office BP. Furthermore, it is a better method than a one-time BP to determine the impact of antihypertensive treatment and predict cardiovascular outcomes. (7).

Technique:
While standard office BP readings often make use of manual labor with a sphygmomanometer, ambulatory BP is measured by automatic BP monitors and use an oscillometric technique (8).
The cuff is wrapped around the upper arm, which should be kept still while recording. Arm cuffs should be preferred over the wrist and finger cuffs, as suggested by the recommendations of the American Society of Hypertension and the International Society of Hypertension 2014 that wrist and finger cuffs are frequently wrong (8).
The cuff is inflated and then when steadily deflating, the oscillations begin to appear as the pressure goes down and disappears below the diastolic blood pressure level (8).

Advantages and limitations:
A major advantage of ABPM is that it enables the diagnosis of white-coat and masked hypertension. In addition, it provides BP measurements during routine daily activities and during sleep. ABPM is continuous and can clarify the diurnal variation (especially nocturnal changes) better than HBPM, which does not cover 24 hours. There is more evidence highlighting the significance of ABPM with cardiovascular events and/or mortality than HBPM. Limitations of ABPM include the lack of ability to accurately record BP during physical activity (9).
Patients often find it uncomfortable while sleeping, and may choose not to get it repeated, if required (5).

Restricted availability, high costs, lack of expertise, understanding, and approach of various practitioners to ambulatory BP monitoring, and shortage of research on the potential benefits of ABPM may be other limitations (5).

Certain parameters are required for the validity of the ABPM readings, none of which is said to be the strongest. This involves obtaining around 70% of the expected readings or recording at least 14 readings during the daytime or at least 10 readings during the daytime and 5 readings at nighttime (10).

**Ambulatory BP dipping:**
Nocturnal dipping (dipping of BP during the night) is a common normal phenomenon, the prevalence of nocturnal dipping in more than 50% of the population, which means nocturnal BP being 10%—20% lower than awake BP (11). It can be discovered only in ABPM, not in HBPM or office BP. The person is considered a non-dipper if the dip is less than 10% of daytime BP. The rise in nighttime BP is called Reverse dipping, and nocturnal BP fall more than 20% of the daytime BP is called extreme dipping (12).

Non-dipping is different from nocturnal hypertension, as nocturnal hypertension is an elevation of nighttime BP, whereas non-dipping occurs because of improper control and regulation mechanism of BP (12).

Non-dippers and reverse dippers have been shown to have more organ damage than dippers, including left ventricular hypertrophy, cerebrovascular stroke, and proteinuria, with the rate being more in reverse dippers than in non-dippers. Extreme dippers have been known to experience increased stroke rates (12).

![Fig. 1. Normotension with preserved nocturnal dipping. Average daytime and nighttime systolic and diastolic blood pressure values within normal limits. (5).](image-url)
Fig. 2. Systo-diastolic hypertension with preserved nocturnal dipping. Average daytime and nighttime systolic and diastolic blood pressure values more than normal limits. (5).

Fig. 3. Systo-diastolic hypertension with reduced nocturnal dipping. Average daytime and nighttime systolic and diastolic blood pressure values more than normal limits. (5). Morning surge is another term that needs to be understood, it is physiological neural and humoral response composing of activation of the sympathetic system. Excess surge is known to be associated with myocardial infarction, stroke, and sudden death (13).
Ambulatory BP in clinical practice:
In clinical practice, ABPM has diagnostic, prognostic, and therapeutic utility. ABPM is the gold standard test to diagnose hypertension, including white coat, masked, and nocturnal hypertension (14). Other indications might include screening for obstructive sleep apnea, and in patients with postprandial heart rate variability and hypotensive symptoms, to rule out autonomic malfunction (14). Genetic syndromes such as neurofibromatosis type 1, Turner syndrome, and syndrome, which may have underlying renal artery stenosis and/or aortic coarctation (14).
For hypertensive patients on medical treatment, it can be useful in monitoring antihypertensive therapy, development of hypotensive symptoms on treatment, drug resistance, and correlation with office BP readings. However, office BP readings are still used in the monitoring of antihypertensive therapy (5).

White-coat hypertension:
White-coat hypertension is a condition in which BP is elevated in the office, but is normal when measured by out-of-office techniques such as ABPM or HBPM. The ‘white-coat effect’ is the difference between the higher office and the lower out-of-office BP and is believed to mainly reflect the pressor response to an alerting reaction provoked by office BP measurements by a doctor or a nurse (15). Although the terms white-coat and masked hypertension were originally defined for people who were not being treated for hypertension, they are now also used to describe discrepancies between office and out-of-office BP in patients treated for hypertension. Masked uncontrolled hypertension (MUCH) refers to the condition in which office BP is controlled but home or ambulatory BP is elevated, and white-coat uncontrolled hypertension (WUCH) means that office BP is elevated but home or ambulatory BP is controlled, compared with sustained uncontrolled hypertension (SUCH) in which both office and home or ambulatory BP are uncontrolled. The difference between an elevated office BP (treated or untreated) and a lower home or ambulatory BP in both untreated and treated patients is called (The white-coat effect) (5).

Although the prevalence varies between studies, white-coat hypertension can account for up to 30-40% of people (and >50% in the very old) with an elevated office BP. It is more common in old age, in women, and in non-smokers. Its prevalence is lower when office BP is based on repeated measurements. A significant white-coat effect can be seen at all grades of hypertension (including resistant hypertension), but the prevalence of white-coat hypertension is greatest in grade 1 hypertension (5).

White-coat hypertension has been shown to be less associated with Hypertension-mediated organ damage (HMOD) than sustained hypertension, and recent studies show that the risk of cardiovascular events associated with white-coat hypertension is also lower than that in sustained hypertension (16). Conversely, compared with true normotensives, patients with white-coat hypertension have increased adrenergic activity, a greater prevalence of metabolic risk factors, more frequent asymptomatic cardiac and vascular damage, and a greater long-term risk of new-onset diabetes and progression to sustained hypertension and LVH (15).
In addition, although the out-of-office BP values are, by definition, normal in white-coat hypertension, they tend to be higher than those of true normotensive people, which may explain the increased long-term risk of CV events reported in white-coat hypertension by recent studies after adjustment for demographic and metabolic risk factors. White-coat hypertension has also been shown to have a greater CV risk in isolated systolic hypertension and older patients, and does not appear to be clinically harmless (17).
The diagnosis of white-coat hypertension should be confirmed by repeated office and out-of-office BP measurements and should include an extensive assessment of risk factors and HMOD. The CV risk appears to be lower (and close to sustained normotension) in those in whom both ABPM and HBPM are both normal, so both ABPM and HBPM are recommended to confirm white-coat hypertension. (15) Although office BP is high in white coat hypertension, such patients do not need treatment apart from lifestyle modification and annual ambulatory BP or home BP monitoring tests to determine progression to sustained hypertension (11).
Therefore, the misdiagnosis and mistreatment of these patients as true hypertensives not only put them on excessive chronic usage of medication, but it is also not cost-effective, and with the use of ABPM, this is avoidable. (18).

Resistant hypertension:
As previously mentioned, White-coat hypertension is reported to happen in hypertensive patients on drug therapy. Many patients who have resistant hypertension turn out to be white coat hypertensives, i.e., their BP is well-controlled on ambulatory BP readings but have falsely elevated office readings. In a study involving 8295 patients with resistant hypertension, de la Sierra et al. (19) found out that 37.5% of patients had white coat resistance.
The latest ACC/AHA guidelines recommend screening of white coat hypertension in hypertensive patients on three or more drugs, with the office BP 5—10 mm Hg higher than the goal (11). Therefore, ambulatory Blood pressure should be considered before up-titration of medication or adding a new medicine (7).

Masked hypertension:
When the office BP reading of a patient is not elevated but out-of-office BP reading is elevated, he or she is having masked hypertension (MH). More than 30% of the population with normal office BP is diagnosed with MH, based on ambulatory BP readings (20).
The prevalence is greater in younger people, smokers, men, and those with higher levels of alcohol consumption, job stress, and anxiety (20). Diabetes, Obesity, family history of hypertension, CKD, and high normal office BP are also associated with an increased prevalence of masked hypertension (20). Meta-analyses and recent studies have shown that the risk of CV events is significantly greater in masked hypertensive individuals compared with normotensives, and close to or greater than that of sustained hypertension (18). Masked hypertension has also been shown to increase the risk of CV and renal events in diabetes, particularly when BP increases at the night (21).
As previously mentioned, it is suspected in patients with elevated office BP at any time, people with LVH and normal or high normal BP, people with a positive family history of hypertension in both parents, and diabetic and obese individuals (22). Moreover, it should be tested if office BP is increased for 3 months after lifestyle modification (5).
It is confirmed if ambulatory BP or home BP reading is more than the cut-off value (table 2) compares between the ESH 2018 criteria and the ACC/AHA 2017 criteria cut-off value of ABPM to diagnose masked hypertension.

**Table 1:** Comparison between the ESH 2018 criteria and the ACC/AHA 2017 criteria cut-off value of ABPM to diagnose masked hypertension (MH) and masked uncontrolled hypertension (MUCH) in patients with office BP <130/80 mm Hg on antihypertensive treatment.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>ESH, 2018</th>
<th>ACC/AHA, 2017</th>
</tr>
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<tbody>
<tr>
<td>Mean daytime ABPM</td>
<td>&gt;135 or 85 mm Hg</td>
<td>&gt;130/80 mm Hg</td>
</tr>
<tr>
<td>Mean 24-h ABPM</td>
<td>&gt;130 or 80 mm Hg</td>
<td>&gt;125/75 mm Hg</td>
</tr>
<tr>
<td>Mean night-time ABPM</td>
<td>&gt;120 or 70 mm Hg</td>
<td>&gt;110/65 mm Hg</td>
</tr>
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ACC/AHA, American College of Cardiology/American Heart Association; ESH, European Society of Hypertension; ABPM: ambulatory blood pressure monitoring.

However only daytime ambulatory BP readings will result in underestimation of the actual burden of the problem and it is recommended that daytime, nighttime and 24-hour ambulatory BP readings should be taken (23).

For example, the prevalence of MH in the Jackson Heart study was 22 percent, 41 percent, and 26 percent respectively based on individual day time, night time, and 24-hour readings, while the total prevalence of all three was 44.1 percent combined (23). Therefore, all of them should be taken into account, but no single time span reading has been known to reliably measure the prevalence (23). These patients are at increased risk of organ damage, including renal dysfunction (proteinuria, decreased GFR), increased left ventricular index and hypertrophy, carotid atherosclerosis, stroke, myocardial infarction and increased level of urine albumin-to-creatinine ratio and serum cystatin C (23).

**Nocturnal hypertension:**

According to the latest ACC/AHA 2017 guidelines, nocturnal hypertension is classified as BP more than 110/65 mm Hg (lower than the previous value of >120/70 mm Hg at night, which is the current value in the ESC guidelines). According to a study of more than 30,000 untreated patients and more than 60,000 patients on antihypertensive therapy (from Spanish Ambulatory Blood Pressure monitoring registry), it’s prevalence was found to be more than 40% in the untreated group and almost 50% in the treated group (19).

As previously mentioned, nocturnal hypertension and nocturnal dipping are different entities; however, they are both associated, separately or together, with poor cardiovascular outcomes. Independently, nocturnal hypertension was also shown to be associated with subclinical end-organ damage, especially microalbuminuria, even when not associated with nocturnal dip (19). Cerebrovascular bleeding, smoking, and diabetes also correlate with nocturnal hypertension, the prevalence of nocturnal hypertension is found to be greater in the male population (19).

Control of night-time BP carries more significance in patients with a once-daily morning dose of antihypertensive medication, as the BP is usually well controlled during the day (24).
In a large cohort study, night-time BP elevation in patients on antihypertensive drugs had a poor prognosis regarding cardiovascular complications (fatal and nonfatal), as the BP was controlled during the day but remained high at night (24).

**Pregnancy:**
Ambulatory BP has been shown to be useful in the monitoring of BP in pregnant women, especially during the last trimester of pregnancy. It has been shown to predict the outcome of pregnancy, with an increased risk of lower segment cesarean section for hypertensive patients (25). Normal ambulatory BP values are available in different trimesters of pregnancy and are usually higher than conventional BP levels (25).

The most important use of ABPM during pregnancy is to exclude white coat hypertension, the prevalence of which was found to be approximately 30% in the Bellomo et al report. These women can avoid the use of antihypertensive drugs without having any effect on the outcome of pregnancy (26).

**Monitoring drug therapy:**
ABPM is indicated in all patients prior to beginning pharmacological therapy. In addition to the initiation of antihypertensive therapy, ABPM can also be used to evaluate the treatment of patients already on antihypertensive medications (s). For example, after the initiation of therapy, ABPM should be repeated every 15—20 days to check for effective impact until the optimal BP has been achieved. When sufficient control has been achieved, it can be replicated on an annual or biannual basis (27).

The overall monitoring frequency with ABPM varies according to the degree of hypertension and treatment response with dose and/or medication alteration (27). However, the use of ABPM in the assessment of the effectiveness of antihypertensive treatment is not standardized (27).

**Ambulatory hypotension and autonomic dysfunction:**
The BP variability over the whole 24-hour cycle, including the fall in BP, can be measured using ABPM. In a cohort study of more than 5000 elderly patients (>80 years of age), more than 50 percent of these patients had ABPM daytime hypotension, although no such BP changes were reported at the office BP readings (27).

It can also be used to identify hypotensive events in young patients and in patients on antihypertensive medications (27).

**Underlying systemic abnormalities:**
In untreated hypertensive patients with snoring, ABPM has been used to screen them for obstructive sleep apnea (28).

It is often used in Parkinson’s disease, which can present with cardiovascular complications including supine hypertension, and postural hypotension, which are the most common findings. Other findings might include non-dipping, postprandial and exercise-dependent hypotension, and drug-induced hypotension (28).

It may also be used during the assessment of stroke and in causes of endocrine hypertension, such as adrenal disorders, pituitary disorders, thyroid disorders, and diabetes (5).
Follow up:
Considering when to repeat ABPM is mainly at the discretion of the physician on the basis of underlying patient conditions, including high variability in BP, unexpected response to medication, the presence of adverse risk factors, and the need for straight night time BP control in patients with heart disease, kidney disease or diabetes (27).

Due to patient inconvenience, the chances of repeating are further reduced. The most common reasons for repeating ABPM include equivocal results with initial measurement, confirmation of the existence of white coat and MH, patients who have had insufficient results with antihypertensive therapy or who have had their medication changed. It is also recommended to diagnose nocturnal hypertension since ABPM is the only non-invasive way to diagnose it (27).

Contraindications:
While ABPM has been shown to be superior to the Office BP measurement, some contraindications need to be ruled out when taking the history. That includes severe clotting disorders, severe heart rhythm disturbances, such as severe atrial fibrillation, and latex allergy that can be identified when using unique equipment brands (29).

References


