



Role of Ambulatory Blood Pressure Monitoring in Hypertensive Patients

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ABSTRACT:

Introduction: Ambulatory Blood Pressure Monitoring (ABPM) measures blood pressure during daily activities and sleep, offering a thorough evaluation of hypertension and cardiovascular (CV) risk. It is superior to office blood pressure (OBP) measurements in predicting CV events and mortality. This study aimed to explore the role of both office and ambulatory BP monitoring in the management of treated hypertensive patients.

Methodology: This prospective study involved 271 hypertensive patients with controlled office BP per JNC 8 guidelines. Detailed demographic data and antihypertensive medication were recorded. OBP was measured following standard practices, and ABPM was recorded over 24 hours using a portable device, with measurements at 15-minute intervals during the day and 30-minute intervals at night.

Results: The enrolled patients had a mean age of 48.47 years, predominantly female (66.05%). Among them, 16.2% had White Coat Hypertension (WCH), and 17.4% had Masked Uncontrolled Hypertension (MUCH). Diuretics + ARBs were the most common medication regimen (16%). Non-dippers were 51%, normal dippers 35%, extreme dippers 8%, and reverse dippers 6%. Systolic OBP had a sensitivity of 78.73% and specificity of 41.62%, while diastolic OBP showed 76.26% sensitivity and 67.29% specificity.

Conclusion: ABPM is essential for managing hypertension, providing a more thorough assessment than single OBP measurements. It accurately detects white-coat and masked hypertension, helping with cardiovascular risk stratification. Routine use of ABPM is advised for optimizing antihypertensive treatment.

1. Introduction

Ambulatory blood pressure monitoring (ABPM) facilitates the measurement of blood pressure during daily activities, including mild to moderate physical activity and sleep. [1,2] This method is recommended by almost all major hypertension guidelines as an out-of-office technique for blood pressure measurement. [3] There is substantial evidence that ABPM surpasses office blood pressure (OBP) measurement in evaluating blood pressure and predicting cardiovascular (CV) disease risk and events. [4-6] Studies have demonstrated that ABPM, particularly nighttime blood pressure, is more effective

than OBP in predicting total mortality and CV complications. [7,8] ABPM helps distinguish between masked hypertension and normotension, as well as white-coat hypertension and sustained hypertension. It has been established that masked and sustained hypertension, but not white-coat hypertension, are associated with high CV risk. [1,2] Additionally, ABPM captures variations in blood pressure and heart rate throughout the day in response to environmental, postural, and emotional changes. This makes ABPM an indispensable tool for diagnosing hypertension, assessing CV risk, monitoring therapy, and guiding



individualized treatment plans. [9] Several studies have highlighted the cost-effectiveness of Ambulatory Blood Pressure Monitoring (ABPM), noting its potential to reduce healthcare expenses by preventing unnecessary antihypertensive treatment in patients with white-coat hypertension. [10,11] With over Many years of research establishing ABPM as the gold standard for blood pressure measurement, [9] this study aims to investigate the specific role of ABPM in managing hypertensive patients.

2. Methods

A prospective study was conducted in the Department of Cardiology, Medanta Hospital, Lucknow, from 2023 to 2024, involving 271 hypertensive patients who were receiving treatment and had controlled office blood pressure according to the JNC 8 hypertension guidelines. Written informed consent was obtained from all participants. [12] Inclusion criteria for the study required patients to be hypertensive and on pharmacological treatment, with at least one office blood pressure reading meeting the JNC8 hypertension guideline criteria. Exclusion criteria included hypertensive patients under 18 years of age, those not on medical management, individuals with newly detected hypertension, patients with uncontrolled hypertension, normotensive individuals, and patients with atrial fibrillation as detected by baseline ECG, due to its potential to cause inaccuracies in blood pressure measurements. [13] Sample size was calculated by using the formula: [14]

$$\text{Sample size } n = \frac{DEFF * Np(1-p)}{[(d2/Z21-\alpha/2*(N-1)+p*(1-p)]}$$

Detailed demographic information was recorded, including age, gender, socioeconomic status (SES), and educational attainment. The type of antihypertensive medication taken by the patients were also recorded. Subsequently, office blood pressure (OBP) was measured according to standard practices. Each measurement was performed following accepted procedures to ensure accuracy. Ambulatory Blood Pressure (ABP) was conducted using a portable BP measuring device worn on the non-dominant arm for a 24-hour period. Care was taken to ensure the difference between initial values and those measured by the operator did not exceed 5 mmHg. If a larger difference was observed, the ABPM cuff was refitted. Participants were instructed to maintain normal activities but avoid

strenuous exercise during cuff inflation, remain still, and keep the cuff at heart level during measurements. They were also asked to record symptoms, events influencing BP, times of drug ingestion, meals, and sleep in a diary. Measurements were taken at 15-minute intervals during the day and 30-minute intervals overnight. Excessive intervals between BP readings were avoided to maintain the accuracy of the 24-hour BP estimates. Data were downloaded to a computer, and a range of analyses was performed. At least 70% of BP readings during both daytime and nighttime periods had to be satisfactory; otherwise, the monitoring was repeated.

Statistical Analysis:

The data obtained from the study were subjected to statistical analysis using SPSS version 26.0 for further evaluation at the significance level of $p\text{-value} = 0.05$. Continuous variables were presented as Mean \pm standard deviation, while categorical variables were presented as frequencies. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of office blood pressure measurements compared to ABPM were calculated to assess diagnostic accuracy.

3. Results

The study participants, with a mean age of 48.47 years (SD = 16.52), were predominantly female (66.05%). Socioeconomically, 35.79% fell into the Upper Middle category, while 28.78% had attained higher education levels. [Table-1] The study measured various blood pressure and cardiovascular parameters. [Table-2] Among 271 patients, 44 patients (16.2%) were identified as having White Coat Hypertension (WCH), and 47 patients (17.4%) were diagnosed with Masked Uncontrolled Hypertension (MUCH). This indicates that a significant portion of the cohort experienced these specific types of hypertension despite being part of the overall group of treated hypertensive patients. [Table-3] Among treated hypertensive patients, the most common medication regimen was Diuretics + ARBs (16%). [Table-4] Among the enrolled patients, dipping patterns varied. Fifty-one percent were non-dippers, 35% were normal dippers, 8% were extreme dippers, and 6% were reverse dippers. Among females ($n=92$), 49% were non-dippers, while among males ($n=179$), 52% were non-dippers. In different age groups, non-dipping was most prevalent in the 18-39 age group (54%), while reverse dipping was highest in those aged 60 and above (36%).



These results indicate gender and age-related differences in dipping patterns among hypertensive patients. [Table-5] Table 5 compares the diagnostic accuracy of office BP measurements with ABPM. Systolic office BP showed 78.73% sensitivity and 41.62% specificity, with a positive predictive value (PPV) of 78.02% and a negative predictive value (NPV) of 43.25%. Diastolic office BP demonstrated 76.26% sensitivity, 67.29% specificity, a PPV of 88.31%, and an NPV of 62.37%. [Table-6].

4. Discussion

In the present study, the mean age of patients was 48.47 ± 16.52 years, were predominantly female (66.05%). In terms of socioeconomic status, the most common category was Upper Middle (16-25), which included 35.79% of participants, followed by Lower Middle (11-15) at 22.51%, Upper (26-29) at 19.56%, Upper Lower (5-10) at 15.50%, and Lower (<5) at 6.64%. Regarding educational status, a higher proportion of participants had higher education (28.78%), followed by those who had completed graduation (26.94%), secondary education (19.19%), matriculation (15.13%), primary education (5.90%), and a small fraction were illiterate (4.06%). Mizuno H et al. [15] included 379 participants, the mean of age was 41.5 ± 13.2 years, 59.1% were women, Similarly, Mohammad J et al. [16] included 561 patients where most of them were females (59%) and the mean age of the enrolled patients was 46.98 years. The study measured various blood pressure and cardiovascular parameters. The mean systolic and diastolic office BPs were approximately 118 mmHg and 80 mmHg, respectively. During active periods, the mean systolic BP was around 126 mmHg and diastolic BP about 79 mmHg. The 24-hour mean BP was roughly 123/75 mmHg. Minimum BPs recorded were 75/41 mmHg. During passive periods, the mean BP was 111/66 mmHg. The diurnal index averaged 8%. Additional measures included a wide-ranging Hyperbaric Impact, a morning BP surge of about 11 mmHg, mean arterial pressure of 90 mmHg, and a BP percent time elevation of 26%. The mean pulse pressure was 39 mmHg, pulse rate 75 bpm, and the double product indicated significant cardiac workload. These results were similar to the study by Mizuno H et al. [15] and others. [16] Of 271 patients, 44 patients (16.2%) were identified as having White Coat Hypertension (WCH), and 47 patients (17.4%) were diagnosed with Masked Uncontrolled Hypertension (MUCH). The prevalence rates of WCH and MUCH in

our study are similar to those reported by Mohammad J et al. [16], which were 16% and 17%, respectively. Previous research indicates that the prevalence of WCH in clinical settings typically ranges from 13% to 23% and tends to be higher among older adults with minimal gender differences. [17-19] There is limited evidence to suggest that medication for WCH or aggressively treating white-coat uncontrolled hypertension significantly impacts clinical outcomes. Another recent study noted a prevalence of 25.2% among patients. [15] In a meta-analysis of 27 studies, white-coat hypertension was associated with increased cardiovascular events (HR 1.36, 95% CI: 1.03–2.00), all-cause mortality (HR 1.33, 95% CI: 1.07–1.67), and cardiovascular mortality (HR 2.09, 95% CI: 1.23–4.48), compared to normotension. The risk was attenuated with stroke included in CV events (HR 1.26, 95% CI: 1.00–1.54) and became non-significant with 24-hour systolic/diastolic blood pressure measurements. [20] Studies reported that the masked hypertension prevalence ranges between 10% and 18%, with factors such as office blood pressure, gender, obesity, diabetes, chronic kidney disease, and smoking increasing the likelihood of its occurrence. [21-23] In population-based studies, approximately 15% of individuals are affected by masked hypertension. [5] Within this study, the predominant medication regimen among treated hypertensive patients was a combination of Diuretics and ARBs (16%), with Calcium Channel Blockers (12.80%) and ARBs alone (10.30%) following closely. Multiple drug class combinations were also commonly prescribed. Consistent findings were reported by other studies. [16,24] Among the enrolled patients, dipping patterns varied. Fifty-one percent were non-dippers, 35% were normal dippers, 8% were extreme dippers, and 6% were reverse dippers. Among females (n=92), 45 patients were non-dippers, while among males (n=179), 93 were non-dippers. In different age groups, non-dipping was most prevalent in the 18-39 age group (54%), while reverse dipping was highest in those aged 60 and above (22 individuals). These results indicate gender and age-related differences in dipping patterns among hypertensive patients. Similarly, Mohammad J et al. [16] noted a male predominance among non-dippers (61.3%) and reverse dippers (50%). Additionally, younger patients were more likely to exhibit a non-dipping pattern. It has been observed that non-dippers and risers face elevated risks of severe target



organ damage and cardiovascular events compared to dippers. [9] Furthermore, recent participant-level meta-analysis indicated significant differences in the sex- and age-adjusted 10-year cumulative incidence of composite cardiovascular outcomes based on dipping status, with reverse dippers showing the highest risk and extreme dippers showing the lowest. However, the prognostic significance of dipping status became insignificant after additional adjustments for nighttime systolic blood pressure. [8] This finding aligns with results from another prospective study, which demonstrated a 48% higher overall cardiovascular disease risk in risers compared to dippers, with the risk for heart failure being particularly pronounced and independent of nighttime blood pressure. [25] Non dipping and reverse dipping patterns have consistently been associated with increased cardiovascular event risks. [26] The diagnostic accuracy of OBP measurements with ABPM showed that the systolic OBP showed 78.73% sensitivity and 41.62% specificity, with a positive predictive value (PPV) of 78.02% and a negative predictive value (NPV) of 43.25%. Diastolic OBP demonstrated 76.26% sensitivity, 67.29% specificity, a PPV of 88.31%, and an NPV of 62.37%. Our study found that the negative predictive value of office BP measurements is much lower compared to ambulatory BP monitoring. This indicates that a normal office BP reading cannot reliably rule out poor control in treated hypertensive patients, highlighting the importance of ABPM for effective and optimal care. In their study, Mohammad J et al. [16] provided insights into the diagnostic accuracy of systolic and diastolic OBP measurements. They found that systolic office BP exhibited a sensitivity of 76.94% and a specificity of 40.74%, while diastolic office BP showed a sensitivity of 77.63% and a specificity of 63.16%. Similarly, Sisó-Almirall A et al. [27] investigated various BP measurement methods, including 1-hour automated office BP measurement, and found it to have a sensitivity of 76.6% and a specificity of 64.8%, with the best diagnostic accuracy among the methods evaluated. Additionally, another study examined the diagnostic sensitivity and specificity of the 140/90 mm Hg threshold for office BP, revealing values of 77.7% and 70.6%, respectively, with an overall diagnostic accuracy of 75.8%. [28] Several guidelines have highlighted ABPM's superiority in managing hypertension. [29,30] Nevertheless, the impact of ABPM-guided

antihypertensive treatment on clinical outcomes is still being explored.

5. Conclusion

Our study demonstrates the critical role of Ambulatory Blood Pressure Monitoring (ABPM) in managing hypertensive patients. Unlike a single office BP measurement, which fails to provide a comprehensive picture of hypertension control, ABPM offers a more reliable assessment. Office BP measurements show a low negative predictive value in ruling out hypertension in treated patients. ABPM is particularly effective in identifying white-coat and masked hypertension, including isolated nocturnal hypertension, and is valuable for cardiovascular risk assessment and stratification by analyzing circadian rhythms, BP variability, and arterial properties. Therefore, incorporating ABPM into routine practice is essential for optimizing antihypertensive treatment in managed patients. However, the study's small sample size, limited duration and potential patient adherence issues may affect the results' accuracy and generalizability. Future research should involve larger, diverse populations and consider extended durations. Routine use of ABPM in clinical practice is recommended, along with enhanced patient education on adherence to monitoring protocols for better treatment outcomes.

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