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Original Research Article

ROLE OF AMBULATORY BLOOD PRESSURE MONITORING IN CHRONIC HYPERTENSIVE PATIENTS ON ANTIHYPERTENSIVE THERAPY

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ABSTRACT

Background: Hypertension is a significant global health issue, with circadian blood pressure (BP) patterns offering valuable prognostic information regarding cardiovascular risk. This study aimed to investigate the relationship between dipping patterns, BP variability, and demographic factors in hypertensive individuals. Specifically, we focused on the association of reverse dipping with clinical characteristics such as age, duration of hypertension, and comorbidities.
Material and Methods: A cross-sectional study was conducted on 120 hypertensive patients (aged 40-70 years) attending a tertiary care hospital between January and December 2023. Ambulatory BP monitoring (ABPM) was used to classify patients into three groups: dippers, non-dippers, and reverse dippers. Demographic and clinical data were collected, including age, gender, BMI, duration of hypertension, comorbidities (diabetes, dyslipidemia), and waist-to-hip ratio. BP measurements were taken over a 24-hour period, and data analysis was performed using SPSS version 26, employing ANOVA for group comparisons and Pearson's correlation for associations.
Results: Reverse dippers had the highest mean age (58.7 ± 9.8 years) and longest hypertension duration (8.1 ± 2.7 years). They also had the highest 24-hour systolic (141.2 ± 11.4 mmHg) and diastolic BP (86.5 ± 7.8 mmHg) compared to dippers ($p < 0.05$). A significant correlation was found between BP variability and comorbidities, with diabetes showing a positive correlation with 24-hour BP measurements ($r = 0.368$, $p = 0.029$). Dipping patterns were also influenced by waist-to-hip ratio, with reverse dippers exhibiting greater central obesity (0.94 ± 0.03). BP variability was significantly higher in reverse dippers, indicating a higher risk of cardiovascular complications.
Conclusion: The study highlights the clinical significance of dipping patterns in hypertensive individuals, particularly in identifying those at higher risk for adverse cardiovascular outcomes. Reverse dipping is associated with older age, longer duration of hypertension, and comorbidities such as diabetes. These findings suggest the importance of using 24-hour ABPM for comprehensive BP monitoring and early detection of individuals with abnormal dipping patterns who may require more intensive management.
Key Words: Hypertension, Ambulatory Blood Pressure Monitoring, Dipping Patterns, Reverse Dipping, Diabetes.

INTRODUCTION

Hypertension is a prevalent condition affecting approximately 1.28 billion adults globally, with nearly two-thirds of cases occurring in low- and middle-income countries.[1] In India, the prevalence of hypertension is estimated to be 29.8% in urban areas and 27.6% in rural areas, with significant variability across different states.[2] Despite the availability of effective antihypertensive medications, only 12% of hypertensive patients in India achieve optimal blood pressure (BP) control, contributing to a substantial burden of cardiovascular morbidity and mortality.[3]

Traditional office-based BP measurements are the cornerstone of hypertension diagnosis and management. However, they are prone to inaccuracies due to phenomena such as white-coat hypertension, observed in 15–30% of patients, and masked hypertension, present in approximately 10–20% of individuals.[4] These conditions may lead to inappropriate therapeutic decisions, either overtreatment or undertreatment. Ambulatory Blood Pressure Monitoring (ABPM) has emerged as a superior alternative, offering a 24-hour profile of BP, including daytime, nighttime, and early morning readings, which are often more predictive of cardiovascular outcomes.[5]

ABPM has also highlighted the clinical significance of circadian BP variations, such as the dipping and non-dipping patterns. Studies indicate that nearly 30–40% of hypertensive patients exhibit a non-dipping pattern, characterized by less than a 10% reduction in nighttime BP, which is strongly associated with an increased risk of stroke, myocardial infarction, and left ventricular hypertrophy.[6,7] Moreover, ABPM provides insights into BP variability, a parameter independently linked to cardiovascular and renal complications.[8]

In chronic hypertensive patients on long-term antihypertensive therapy, ABPM plays a pivotal role in evaluating therapeutic efficacy. Studies have shown that up to 25% of patients classified as uncontrolled based on office BP readings are actually controlled when assessed via ABPM, underscoring its ability to avoid unnecessary medication escalation.[9] Furthermore, ABPM can detect periods of uncontrolled BP, such as nocturnal hypertension, which is often overlooked in routine clinical practice.[10]

Despite these advantages, ABPM remains underutilized in clinical practice, particularly in resource-constrained settings like India, due to factors such as cost, limited availability, and lack of awareness among healthcare providers.[11] This study aimed to evaluate the role of ABPM in chronic hypertensive patients on antihypertensive therapy, focusing on its utility in identifying BP control patterns, circadian variations, and therapeutic efficacy. By integrating ABPM into routine care, the study seeks to provide evidence for improved hypertension management strategies tailored to individual patient profiles.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted at the Department of Medicine, a tertiary care center in North India, India, over a period of one year from June 2023 to May 2024. The primary objective of the study was to evaluate the role of Ambulatory Blood Pressure Monitoring (ABPM) in identifying blood pressure (BP) control patterns, circadian variations, and therapeutic efficacy in patients with chronic hypertension on antihypertensive therapy.

Study Population

The study enrolled adult patients aged 18 years and older, who were diagnosed with essential hypertension and had been receiving stable antihypertensive therapy for at least three months. Inclusion criteria required participants to have a diagnosis of hypertension as per the Joint National Committee (JNC-8) guidelines, with adherence to prescribed antihypertensive medications. Patients with secondary hypertension, such as those with renovascular or endocrine causes, were excluded. Additional exclusion criteria included pregnant or lactating women, individuals with arrhythmias or severe anemia that could interfere with ABPM recordings, and patients unwilling to comply with the ABPM protocol. Written informed consent was obtained from all participants before inclusion.

Sample Size

The sample size calculation was based on the prevalence of non-dipping hypertension, which is estimated to be 40% among hypertensive patients on therapy.[12] Using a 95% confidence level and a margin of error of 5%, the sample size was determined to be 120 patients, accounting for a 10% dropout rate.

Data Collection

Each participant underwent a comprehensive evaluation, including detailed demographic and clinical data collection. Demographic variables included age, gender, body mass index (BMI), and socioeconomic status. Clinical history encompassed the duration of hypertension, antihypertensive medication regimen, comorbid conditions such as diabetes or dyslipidemia, and lifestyle factors, including dietary habits, physical activity levels, and smoking history. Office blood pressure measurements were taken using a validated automated sphygmomanometer, ensuring proper cuff size and adherence to standard measurement guidelines.

Ambulatory Blood Pressure Monitoring

ABPM was conducted using a validated ABPM device, such as the Spacelabs 90217 or a similar model, programmed to measure BP at 15-minute intervals during the daytime (6:00 AM to 10:00 PM) and at 30-minute intervals during the nighttime (10:00 PM to 6:00 AM). Participants were instructed to follow their usual daily activities but to avoid strenuous exercise during the monitoring period. Data collected from ABPM included 24-hour mean BP, daytime mean BP, nighttime mean BP, and BP variability. Circadian patterns were categorized based on the percentage drop in nighttime BP compared to daytime BP, with participants classified as dippers (≥10% nighttime BP reduction) or non-dippers (<10% nighttime BP reduction). Instances of masked hypertension, white-coat hypertension, and nocturnal hypertension were also recorded.

Laboratory Investigations

All participants underwent baseline laboratory investigations, including complete blood count, fasting blood glucose, serum creatinine, lipid profile, and urine albumin-creatinine ratio, to rule out secondary causes of hypertension and to assess cardiovascular risk factors.

Outcome Measures

The primary outcomes of the study included the proportion of patients achieving BP control, defined as a 24-hour mean BP of <130/80 mmHg, and the prevalence of non-dipping patterns. Secondary outcomes included the detection of masked and white-coat hypertension, evaluation of BP variability, and its correlation with therapeutic efficacy. Additionally, associations between ABPM parameters and cardiovascular risk factors, such as diabetes and dyslipidemia, were explored.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Ethics Committee. All participants provided written informed consent before enrollment, and confidentiality of data was maintained in accordance with ethical guidelines. Participants were informed about the purpose of the study, potential risks, and benefits.

Statistical Analysis

Data were analyzed using SPSS software version 20.0. Continuous variables, such as 24-hour mean BP, BP variability, and other hematological parameters, were expressed as mean ± standard deviation (SD). For categorical variables, including dipping status, anemia classification, and disease severity, frequencies and percentages were calculated. Comparisons between dippers and non-dippers for continuous variables were performed using independent t-tests, while chi-square tests were used for categorical variables. To assess associations between BP variability and clinical characteristics (e.g., hypertension severity, comorbidities), Pearson correlation coefficients were calculated. Multivariate logistic regression analysis was conducted to identify independent predictors of non-dipping patterns and BP variability, adjusting for potential confounders such as age, gender, and comorbid conditions. A p-value of <0.05 was considered statistically significant.

RESULTS

The study analyzed the clinical and demographic characteristics of 120 hypertensive individuals stratified by dipping patterns. Age differed significantly among the groups, with reverse dippers being the oldest (58.7 ± 9.8 years, p = 0.045). Waist-hip ratio was significantly higher in reverse dippers (0.94 ± 0.03) compared to dippers (0.89 ± 0.03) and non-dippers (0.92 ± 0.05, p = 0.036). Duration of hypertension was also longer in reverse dippers (8.1 ± 2.7 years) than in dippers (5.5 ± 2.6 years) and non-dippers (7.3 ± 3.1 years, p = 0.042). No significant differences were observed among the groups for gender distribution, BMI, diabetes prevalence, smoking, sedentary activity, or alcohol consumption. [Table 1]

Systolic BP showed a significant difference across the measurements, with office BP being higher (141.7 ± 13.6 mmHg) compared to the 24-hour (134.8 ± 11.2 mmHg), daytime (137.2 ± 11.8 mmHg), and nighttime (129.6 ± 10.7 mmHg) values, resulting in significant BP variability (12.8 ± 4.3 mmHg, p = 0.041). Diastolic BP also exhibited a significant decrease over the 24-hour period, with office BP at 87.3 ± 8.4 mmHg and nighttime BP at 80.1 ± 6.5 mmHg (p = 0.038). Mean Arterial Pressure (MAP) followed a similar trend, showing significant reductions, with office MAP at 105.4 ± 9.8 mmHg and nighttime MAP at 96.5 ± 7.6 mmHg (p = 0.035). Pulse pressure and heart rate showed no significant differences, with pulse pressure showing a slight decrease from office BP (54.4 ± 8.1 mmHg) to nighttime BP (49.5 ± 6.9 mmHg, p = 0.054), and heart rate showing no significant time-related variations (p = 0.062). [Table 2]

Dippers (30%) had a significant nighttime BP reduction of 12.4 ± 1.9 mmHg, with a 24-hour systolic blood pressure (SBP) of 130.4 ± 9.2 mmHg and diastolic blood pressure (DBP) of 77.8 ± 6.5 mmHg, serving as the reference group. Non-Dippers (50%) exhibited a lower nighttime BP reduction of 7.3 ± 1.5 mmHg, with higher 24-hour SBP (137.1 ± 10.8 mmHg) and DBP (83.6 ± 7.1 mmHg), with a statistically significant difference compared to Dippers (p = 0.029). Reverse Dippers (20%) demonstrated a negative nighttime BP reduction (-5.4 ± 1.3 mmHg), with the highest 24-hour SBP (141.2 ± 11.4 mmHg) and DBP (86.5 ± 7.8 mmHg), showing a significant difference from Dippers (p = 0.017). [Table 3]

Individuals with Controlled Hypertension (40%) had the lowest office BP (135.7 ± 8.5/84.3 ± 6.7 mmHg), 24-hour BP (128.5 ± 7.9/77.4 ± 5.8 mmHg), daytime BP (130.8 ± 8.1/79.2 ± 6.0 mmHg), and nighttime BP (126.1 ± 7.6/76.8 ± 5.5 mmHg), serving as the reference group. Masked Hypertension (16.7%) exhibited significantly higher values for 24-hour SBP (140.4 ± 9.3 mmHg) and DBP (87.3 ± 7.0 mmHg) compared to Controlled Hypertension (p = 0.041). White-Coat Hypertension (13.3%) also showed elevated SBP (147.6 ± 9.6 mmHg) and DBP (91.4 ± 7.2 mmHg), with a significant difference (p = 0.037). Sustained Hypertension (30%) had the highest SBP (149.3 ± 9.8 mmHg) and DBP (94.6 ± 7.4 mmHg), with significant differences in 24-hour BP (p = 0.032). [Table 4]

Age showed a significant negative correlation with 24-hour BP (r = -0.342, p = 0.041), while no significant correlations were found with other BP measures. BMI had no significant associations with any BP parameters (p > 0.05). Duration of hypertension was negatively correlated with 24-hour

BP (r = -0.284, p = 0.049) and positively correlated with daytime BP (r = 0.308, p = 0.037), nighttime BP (r = 0.349, p = 0.022), and BP variability (r = 0.267, p = 0.054). Diabetes was positively correlated with 24-hour BP (r = 0.368, p = 0.029), daytime BP (r = 0.324, p = 0.041), nighttime BP (r = 0.402, p = 0.019), and BP variability (r = 0.309, p = 0.045). [Table 5]

Table 1: Demographic and Clinical Characteristics of Participants

Variable	Total (n=120)	Dippers (n=36)	Non-Dippers (n=60)	Reverse Dippers (n=24)	p-value
	Frequency (%)/Mean ± SD				
Age (years)	54.6 ± 10.1	51.2 ± 8.9	55.8 ± 10.3	58.7 ± 9.8	0.045
Gender					
Male	68 (56.7)	20 (55.6)	34 (56.7)	14 (58.3)	0.082
Female	52 (43.3)	16 (44.4)	26 (43.3)	10 (41.7)	
BMI (kg/m²)	27.4 ± 3.6	26.8 ± 3.2	28.1 ± 3.9	26.7 ± 3.3	0.073
Waist-Hip Ratio	0.91 ± 0.04	0.89 ± 0.03	0.92 ± 0.05	0.94 ± 0.03	0.036
Duration of Hypertension (years)	6.8 ± 2.9	5.5 ± 2.6	7.3 ± 3.1	8.1 ± 2.7	0.042
Diabetes	40 (33.3)	8 (22.2)	24 (40.0)	8 (33.3)	0.122
Smoker	24 (20.0)	6 (16.7)	14 (23.3)	4 (16.7)	0.154
Sedentary Physical Activity	72 (60.0)	18 (50.0)	38 (63.3)	16 (66.7)	0.121
Alcohol Consumption	22 (18.3)	6 (16.7)	12 (20.0)	4 (16.7)	0.162

Table 2: Correlation Between Dipping Status and Blood Pressure Measures

Parameter	Office	24-Hour	Daytime	Nighttime	BP Variability	p-value
	Mean ± SD					
Systolic BP (mmHg)	141.7 ± 13.6	134.8 ± 11.2	137.2 ± 11.8	129.6 ± 10.7	12.8 ± 4.3	0.041
Diastolic BP (mmHg)	87.3 ± 8.4	81.7 ± 7.6	83.4 ± 7.8	80.1 ± 6.5	7.9 ± 2.8	0.038
Mean Arterial Pressure (mmHg)	105.4 ± 9.8	99.3 ± 8.4	101.5 ± 8.9	96.5 ± 7.6	9.8 ± 3.4	0.035
Pulse Pressure (mmHg)	54.4 ± 8.1	53.1 ± 7.7	53.9 ± 7.8	49.5 ± 6.9	5.8 ± 1.9	0.054
Heart Rate (bpm)	74.6 ± 8.5	71.8 ± 7.8	73.2 ± 7.9	69.5 ± 6.7	3.9 ± 1.8	0.062

Table 3: Blood Pressure Measurements Across Different Dipping Status Groups

Dipping Pattern	Frequency (%)	Nighttime BP Reduction (%)	24-Hour SBP (mmHg)	24-Hour DBP (mmHg)	p-value
		Mean ± SD			
Dippers	36 (30.0)	12.4 ± 1.9	130.4 ± 9.2	77.8 ± 6.5	Reference
Non-Dippers	60 (50.0)	7.3 ± 1.5	137.1 ± 10.8	83.6 ± 7.1	0.029
Reverse Dippers	24 (20.0)	-5.4 ± 1.3	141.2 ± 11.4	86.5 ± 7.8	0.017

Table 4: Comparison of BP Parameters by Hypertension Type

Hypertension Type	Frequency (%)	Office BP (mmHg)	24-Hour BP (mmHg)	Daytime BP (mmHg)	Nighttime BP (mmHg)	p-value
		Mean ± SD				
Controlled Hypertension	48 (40.0)	135.7 ± 8.5 / 84.3 ± 6.7	128.5 ± 7.9 / 77.4 ± 5.8	130.8 ± 8.1 / 79.2 ± 6.0	126.1 ± 7.6 / 76.8 ± 5.5	Reference
Masked Hypertension	20 (16.7)	134.2 ± 8.1 / 82.6 ± 6.5	140.4 ± 9.3 / 87.3 ± 7.0	142.6 ± 9.8 / 89.1 ± 7.3	138.3 ± 8.9 / 86.5 ± 6.8	0.041
White-Coat Hypertension	16 (13.3)	147.6 ± 9.6 / 91.4 ± 7.2	128.6 ± 8.0 / 77.9 ± 5.9	130.7 ± 8.4 / 79.4 ± 6.1	126.4 ± 7.7 / 77.3 ± 5.6	0.037
Sustained Hypertension	36 (30.0)	149.3 ± 9.8 / 94.6 ± 7.4	141.5 ± 9.5 / 88.1 ± 6.8	143.9 ± 9.9 / 89.8 ± 7.1	139.4 ± 9.2 / 87.6 ± 6.7	0.032

Table 5: Clinical and Demographic Characteristics by Dipping Status

Variable	Dipping Status	24-Hour BP (r, p)	Daytime BP (r, p)	Nighttime BP (r, p)	BP Variability (r, p)
	(Correlation Coefficient r, p-value)				
Age (years)	-0.342 (0.041)	0.261 (0.092)	0.217 (0.128)	0.294 (0.075)	0.212 (0.134)
BMI (Kg/m²)	-0.159 (0.245)	0.127 (0.352)	0.143 (0.308)	0.183 (0.197)	0.225 (0.109)
Duration of Hypertension	-0.284 (0.049)	0.308 (0.037)	0.257 (0.062)	0.349 (0.022)	0.267 (0.054)
Diabetes (Yes)	-0.377 (0.025)	0.368 (0.029)	0.324 (0.041)	0.402 (0.019)	0.309 (0.045)

DISCUSSION

The findings from this study provide valuable insights into the clinical and demographic characteristics of hypertensive individuals based on their dipping patterns and blood pressure variability. In our study, reverse dippers exhibited the oldest age (58.7 ± 9.8 years) compared to dippers (51.2 ± 8.9

years) and non-dippers (55.8 ± 10.3 years), with this difference being statistically significant (p = 0.045). These results align with previous studies, where aging has been shown to influence circadian blood pressure patterns, with older individuals more likely to present with reverse dipping patterns, possibly due to the diminished capacity of the cardiovascular system to maintain normal circadian rhythms as seen in age-related pathophysiological changes.[13,14] The reverse dippers also had a significantly higher waist-to-hip ratio (0.94 ± 0.03), suggesting a link between central obesity and abnormal dipping patterns, which is consistent with research indicating that visceral fat accumulation can impair circadian blood pressure regulation.[15,16]

Duration of hypertension was another key factor affecting dipping patterns. Reverse dippers had the longest hypertension duration (8.1 ± 2.7 years) compared to dippers (5.5 ± 2.6 years) and non-dippers (7.3 ± 3.1 years, p = 0.042). This finding supports previous studies that have highlighted the progressive nature of hypertension, which can lead to vascular remodeling and loss of the normal nocturnal BP dip.[17] The longer the duration of hypertension, the more likely patients are to develop sustained or reverse dipping patterns, which are associated with worse cardiovascular outcomes.[18]

Regarding blood pressure variability, systolic blood pressure exhibited significant fluctuations across the 24-hour period, with a marked decrease during nighttime (p = 0.041). Diastolic blood pressure followed a similar trend (p = 0.038), and mean arterial pressure also showed significant reductions (p = 0.035). These findings are consistent with the physiological notion that BP typically dips during sleep to support vascular repair processes. However, when this dip is blunted or reversed, as seen in reverse dippers, there may be an increased risk for cardiovascular events, as abnormal BP patterns are linked with greater end-organ damage.[19,20] Additionally, pulse pressure and heart rate showed no significant differences in time-related changes, suggesting that while BP variability is influenced by circadian rhythms, other hemodynamic parameters may remain stable.[21]

Our results also revealed that reverse dippers had the highest 24-hour systolic (141.2 ± 11.4 mmHg) and diastolic BP (86.5 ± 7.8 mmHg), in line with previous studies that demonstrate the association between reverse dipping and higher average BP levels.[22] In contrast, dippers exhibited the lowest average BP readings, making them a reference group for comparison. This highlights the importance of monitoring BP throughout the 24-hour cycle, as relying solely on office measurements may miss critical variations, particularly for individuals with reverse dipping patterns, who may appear normotensive during office visits but are at higher cardiovascular risk.[23]

Further analysis of hypertension types revealed significant differences in BP levels between the groups. Those with sustained hypertension had the highest BP levels, particularly in the 24-hour and daytime measurements, which is consistent with findings by who showed that sustained hypertension is often characterized by higher BP throughout the day and night, contributing to a greater risk of cardiovascular complications.[24] Conversely, masked hypertension, where individuals present with normal BP in the clinic but have elevated readings outside the clinical setting, exhibited higher 24-hour BP values than those with controlled hypertension. This underscores the clinical relevance of out-of-office BP measurements for accurate diagnosis and risk stratification.[25]

Our study also revealed significant correlations between demographic factors and BP measurements. Age showed a significant negative correlation with 24-hour BP (r = -0.342, p = 0.041), suggesting that older age may be associated with a lower tendency to exhibit elevated BP across the full 24-hour period. Additionally, duration of hypertension was positively correlated with daytime and nighttime BP and BP variability, indicating that longer exposure to hypertension exacerbates BP fluctuations, a known risk factor for cardiovascular disease.[26] Moreover, diabetes was found to correlate positively with 24-hour and nighttime BP (r = 0.368, p = 0.029), aligning with the established link between diabetes and increased BP variability due to impaired vascular function and autonomic regulation.[27]

CONCLUSION

In conclusion, the results of this study reinforce the importance of monitoring circadian BP patterns in hypertensive patients, especially those with longer hypertension duration, older age, and diabetes, who may be at increased risk for abnormal dipping patterns and associated cardiovascular complications. The findings also support the growing body of evidence suggesting that reverse dipping, characterized by a lack of nocturnal BP reduction, is an important marker of adverse cardiovascular outcomes. Further studies with larger sample sizes are needed to explore the long-term clinical implications of these findings and the potential benefits of personalized treatment strategies that take into account circadian BP patterns.

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