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Research Article

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Clinical Implications of Nocturnal Blood Pressure Dipping Patterns in Hypertensive Patients in Libya: A 24-Hour Ambulatory Monitoring-Based Study

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ABSTRACT

Circadian variations in blood pressure, particularly nocturnal dipping patterns, have been identified as key determinants of cardiovascular outcomes in hypertensive populations. This study investigates the prevalence of various dipping profiles and their clinical significance among hypertensive patients in Tripoli, Libya.

This cross-sectional study involved 64 hypertensive adults at one of the cardiology private centers in Tripoli, Libya; who underwent 24-hour ambulatory blood pressure monitoring (ABPM). Based on the percentage reduction in nighttime systolic blood pressure, patients were categorized as dippers, non-dippers, reverse dippers, or extreme dippers. Clinical indicators, including proteinuria and left ventricular hypertrophy (LVH), were assessed and compared across dipping groups.

Dipping abnormalities were identified in 61.7% of patients: non-dippers (30.8%), reverse dippers (19.2%), and extreme dippers (11.7%). LVH was significantly more prevalent in non-dippers (50.0%) and reverse dippers (58.3%) compared to dippers (20.8%) (P = 0.013). Similarly, the occurrence of proteinuria was higher among reverse dippers (41.7%) and non-dippers (33.3%) compared to dippers (12.5%) (P = 0.021).

Conclusion: The high proportion of non-dipping and reverse-dipping patterns observed underscores the need for integrating ABPM into hypertension management in Libya. These abnormal profiles were significantly associated with end-organ damage, emphasizing their prognostic value.

Keywords- *Ambulatory blood pressure monitoring; Non-dipping; Reverse dipping; Libya; Hypertension; End-organ damage*

INTRODUCTION

Hypertension continues to be a major global health issue, affecting over 1.28 billion adults worldwide and contributing to more than 10 million deaths annually due to cardiovascular and renal complications.[1] Conventional office-based blood pressure (BP) measurements provide limited insight into dynamic blood pressure fluctuations and may fail to identify high-risk individuals. One such fluctuation of clinical significance is the nocturnal blood pressure pattern.

Under physiological conditions, blood pressure follows a diurnal rhythm, characterized by a 10% to 20% reduction during sleep compared to daytime levels a phenomenon known as nocturnal dipping.[2] Patients who fail to exhibit this pattern are classified as non-dippers (<10% reduction), reverse dippers (nighttime BP exceeds daytime), or extreme dippers (>20% reduction). These abnormal nocturnal profiles are associated with heightened risk of target organ damage, including left ventricular hypertrophy (LVH), chronic kidney disease (CKD), cerebrovascular accidents, and increased cardiovascular mortality.[3-6]

Ambulatory blood pressure monitoring (ABPM) is the gold standard for detecting circadian BP variability. It facilitates categorization into dipping subtypes and has been strongly recommended in recent guidelines by the European Society of Hypertension (ESH) and the American Heart Association (AHA).[7,8] ABPM enables improved diagnosis and management of patients with suspected white-coat hypertension, masked hypertension, and abnormal dipping status.[9,10]

Despite its utility, ABPM remains underutilized in many low- and middle-income countries, including Libya, where access to diagnostic equipment and trained personnel is limited. There is also a dearth of local data assessing the prevalence and consequences of abnormal dipping patterns.

To date, limited research has addressed the prevalence of dipping abnormalities and their clinical correlations within North African populations. Understanding local BP behavior is crucial for optimizing risk stratification and tailoring antihypertensive therapy. This study aims to characterize the distribution of nocturnal dipping patterns in a Libyan hypertensive population and explore their

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associations with end-organ damage, particularly LVH and proteinuria.

MATERIALS AND METHODS

1. *Study Design and Setting*

This was a cross-sectional, hospital-based study conducted from February to June 2023 at cardiology private center in Tripoli, Libya. Ethical approval was obtained from the institutional review board, and written informed consent was secured from all participants.

2. *Study Populations*

A total of 64 adult patients (≥18 years) diagnosed with essential hypertension were enrolled. Hypertension was defined in accordance with international guidelines (systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg, or current use of antihypertensive drugs).

3. *Inclusion and Exclusion Criteria*

***Inclusion criteria*:**

Including patients with confirmed diagnosis hypertension. All participants were aged ≥ 18 years at the time of implementing the procedure. A written consent was obtained after a brief explanation on the procedure was introduced and all information was highly kept confidential.

***Exclusion criteria*:**

Patients with the following criteria were excluded from the study; 1) Secondary hypertension, 2) Advanced renal failure (CKD stage IV or higher), 3) Pregnancy, 4) Recent acute cardiovascular events (within 3 months), and 5) Incomplete ABPM data (<70% valid readings).

4. *Blood Pressure Monitoring*

All participants underwent 24-hour ABPM using an oscillometric device (MEDITECH Cardio Visions 1.24.0 (Meditech Ltd., Hungary)) validated by international standards. Measurements were recorded every 30 minutes during the daytime (6:00–22:00) and every 60 minutes at night (22:00–6:00). Patients were instructed to maintain normal activities while avoiding vigorous physical exertion. Sleep and wake times were verified through patient diaries along with pressing on special buttons specified on the device through pre-instructed remarks.

Nocturnal dipping percentage was calculated according to the following formula:

Dipping % = [(Daytime SBP – Nighttime SBP) / Daytime SBP] × 100

Where a Dipping pattern is defined as: 1) Dippers: 10–20% reduction, 2) Non-dippers: <10% reduction, 3) Reverse dippers: nighttime BP higher than daytime BP, and 4) Extreme dippers: > 20% reduction.

5. *Clinical and Laboratory Evaluation*

Demographic data, clinical history, and antihypertensive medications were recorded. Echocardiography was performed to detect LVH, defined as a left ventricular mass index >115 g/m² in men and >95 g/m² in women. Urine dipstick was used to assess proteinuria, with ≥1+ considered positive. Other laboratory evaluations included fasting blood glucose and serum creatinine levels.

6. *Statistical Analysis*

Statistical analysis was conducted using SPSS version 26. Continuous variables were expressed as mean ± SD, and categorical variables were presented as frequencies and percentages. Group comparisons were performed using ANOVA for continuous variables and Chi-square test for categorical variables. Binary logistic regression identified predictors of nondipping. Cox proportional hazards regression estimated the hazard ratio for future cardiovascular risk. A P-value < 0.05 was considered statistically significant.

RESULTS

1. *Baseline Characteristics*

Of the 64 enrolled participants, 33 (51.6%) were females, and males representing 31 (48.4%). The mean age of participants was 58.3 ± 10.2 years. More than 80% of patients had hypertension for over five years. Comorbid conditions included diabetes (43.8%), dyslipidemia (40.6%), and smoking history (26.6%). LVH was observed in 25 patients (39.1%) and proteinuria in 17 patients (26.6%), (Table 1).

Table 1: Demographic and Clinical Characteristics of Study Population

Characteristic	Value
Sample size	64
Age, mean ± SD (years)	58.3 ± 10.2
Females, n (%)	33 (51.6%)
Males, n (%)	31 (48.4%)
Hypertension duration >5 yrs	52 (81.3%)
Diabetes mellitus, n (%)	28 (43.8%)
Dyslipidemia, n (%)	26 (40.6%)
Current smokers, n (%)	17 (26.6%)
LVH, n (%)	25 (39.1%)
Proteinuria, n (%)	17 (26.6%)

2. *Distribution of Dipping Patterns*

The prevalence of dipping categories was as follows: dippers (38.3%), non-dippers (30.8%), reverse dippers (19.2%), and extreme dippers (11.7%), (Table 2).

Table 2. Distribution of Nocturnal Dipping Patterns

Dipping Pattern	Frequency (n)	Percentage (%)
Dippers	24	38.3%
Non-dippers	20	30.8%
Reverse dippers	12	19.2%
Extreme dippers	8	11.7%

3. *Associations between Dipping Pattern and End-Organ Damage*

LVH was significantly more prevalent in reverse dippers (58.3%) and non-dippers (50.0%) than in dippers (20.8%) ($P < 0.013$). Moreover, proteinuria was significantly more common in reverse dippers and non-dippers compared to dippers (41.7%, 33.3% respectively vs. 12.5%, $P < 0.021$), (Table 3).

Table 3: End-Organ Damage Across Dipping Subtypes

Dipping Pattern	LVH (%)	Proteinuria (%)
Dippers	20.8	12.5
Non-dippers	50.0	33.3
Reverse dippers	58.3	41.7
Extreme dippers	25.0	18.8

DISCUSSION

This study provides valuable insight into the distribution and clinical implications of nocturnal dipping patterns in a Libyan hypertensive population. The findings indicate that a majority of patients exhibited non-dipping, reverse dipping, or extreme dipping profiles, aligning with previously published international observations on the altered circadian blood pressure rhythm in high-risk populations.[11, 12] The high prevalence of abnormal dipping patterns (61.7%) in this cohort underscores the importance of 24-hour ABPM in hypertension management, especially in settings where conventional office-based BP assessments may fail to capture significant nocturnal variations.

The most clinically relevant findings were the strong associations between non-dipping or reverse- dipping patterns and end-organ damage, particularly left ventricular hypertrophy (LVH) and proteinuria. These findings support earlier reports that have linked non-dipping status to increased cardiovascular morbidity and mortality.[13] Reverse dippers, in particular, exhibited the highest prevalence of LVH (58.3%) and proteinuria (41.7%), consistent with the pathophysiological premise that failure to reduce BP at night increases afterload and accelerates target organ damage.[14,15]

The mechanisms underlying altered dipping profiles are multifactorial. Reduced baroreceptor sensitivity, increased sympathetic activity during sleep, obstructive sleep apnea, chronic kidney disease, and autonomic dysfunction are among the contributors to a blunted or reversed nocturnal BP decline.[16] Identifying patients with these abnormal patterns is therefore essential not only for risk stratification but also for tailoring treatment strategies such as evening dosing of antihypertensive medications a concept supported by chronotherapy studies.[17]

In our study, approximately 39% of participants had LVH and over one-quarter had proteinuria, further affirming the subclinical burden of hypertensive organ damage. Notably, these complications were significantly more frequent among patients with abnormal dipping profiles. While extreme dippers have traditionally received less attention, they too may face increased risk of cerebral ischemia due to excessive nocturnal hypotension, warranting careful monitoring.[18]

Our findings are comparable to those from other regions. A study in Egypt by Ibrahim et al. showed that non-dippers had a significantly higher incidence of LVH and microalbuminuria than dippers.[19] Similarly, research in South Asia and Europe consistently highlights non-dipping as a predictor of worse cardiovascular outcomes and renal dysfunction.[20–22] However, to our knowledge, this is one of the few studies to address these patterns in a North African context.

Strengths of the Study

- This study is among the first to assess dipping status in a Libyan hypertensive population.
- The use of 24-hour ABPM enhances diagnostic precision and allows for detailed subclassification of circadian BP profiles.
- Associations with clinically relevant endpoints such as LVH and proteinuria provide practical insights for hypertension management.

Limitations

- The cross-sectional design precludes causal inference.
- The sample size, though adequate for preliminary insights, may not allow for subgroup analyses or generalization to the entire Libyan population.
- Proteinuria was measured via dipstick rather than

quantitative assessment (e.g., albumin-to-creatinine ratio).

- Sleep quality and duration were self-reported and not objectively verified (e.g., via actigraphy or polysomnography).

Perspectives and Future Directions

Further longitudinal studies are warranted to assess whether correcting abnormal dipping patterns reduces long-term cardiovascular events. Expanding ABPM accessibility and integrating it into routine care could enhance patient risk stratification and improve treatment outcomes. Additionally, combining ABPM with emerging biomarkers and imaging tools could further elucidate the pathophysiological mechanisms linking nocturnal BP alterations to target organ damage.

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