Increased Retinal Capillary Density in Non-Dipper Hypertensive Patients: A Cross-sectional OCTA Study

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ABSTRACT

Purpose: To investigate the effect of nocturnal blood pressure (BP) patterns on macular microvasculature in patients with newly diagnosed essential hypertension using optical coherence tomography angiography (OCTA).

Methods: This cross-sectional, observational study included 26 patients with newly diagnosed essential hypertension. Based on 24-hour ambulatory blood pressure monitoring (ABPM), patients were classified as "dippers" (≥10% nocturnal systolic BP reduction) or "non-dippers" (<10% reduction). All participants underwent macular OCTA (6×6 mm scan) and echocardiographic assessment. OCTA parameters included foveal avascular zone (FAZ) area, foveal density, and vessel densities in the superficial capillary plexus (SCP) and deep capillary plexus (DCP). Demographic, BP, and OCTA data were compared between groups.

Results: The study included 52 eyes from 26 patients (mean age: 53.8 ± 7.8 years; 17 females). Of these, 10 were dippers and 16 were non-dippers. SCP whole image, inferior, and perifoveal, as well as DCP parafoveal and perifoveal vessel densities, were significantly higher in non-dippers (p-values <0.05). No significant differences were found in FAZ area or foveal density.

Conclusion: Non-dipper patients exhibited increased retinal capillary density in selected macular regions, suggesting early vascular remodeling or venular dilation in response to altered nocturnal BP regulation. OCTA may serve as a non-invasive tool to detect early retinal microvascular changes associated with hypertension.

Keywords: Optical coherence tomography angiography, OCTA, Nocturnal hypertension, Retinal microvasculature, Ambulatory blood pressure monitoring, ABPM

INTRODUCTION

Systemic hypertension has a profound effect on both the function and structure of the microvasculature.[1] Microvascular rarefaction has been identified as a pathological hallmark of hypertension [2] and has been implicated in the pathogenesis of cardiovascular disease[3], stroke, left ventricular dysfunction and nephropathy. [4,5] Because of its role in end-organ damage, microcirculation is increasingly being considered as a therapeutic target.[6] In addition, hypertension is a major risk factor for several sight-threatening ocular diseases such as diabetic retinopathy,[7] age-related macular degeneration[8] and glaucoma.[9]

Despite its clinical importance, in vivo assessment of the microcirculation in patients with hypertension remains technically challenging.[10] The recent development of optical coherence tomography angiography (OCTA)[11] has enabled rapid and non-invasive visualization of the retinal and choroidal microvasculature and has been increasingly used in the assessment of diseases such as glaucoma[12] and diabetic retinopathy.[13] OCTA allows assessment of

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microvascular perfusion at the capillary level, potentially detecting early ischemic or hypoxic changes before changes in larger vessels are apparent.

Ambulatory blood pressure monitoring (ABPM) enables continuous 24-hour blood pressure (BP) measurement, including physiological diurnal variations. Nocturnal BP in normotensive people is usually 10-20% lower than daytime BP - a so-called "dipping pattern". On the other hand, a nocturnal fall of <10% (non-dippers) or >20% (extreme dippers), is an atypical pattern. [14,15] Although office BP measurement remains the cornerstone of diagnosis, ABPM has been associated with higher correlations with target organ damage due to hypertension. [16] Non-dipper status has also been associated with higher cardiovascular morbidity and more widespread target organ damage. [17]

In this study, we aimed to investigate the effect of nocturnal hypertension on macular microvascular parameters in patients with newly diagnosed essential hypertension using OCTA.

MATERIALS AND METHODS

This cross-sectional observational study included patients with newly diagnosed essential hypertension who presented to the Departments of Ophthalmology and Cardiology at Gazi University Faculty of Medicine between February 2022 and February 2023. Ethical approval was obtained from the institutional ethics committee (No: 2025-838), and all participants provided informed consent in accordance with the Declaration of Helsinki.

Patients underwent 24-hour ABPM to determine their circadian BP profile. Those with a nocturnal systolic BP reduction of ≥10% compared to daytime values were classified as "dippers," while those with a reduction of <10% were categorized as "non-dippers." Patients with hypertensive retinopathy, history of ocular surgery, diabetes mellitus, media opacities, or other ocular or systemic diseases affecting the microvasculature were excluded.

All participants received a complete ophthalmologic examination, and a 6×6 mm macular scan using OCTA (AngioVue, Optovue Inc., Fremont, CA, USA) was obtained. OCTA parameters included foveal avascular zone (FAZ) area, foveal density, and vessel densities in the superficial capillary plexus (SCP) and deep capillary plexus (DCP), reported for the whole image, parafoveal, perifoveal, superior, and inferior sectors.

Demographic characteristics (age, gender), smoking status, and echocardiographic parameters—left ventricular ejection fraction (LVEF) and left ventricular mass index (LVMI)—were recorded. BP parameters from ABPM were documented for 24-hour, daytime, and nighttime periods. The percentage of nocturnal decline in systolic and diastolic BP was calculated.

Statistical Analyses

Categorical variables were compared using the chi-square test. Continuous variables, including OCTA parameters, BP values, and echocardiographic data, were analyzed using the independent samples t-test. A p-value <0.05 was considered statistically significant. Statistical analyses were conducted using SPSS (version 22, IBM Corp., Armonk, NY, USA).

RESULTS

A total of 52 eyes from 26 patients with newly diagnosed essential hypertension were included in the study. Of these, 17 were female and 9 were male. Based on 24-hour ABPM, 10 patients (38.5%) were classified as dippers and 16 patients (61.5%) as non-dippers. The mean age of the study population was 53.8 ± 7.8 years, with no significant difference between groups (p = 0.623).

Baseline demographic and clinical characteristics are summarized in **Table 1**. Smoking prevalence was significantly higher in the dipper group (70%) compared to non-dippers (18.8%) (p = 0.015). There were no significant intergroup differences in 24-hour, daytime, or nighttime systolic and diastolic BP values. However, systolic nocturnal decline was significantly lower in the non-dipper group (6.09 ± 5.9%) compared to dippers (11.73 ± 5.05%, p = 0.020). Left ventricular mass index and ejection fraction were similar between groups.

The comparison of OCTA parameters is provided in **Table 2**. The non-dipper group demonstrated significantly higher vessel densities in several regions of the SCP and DCP. Specifically, SCP whole image (p = 0.026), SCP inferior (p = 0.010), SCP perifoveal (p = 0.019), DCP parafoveal (p = 0.017), and DCP perifoveal (p = 0.048) vessel densities were significantly greater in non-dippers. No significant differences were observed in FAZ area or foveal density.

Table 1. *Baseline characteristics of the study population*

	Dipper (n=10)	Non-Dipper (n=16)	P value
Age (years, mean±SD)	52.10±8.6	54.80±8.6	0.623
Sex (F/M)	5/5	12/4	0.234
Smoking status (%)	7 (%70)	3 (%18.8)	**0.015**
24-hour SBP (mmHg, mean±SD)	138.80±13.18	136.56±14.47	0.695
24-hour DBP (mmHg, mean±SD)	83.10±6.87	79.94±10.93	0.422
Daytime SBP (mmHg, mean±SD)	144.20±13.83	138.81±14.23	0.352
Daytime DBP (mmHg, mean±SD)	86.80±6.73	82.44±11.03	0.273
Nighttime SBP (mmHg, mean±SD)	124.20±11.68	131.56±16.67	0.235
Nighttime DBP (mmHg, mean±SD)	75.00±8.79	74.56±11.70	0.920
SBP Nocturnal Decline (%)	11.73±5.05	6.09±5.9	**0.020**
DBP Nocturnal Decline (%)	13.70±7.4	9.4±7.4	0.174
Ejection Fraction	64.20±3.99	64.93±5.57	0.720
Left Ventricular Mass Index	95.26±23.04	92.05±23.81	0.738

SD: standard deviation, F: female, M: male, SBP: systolic blood pressure, DBP: diastolic blood pressure

Table 2: *Comparison of OCTA parameters between dippers and non-dippers*

	Dipper	Non-Dipper	P value
FAZ area (mm², mean±SD)	0.3±0.08	0.28±0.11	0.620
Foveal density (%, mean±SD)	52.31±6.4	53.02±5.16	0.664
SCP (%, mean±SD)			
Whole image	46.31±3.09	48.58±3.7	**0.026**
Superior	46.63±3.12	48.53±4.04	0.079
Inferior	46.01±3.4	48.64±3.47	**0.010**
Parafoveal	49.92±3.16	51.02±4.44	0.336
Perifoveal	46.76±3.45	49.42±4.08	**0.019**
DCP (%, mean±SD)			
Whole image	43.87±4.93	46.4±5.54	0.102
Superior	44.1±5.6	46.75±5.78	0.109
Inferior	43.66±4.52	46.09±5.5	0.104
Parafoveal	49.87±3.91	52.72±4.11	**0.017**
Perifoveal	44.9±5.73	48.22±5.74	**0.048**

SCP: Superficial capillary plexus vessel density, DCP: Deep capillary plexus vessel density

DISCUSSION

This study investigated the impact of nocturnal BP patterns on macular microvasculature in patients with newly diagnosed essential hypertension. We observed that non-dipper patients exhibited significantly higher vessel densities in specific regions of both the SCP and DCP compared to dipper patients. These findings suggest that a diminished nocturnal decline in BP may be associated with alterations in retinal microvascular architecture.

These findings align with previous research indicating that alterations in nocturnal BP patterns can influence retinal microvascular structures. [18-20] For instance, Nolde et al. reported that a less pronounced nocturnal dip in BP was associated with increased capillary vascular density in the central foveal area of hypertensive patient. [18] Similarly, Chua et al. demonstrated that hypertensive individuals with poor BP control exhibited reduced retinal capillary densities, suggesting that nocturnal BP variations may contribute to microvascular changes. [19,20]

Interestingly, our results contrast with the dominant trend in existing literature, which often reports reduced capillary density in non-dippers. [18-21] In our cohort—comprising newly diagnosed hypertensive individuals—non-dippers demonstrated increased retinal vessel density in the SCP and DCP. This divergence might be attributable to early compensatory vascular remodeling, potentially driven by sustained nocturnal perfusion pressure. Such changes could precede eventual rarefaction observed in more advanced or chronic hypertension. Alternatively, venular dilation and microvascular stasis—rather than rarefaction—may explain the elevated vessel density in early hypertensive states.

The clinical implications of our findings underscore the importance of monitoring nocturnal BP patterns in hypertensive patients. Identifying individuals with a non-dipping profile may facilitate early detection of microvascular changes, allowing for timely intervention to prevent progression to hypertensive retinopathy and other organ damage.

Our study has certain limitations, including a relatively small sample size and its cross-sectional design, which precludes establishing causality. Future longitudinal studies with larger cohorts are warranted to elucidate the temporal relationship between nocturnal BP patterns and retinal microvascular changes.

In conclusion, our findings suggest that a non-dipping nocturnal BP pattern in newly diagnosed hypertensive patients is associated with increased retinal capillary density in specific macular regions. These results highlight the potential role of OCTA as a non-invasive tool for detecting early microvascular alterations related to hypertension and emphasize the need for comprehensive BP monitoring, including nocturnal measurements, in the management of hypertensive patients.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author Contributions: HBÖ and MC contributed to the conception and design of the study. Data acquisition was performed by BAY, İA, MO, MC and HBÖ. Data analysis was carried out by MO and HBÖ. Data interpretation was performed by HBÖ, BAY and MC. The manuscript was drafted by HBÖ. All authors contributed to the critical revision of the manuscript and approved the final version for submission. All authors have read and agreed to the published version of the manuscript.

Ethical Approval: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of Gazi University Faculty of Medicine (protocol number: 2025-838).

Competing Interests: The authors declare no competing interests.

Informed Consent: Written informed consent was obtained from all participants prior to inclusion in the study.

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