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# Microvascular Changes in Primary Open-Angle Glaucoma Associated with Hypertension: A Prospective OCT-Angiography Analysis

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## ABSTRACT

**Background**: Primary open-angle glaucoma (POAG) is a progressive optic neuropathy associated with visual field loss and optic disc cupping. Although elevated intraocular pressure is the primary risk factor, the contribution of systemic arterial hypertension (HTN) remains uncertain. Optical coherence tomography angiography (OCT-A) enables non-invasive evaluation of retinal and peripapillary microvasculature. This study investigated the association between systemic hypertension and microvascular alterations in POAG using OCT-A.

**Methods:** This prospective observational cohort study was conducted in a tertiary eye care setting and included 40 eyes from 40 adults with confirmed POAG receiving topical anti-glaucoma therapy. Participants were grouped as hypertensive (n=20) or normotensive (n=20). OCT-A imaging was performed using the Cirrus 5000 HD-OCT with Angioplex. Macular and peripapillary vessel density of the superficial and deep retinal capillary plexuses was quantified from 6×6 mm scans. Only high-quality images (signal strength ≥7/10, no motion or segmentation artifacts) were analyzed to minimize measurement bias. Additional assessments included visual field testing, retinal nerve fiber layer thickness, and cup-to-disc ratio. Group comparisons and correlation analyses were performed, with statistical significance set at $p<0.05$.

**Results:** Hypertensive POAG patients demonstrated significantly lower macular and peripapillary vessel density compared with normotensive patients ($p<0.05$). In the hypertensive group, reduced vessel density was associated with progressive visual field deterioration and increased cup-to-disc ratio. These associations were less pronounced among normotensive patients.

**Conclusion:** Systemic hypertension is associated with greater microvascular compromise in POAG, supporting a vascular contribution to glaucoma progression and highlighting the importance of blood pressure control in glaucoma management.

**Keywords**: Primary open-angle glaucoma; hypertension; OCT-Angiography; microvasculature; vessel density; retinal circulation.



**How to cite this article**

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## INTRODUCTION

Primary open-angle glaucoma (POAG), a chronically progressive neuropathy of the optic nerve marked by retinal ganglion-cell loss and characteristic cupping of the optic disc. Although elevated intraocular pressure (IOP) is the principal modifiable risk factor, glaucomatous damage can develop in eyes with normotensive IOP levels, implicating additional systemic and vascular contributors to disease pathogenesis [1,2]

Hypertension (HTN), a common systemic condition, has been investigated as a possible contributor to glaucomatous damage. However, the relationship between systemic blood pressure and glaucoma remains controversial (3). Some studies suggest that elevated blood pressure may increase IOP via impaired aqueous humor drainage, while others argue that nocturnal hypotension and vascular dysregulation may reduce optic nerve head perfusion, contributing to glaucomatous damage.

Optical coherence tomography angiography (OCT-A) is a robust, non-invasive imaging modality that affords high-resolution visualization of the retinal and peripapillary microvasculature without the administration of contrast agents.[4,5] In addition, its capacity to quantify vessel density provides critical insights into the microvascular alterations potentially associated with POAG.[6]

This study aims to evaluate the impact of systemic hypertension on retinal and peripapillary microvasculature in POAG patients using OCT-A, and to explore the role of systemic blood pressure in glaucoma progression.

## MATERIALS AND METHODS

### *Study Design and Participants*

A prospective analytical investigation was undertaken in the Department of Ophthalmology B, Ibn Sina University Hospital, Rabat, Morocco, between February 2022 and February 2023. Patients were recruited consecutively from the glaucoma outpatient clinic during routine follow-up visits. Forty patients with a confirmed diagnosis of POAG who met the inclusion criteria were enrolled and divided into two groups: 20 patients with systemic hypertension (HTN group) and 20 normotensive patients (NT group). All participants were under topical anti-glaucoma treatment and had stable systemic status. All participants were under topical anti-glaucoma treatment and had stable systemic status. Comprehensive written informed consent was obtained from all participants during the elaboration of this study. In addition, our study complies with the Declaration of Helsinki and has received ethical agreement from our institution.

### *Inclusion Criteria*

- Diagnosis of POAG confirmed by optic disc changes and visual field defects.
- Age ≥ 40 years.
- For the HTN group: controlled systemic hypertension under treatment.
- Ability to undergo regular follow-up and OCT-A imaging.

### *Exclusion Criteria*

- Secondary glaucoma or angle-closure glaucoma.
- High myopia, media opacities, or poor OCT-A image quality.
- History of ocular surgery or systemic comorbidities (diabetes, heart failure, autoimmune disease).
- Changes in antihypertensive or glaucoma medications during follow-up.

### *Ophthalmic Evaluation*

At starting point and at three-month intervals, all participants underwent a thorough ophthalmological evaluation comprising:

- Best-corrected visual acuity (BCVA).
- Slit-lamp biomicroscopy.
- IOP measurement with Goldmann applanation tonometry (average of 3 readings).
- Gonioscopy using a Goldmann three-mirror lens.
- Fundus examination with +90D lens for C/D ratio assessment.
- Visual field testing (Humphrey Visual Field Analyzer 24-2, SITA Fast).
- OCT (Zeiss Cirrus 5000 HD-OCT) to assess RNFL and ganglion cell complex.



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### *OCT-Angiography Protocol*

OCT-A examinations were conducted at three-month intervals using the Cirrus 5000 HD-OCT system (Carl Zeiss Meditec) equipped with the Angioplex module (Figure 1). This platform applies the Optical Microangiography (OMAG) algorithm to interrogate both superficial and deep vascular plexuses in the peripapillary and macular regions.

Scans with a signal strength index (SSI) < 6 or with segmentation errors/artifacts were excluded. Vessel density (VD) was calculated in standardized 6x6 mm areas centered on the macula and optic nerve head.

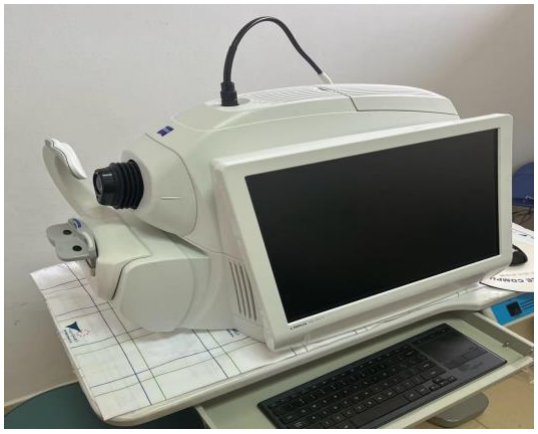

**Figure 1. Cirrus 5000 HD-OCT avec Angioplex (Carl Zeiss Meditec, Dublin, CA, Etats Unis)**

### *Statistical Analysis*

All statistical analyses were performed using IBM SPSS Statistics version 20. Continuous variables were summarized as medians with interquartile ranges, while categorical variables were expressed as absolute numbers and percentages. The Kolmogorov–Smirnov test was used to assess the normality of data distributions. Comparisons between groups were carried out with the Mann–Whitney U test for continuous variables and the Chi-square ($\chi^2$) test for categorical variables. A p-value <0.05 (two-tailed) was considered statistically significant.

## RESULTS

### *Study Population*

A total of 40 patients with primary open-angle glaucoma (POAG) were included in this study: 20 with systemic hypertension (HTN group) and 20 without (normotensive, NT group). The mean age was similar between groups (HTN: 63.4 ± 6.8 years; NT: 62.1 ± 7.3 years), and sex distribution was also comparable, with females accounting for 55% of the HTN group and 50% of the NT group.

### *Antiglaucoma and Antihypertensive Treatment*

All patients were receiving topical antiglaucoma therapy throughout the study period. The most frequently used medications were beta-blockers (75%), prostaglandin analogs (45%), and carbonic anhydrase inhibitors (35%). Combination therapy was more common in the HTN group due to higher baseline IOP. Systemic antihypertensive regimens included beta-blockers (50%), ACE inhibitors (30%), and ARBs (20%). All hypertensive patients had well-controlled blood pressure during the follow-up.

### *Ophthalmic Examination Findings*

Slit lamp and fundus examinations were similar between groups. Gonioscopy revealed open iridocorneal angles. However, at baseline, mean intraocular pressure (IOP) was higher in the HTN group (16.1 ± 1.4 mmHg) compared to the NT group (14.7 ± 1.2 mmHg), though within normal limits under similar medical treatment. The mean vertical cup-to-disc (C/D) ratio was significantly higher in the HTN group (0.74 ± 0.08 vs 0.68 ± 0.07; $p < 0.05$), more rim thinning, and peripapillary atrophy, reflecting more advanced glaucomatous optic nerve head damage (Figure 2).



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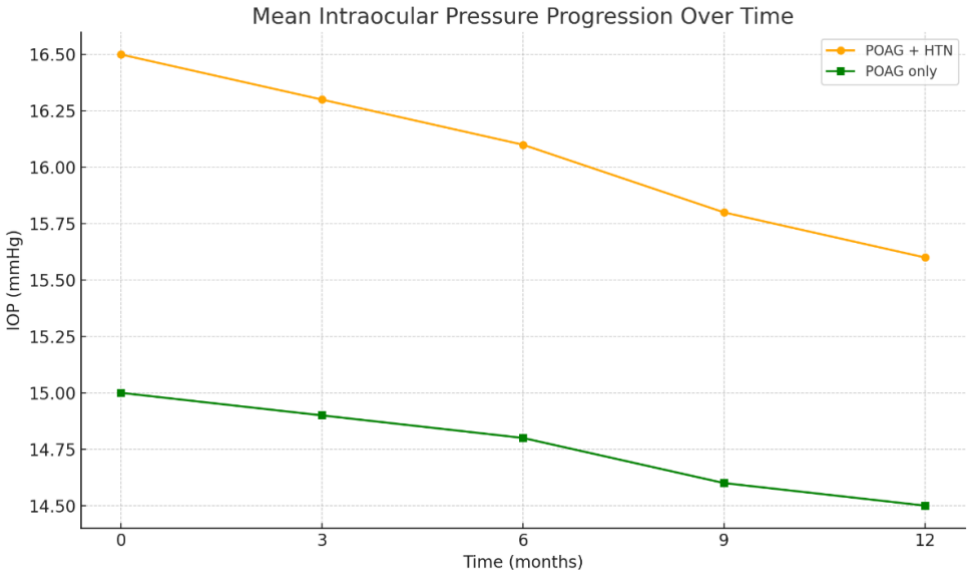


**Figure 2. Mean intraocular pressure progression over 12 months in POAG patients with and without systemic hypertension.**

***Visual Function***

Best-corrected visual acuity (BCVA) remained relatively stable in both groups over the follow-up period, with a slight decrease observed in the HTN group, though not statistically significant. However, visual field progression, assessed through automated perimetry (Humphrey 24-2, SITA Fast strategy) showed a statistically significant deterioration in the HTN group. The mean deviation (MD) was -5.6 ± 1.2 dB in hypertensive patients compared to -4.2 ± 1.0 dB in normotensive patients ($p < 0.05$), suggesting that systemic hypertension may contribute to faster functional decline.

***Retinal Structural Analysis by OCT***

- **RNFL Thickness**

The average retinal nerve fiber layer (RNFL) thickness was lower in the HTN group (76.4 ± 8.5 μm) compared to the non-HTN group (82.1 ± 7.2 μm), indicating more pronounced structural damage ($p < 0.05$). The most affected quadrants were the superior and inferior sectors, which are classically vulnerable to glaucomatous loss.

- **Ganglion Cell Complex (GCC) Thickness**

Similarly, the ganglion cell complex (GCC) thickness was significantly reduced in hypertensive patients (72.3 ± 6.4 μm) compared to non-hypertensive ones (78.9 ± 5.9 μm, $p < 0.05$), underscoring more severe inner retinal degeneration in the HTN group.

**Microvascular Evaluation by OCT-Angiography**

- **Global Vessel Density Comparison**

Optical coherence tomography angiography (OCT-A) analysis revealed a significant reduction in retinal and peripapillary vessel densities in hypertensive POAG patients (Table 1 & Figure 3).

**Table 1: comparative analysis between POAG + HTN and POAG only**

| Microvascular Parameter | POAG + HTN | POAG only | p-value |
|---|---|---|---|
| Peripapillary vessel density (%) | 48.1 ± 3.6 | 52.6 ± 4.2 | < 0.01 |
| Intradisc vessel density (%) | 44.3 ± 3.2 | 48.9 ± 3.5 | < 0.05 |
| Parafoveal VD – superficial plexus (%) | 49.7 ± 3.5 | 54.2 ± 3.6 | < 0.01 |
| Parafoveal VD – deep plexus (%) | 51.2 ± 3.7 | 56.4 ± 3.9 | < 0.01 |

These differences were statistically significant and suggest a direct association between systemic hypertension and decreased microvascular perfusion.



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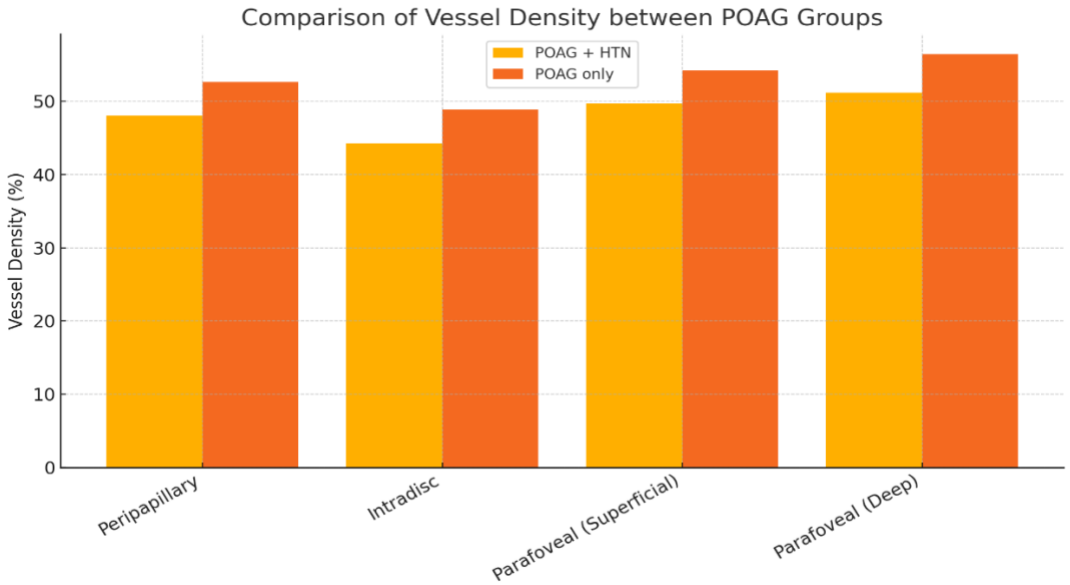



**Figure 3. Comparison of vessel density between POAG groups.**

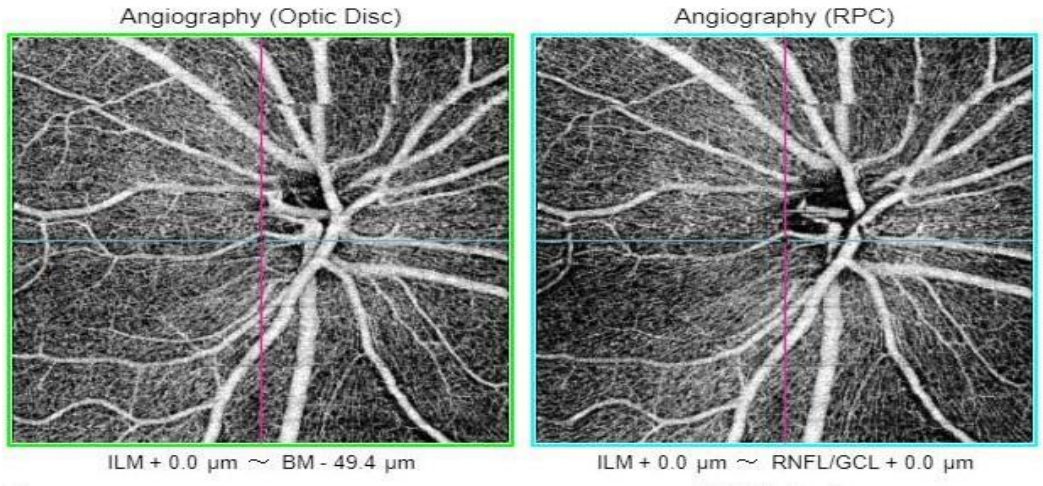
- **Sectoral Vessel Density Analysis**

A detailed analysis of vessel density by peripapillary quadrant demonstrated that the superior and inferior sectors were most vulnerable to microvascular compromise, especially in hypertensive patients (Table 2).

**Table 2: A detailed analysis of vessel density by peripapillary quadrant.**

| Quadrant | POAG + HTN (%) | POAG only (%) | p-value |
|---|---|---|---|
| Superior | 46.2 ± 3.3 | 50.1 ± 3.5 | < 0.01 |
| Inferior | 45.4 ± 3.1 | 49.6 ± 3.4 | < 0.01 |
| Nasal | 49.5 ± 2.8 | 52.7 ± 3.2 | < 0.05 |
| Temporal | 51.2 ± 3.0 | 53.1 ± 3.3 | NS |

This sectoral pattern is consistent with the known topography of glaucomatous damage and may be aggravated by impaired autoregulation of optic nerve head perfusion in hypertensive patients.



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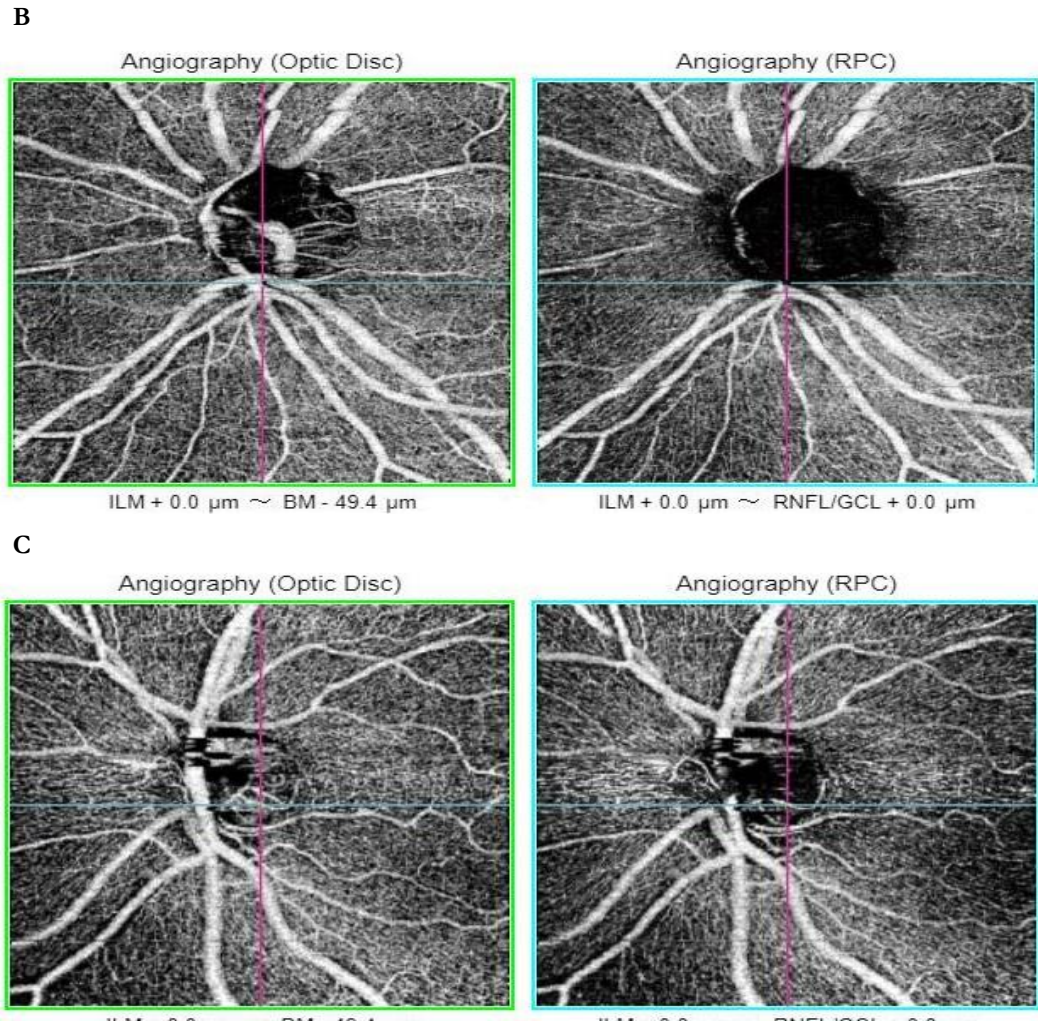


**Figure 4.** OCT-Angiography findings: Optic disc and radial peripapillary capillary (RPC) angiography across groups. (A) Normal subject showing intact optic disc and RPC perfusion. (B) POAG without hypertension showing early capillary dropout. (C) POAG with systemic hypertension demonstrating advanced microvascular attenuation.



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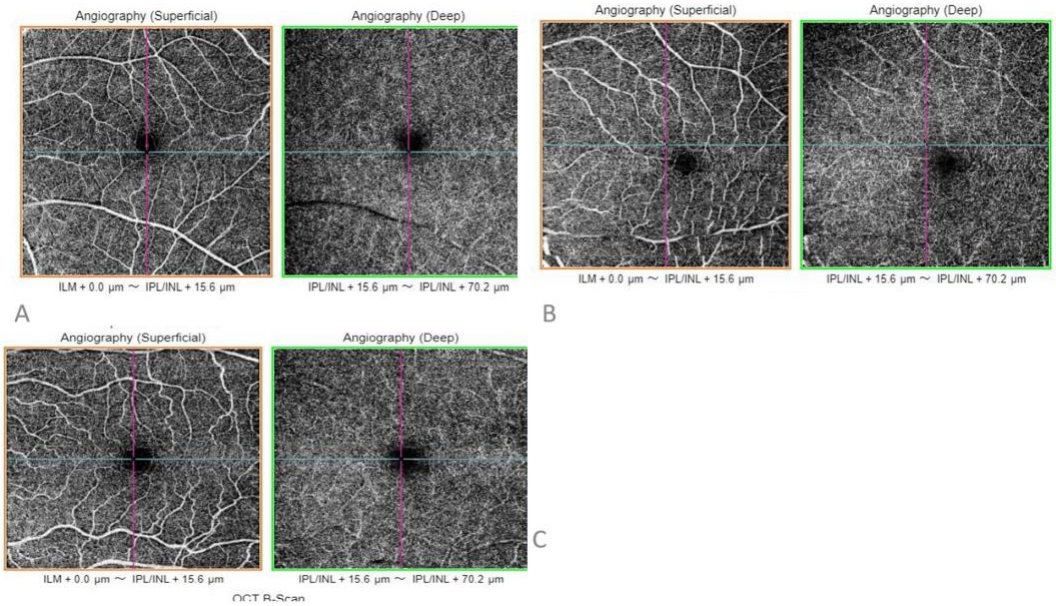
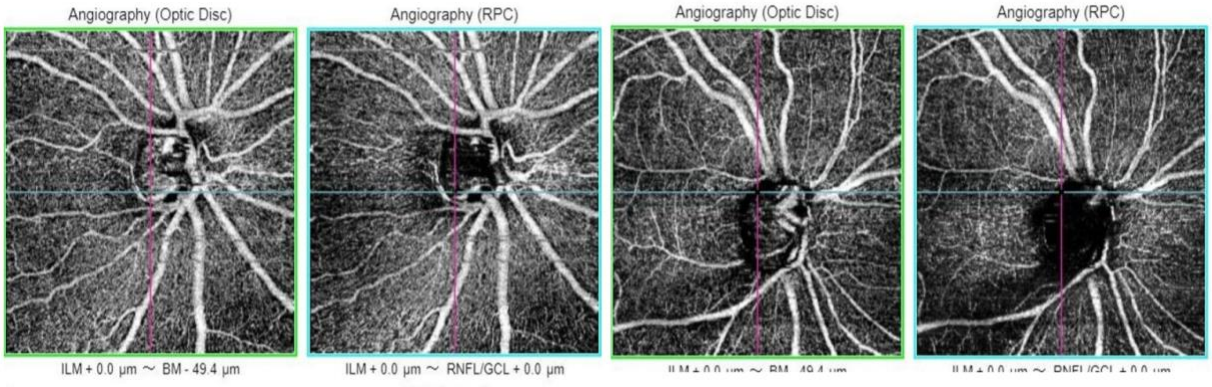



**Figure 5. Macular angiography at superficial and deep plexus levels. Comparative OCT-A views of macular superficial and deep capillary plexuses in (A) normal, (B) POAG, and (C) POAG + HTN patients. Deep capillary loss is more evident in hypertensive eyes.**

**Figure 6. Comparative angiographic patterns in POAG with and without hypertension. Side-by-side examples**




**of optic disc and RPC angiography highlighting microvascular differences related to systemic hypertension.**

- **Longitudinal Evolution of Vessel Density**

Longitudinal follow-up at 3, 6, 9, and 12 months demonstrated a **progressive decrease in vessel density** in the HTN group, particularly in the peripapillary region. This progressive vessel density reduction showed a strong correlation with increasing C/D ratio and worsening visual field metrics, implying a possible link between systemic blood pressure and glaucomatous progression (Figure 7).



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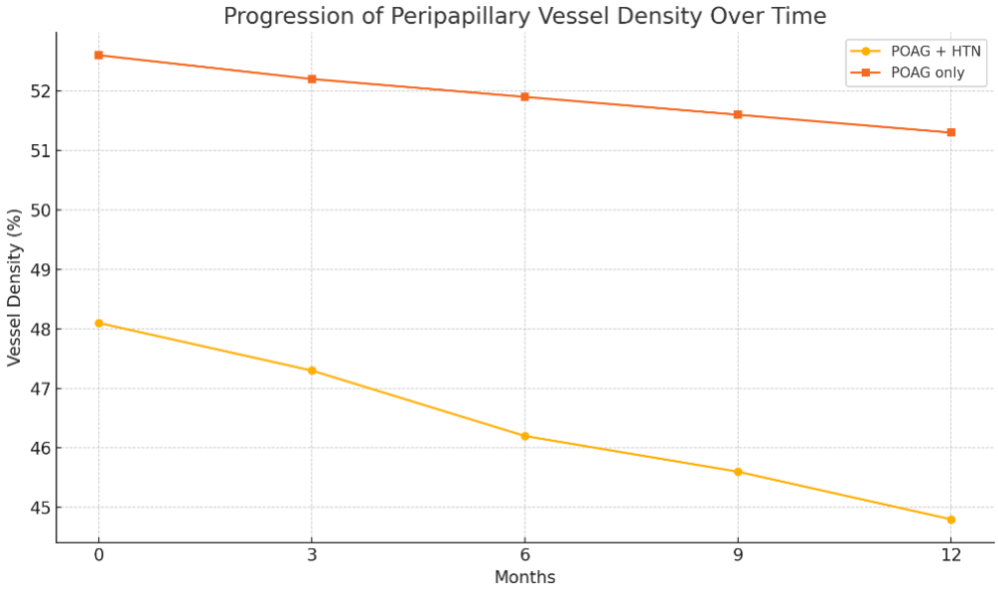


**Figure 7. Progression of Peripapillary vessel density over time.**

## DISCUSSION

In this prospective OCT-A-based study, we observed a significant reduction in peripapillary and macular vessel density among POAG patients with systemic hypertension compared to normotensive counterparts. These findings reinforce the hypothesis that vascular factors — particularly systemic blood pressure — may influence glaucomatous damage beyond intraocular pressure (IOP) alone.[7]

### *Hypertension and Microvascular Damage in Glaucoma*

Systemic hypertension is known to cause vascular remodeling and endothelial dysfunction, which may compromise ocular blood flow.[8] Our results showed lower vessel density in both the superficial and deep retinal plexuses among hypertensive POAG patients, consistent with previous OCT-A studies suggesting capillary dropout in glaucomatous eyes with comorbid hypertension. These microvascular changes could impair perfusion to the optic nerve head and retina, exacerbating neurodegeneration.[5]

### *Peripapillary and Intradisc Vessel Density*

The most pronounced differences were observed in the peripapillary and intradisc regions, where vascular support is critical to ganglion cell axons. Reduced vessel density in these areas correlated with increased cup-to-disc (C/D) ratios and visual field deterioration in the hypertensive group, suggesting that impaired microcirculation may accelerate structural and functional glaucomatous progression.[9,10]

### *OCT-A as a Biomarker Tool*

Our findings support the use of OCT-A as a valuable tool for detecting early vascular changes in POAG. Unlike structural OCT, OCT-A provides dynamic information about tissue perfusion without contrast injection. Progressive decline in vessel density in hypertensive patients may offer a potential biomarker for disease monitoring and treatment adaptation.

### Study Strengths and Limitations

This study has certain limitations. The relatively small sample size and single-center recruitment may limit the generalizability of the findings. In addition, OCT-A measurements are inherently influenced by image quality, motion artifacts, and segmentation errors, which could affect the accuracy of vessel density analysis. Finally, blood pressure fluctuations were not continuously monitored, and only patients with controlled hypertension were included, which may not fully capture the vascular impact of uncontrolled systemic hypertension.

Further multicenter studies with larger cohorts and 24-hour ambulatory BP monitoring are warranted to better



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delineate the interplay between systemic hypertension and ocular microcirculation.

**Implications of the findings**

The findings of this study carry several implications. From a clinical practice perspective, they highlight the importance of integrating systemic vascular assessment into the routine management of glaucoma, particularly in patients with coexisting hypertension. Regular OCT-A monitoring may help identify early microvascular compromise, allowing clinicians to tailor follow-up intensity and consider adjunctive strategies beyond IOP lowering alone.

In terms of policy, the results suggest a need for closer collaboration between ophthalmologists, internists, and cardiologists to ensure optimal systemic blood pressure control in glaucoma patients. Developing shared care guidelines that address both ocular and systemic vascular health could help mitigate the cumulative risk of visual disability.

## CONCLUSION

The present study underscores the deleterious influence of systemic arterial hypertension on the retinal and optic-nerve microvasculature in individuals with primary open-angle glaucoma. Optical coherence tomography angiography disclosed markedly reduced vessel density in hypertensive participants; particularly within the peripapillary and macular regions; and documented a progressive decline in microvascular perfusion over time. These findings suggest that vascular dysregulation related to hypertension may contribute to glaucoma progression, underscoring the importance of comprehensive systemic management alongside intraocular pressure control.

**Conflicts of interest**

Authors declare that they have no conflict of interest.

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