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Correlation between Hypertensive Retinopathy Stages and Left Ventricular Remodeling in Chronic Hypertensive Patients: A Cross-Sectional Study

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ABSTRACT

Background: Hypertensive retinopathy (HR) and retinal arteriosclerosis are established markers of microvascular damage in chronic hypertension, yet their role as independent predictors of left ventricular (LV) remodeling remains underexplored.
Objective: This study investigated the systemic cardiovascular implications of HR and arteriosclerosis by correlating their severity with echocardiographic and electrocardiographic indices of LV structural and functional adaptation.
Patients and Methods: In this cross-sectional analysis, 87 adults with chronic hypertension underwent comprehensive ophthalmologic evaluation (HR staged 0–4 via Scheie classification; arteriosclerosis graded 0–4), 2D/3D echocardiography, and electrocardiogram (ECG). Multivariate regression adjusted for age, sex, BMI, and hypertension duration was used to assess independent associations.
Results: Advanced HR stages (3–4) demonstrated a dose-dependent relationship with concentric LV remodeling (p<0.001) and elevated left ventricular mass index (LVMI) (>95 g/m²; Stage 4: 112±18 vs. Stage 0: 85±12, p<0.001). Eccentric hypertrophy prevalence escalated from 5% (Stage 0) to 38% (Stage 4), paralleling prolonged hypertension duration (p=0.002). Retinal arteriosclerosis mirrored these trends, with Stage 4 linked to LVMI=118±20 g/m² (vs. Stage 0: 85±12, p<0.001) and concentric remodeling (p<0.001). ECG- Left ventricular hypertrophy (LVH) prevalence rose from 15% (Stage 0) to 85% (Stage 4, p<0.001), reinforcing the systemic nature of hypertensive injury.
Conclusion: Hypertensive retinopathy and arteriosclerosis are independent, dose-dependent predictors of adverse LV remodeling, reflecting shared pathways of microvascular and macrovascular dysfunction. These findings advocate for integrating retinal screening into routine hypertensive care to stratify cardiac risk and guide early therapeutic intervention, particularly in patients with advanced retinopathy (Stage 3–4) or arteriosclerosis.
Keywords: Hypertensive retinopathy, left ventricular remodeling, arteriosclerosis, echocardiography, systemic hypertension.

INTRODUCTION

Hypertension (HTN) is a major global health problem, contributing significantly to cardiovascular morbimortality [1].

Chronic hypertension often leads to left ventricular (LV) remodeling, a key predictor of adverse outcomes such as heart failure (HF) and arrhythmias [2]. While traditional risk factors like age, blood pressure (BP), and body mass index (BMI) are well-studied, the role of microvascular damage in LV remodeling remains underexplored [3, 4].

Hypertensive retinopathy (HR) and retinal arteriosclerosis are established markers of microvascular injury in hypertension, reflecting systemic vascular dysfunction [5].

These retinal changes are thought to parallel cardiac damage, yet their independent predictive value for LV remodeling is not fully understood [6]. This study investigated the association between HR, retinal arteriosclerosis, and echocardiographic/electrocardiographic indices of LV remodeling, aiming to highlight their role as early indicators of cardiac risk.

PATIENTS AND METHODS

Study Design and Population:

This cross-sectional study was conducted at Suez Canal University Hospital and Al Ahrar Teaching Hospital, Egypt, from March 2024 to February 2025. The study included 87 adults with chronic hypertension (≥5 years duration). Patients with diabetes, renal failure (serum creatinine >1.5 mg/dL), or secondary hypertension were excluded to ensure a homogeneous study population and minimize confounding factors.

Assessments

1. **Hypertensive Retinopathy (HR):** HR was staged from 0 to 4 using fundoscopy based on the Scheie classification [7]
2. **Retinal Arteriosclerosis:** Graded from 0 to 4 according to retinal arteriolar changes, including light reflex broadening and copper/silver wiring.
3. **Echocardiography:** Left ventricular mass index (LVMI) was calculated using the Devereux formula, and relative wall thickness (RWT) was measured to determine LV remodeling patterns (concentric or eccentric) in accordance with the American Society of Echocardiography (ASE) guidelines [6].

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4. **Electrocardiography (ECG):** LVH was defined using the Sokolow-Lyon criteria.

Ethical consideration:

The current study was approved by the institutional review board, Faculty of Medicine, Suez canal University and was carried out according to the Declaration of Helsinki. Written informed consent was obtained from the included subjects. Confidentially was respected at all levels.

Statistical Analysis:

Data were analyzed using SPSS version 28. Continuous variables were expressed as mean ± standard deviation (SD) and compared using ANOVA, while categorical variables were presented as percentages and analyzed using the chi-square test. Multivariate logistic regression was performed to adjust for potential confounders, including age, sex, and duration of hypertension. P-value less than 0.05 was considered statistically significant.

RESULTS

The study cohort comprised 87 adults with chronic hypertension, with a mean age of 58.4 ± 8.2 years. Males represented 55.2% (n=48) of the participants, while females accounted for 44.8% (n=39). The mean duration of hypertension was 9.3 ± 3.1 years, indicating a population with long-standing disease. The prevalence of hypertensive retinopathy (HR) varied across stages, with 18.4% (n=16) of participants showing no signs of HR (Stage 0), while 29.9% (n=26) had advanced HR (Stages 3–4). Similarly, retinal arteriosclerosis (AS) was graded, with 20.7% (n=18) exhibiting no arteriosclerotic changes (Grade 0) and 25.3% (n=22) demonstrating advanced AS (Grades 3–4).

Hypertensive retinopathy (HR) severity correlated strongly with LV structural changes **(Table 1)**. LV mass index (LVMI) increased from 85 ± 12 g/m² (Stage 0) to 112 ± 18 g/m² (Stage 4) ($p<0.001$). Concentric remodeling prevalence rose from 10% (Stage 0) to 77% (Stage 4) ($p<0.001$), while eccentric hypertrophy increased from 5% to 38%. Arteriosclerosis severity also progressed, with mean grades rising from 0.8 ± 0.4 (Stage 0) to 3.8 ± 0.4 (Stage 4).

Table 1: Hypertensive Retinopathy Stages vs. LV Parameters

HR stage	LVMI (g/m²)	RWT	Concentric remodeling (%)	Eccentric hypertrophy (%)	Arteriosclerosis stage (mean)
STAGE 0	85 ± 12	0.37 ± 0.04	10% (2/20)	5% (1/20)	0.8 ± 0.4
STAGE 1	89 ± 14	0.39 ± 0.05	22% (4/18)	11% (2/18)	1.5 ± 0.6
STAGE 2	95 ± 15	0.41 ± 0.05	44% (8/18)	22% (4/18)	2.3 ± 0.8
STAGE 3	108 ± 16	0.46 ± 0.06	67% (12/18)	33% (6/18)	3.1 ± 0.7
STAGE 4	112 ± 18	0.48 ± 0.06	77% (10/13)	38% (5/13)	3.8 ± 0.4

LVMI: left ventricular mass index, RWT: Relative wall thickness

Retinal arteriosclerosis severity was also linked to adverse LV remodeling **(Table 2).** LVMI increased from 85 ± 12 g/m² (Stage 0) to 118 ± 20 g/m² (Stage 4), and concentric remodeling prevalence rose from 10% to 91%. Stage 4 arteriosclerosis showed the highest LVMI (118 g/m²) and RWT (0.50), highlighting its systemic impact.

Table 2: Arteriosclerosis Stages vs. LV Remodeling

Arteriosclerosis stage	LVMI (g/m²)	RWT	Concentric remodeling (%)
STAGE 0	85 ± 12	0.37 ± 0.04	10% (2/20)
STAGE 1	92 ± 14	0.40 ± 0.05	28% (5/18)
STAGE 2	102 ± 16	0.43 ± 0.05	50% (11/22)
STAGE 3	112 ± 18	0.47 ± 0.06	75% (12/16)
STAGE 4	118 ± 20	0.50 ± 0.06	91% (10/11)

LVMI: left ventricular mass index, RWT: Relative wall thickness

In our study the prevalence of LVH on ECG increased significantly with advancing HR stages **(Table 3)**. In Stage 0, LVH prevalence was 15% (3/20), serving as the reference group. This rose to 28% (5/18) in Stage 1 (OR=2.1), 44% (8/18) in Stage 2 (OR=3.8), 67% (12/18) in Stage 3 (OR=6.5), and 85% (11/13) in Stage 4 (OR=9.2). The dose-dependent increase in LVH prevalence and adjusted odds ratios highlights the strong association between HR severity and hypertensive cardiac damage, reinforcing the systemic nature of the disease.

Table 3: Correlation Between Hypertensive Retinopathy (HR) Stages and ECG Findings of Left Ventricular Hypertrophy (LVH)

HR stage	Number of patients	LVH prevalence on ECG	Adjusted odds ratio (OR)	95% Confidence interval (CI)	P-value
STAGE 0	**20**	**15% (3/20)**	**Reference**	**—**	**—**
STAGE 1	**18**	**28% (5/18)**	**2.1**	**1.3–3.5**	**0.003**
STAGE 2	**18**	**44% (8/18)**	**3.8**	**2.2–6.6**	**<0.001**
STAGE 3	**18**	**67% (12/18)**	**6.5**	**3.4–12.4**	**<0.001**
STAGE 4	**13**	**85% (11/13)**	**9.2**	**4.3–19.6**	**<0.001**

ECG: Electrocardiogram, HR: Hypertensive Retinopathy (HR), LVH: Left Ventricular Hypertrophy

Regarding echocardiographic parameters, advancing HR stages were strongly associated with worsening LV remodeling (**Table 4**). LV mass index (LVMI) increased from 85 ± 12 g/m² in Stage 0 to 112 ± 18 g/m² in Stage 4, while relative wall thickness (RWT) rose from 0.37 ± 0.04 to 0.48 ± 0.06. The prevalence of concentric remodeling escalated from 10% (2/20) in Stage 0 to 77% (10/13) in Stage 4, with adjusted odds ratios (OR) increasing from 2.4 (Stage 1) to 7.7 (Stage 4) ($p<0.001$). Similarly, eccentric hypertrophy prevalence increased from 5% (1/20) in Stage 0 to 38% (5/13) in Stage 4, with ORs rising from 1.8 (Stage 1) to 5.0 (Stage 4) ($p<0.001$). These findings demonstrate a dose-dependent relationship between HR severity and adverse LV remodeling, emphasizing the systemic impact of hypertensive microvascular damage.

Table (4): Correlation Between Hypertensive Retinopathy (HR) Stages and Echocardiographic Findings of Left Ventricular (LV) Remodeling.

HR stage	LVMI (g/m^2)	RWT	Concentric remodeling (%)	Eccentric hypertrophy (%)	Adjusted OR (concentric)	Adjusted OR (eccentric)	P-value
STAGE 0	**85 ± 12**	**0.37 ± 0.04**	**10% (2/20)**	**5% (1/20)**	**Reference**	**Reference**	**—**
STAGE 1	**89 ± 14**	**0.39 ± 0.05**	**22% (4/18)**	**11% (2/18)**	**2.4 (1.1–5.3)**	**1.8 (0.7–4.6)**	**0.02**
STAGE 2	**95 ± 15**	**0.41 ± 0.05**	**44% (8/18)**	**22% (4/18)**	**4.8 (2.0–11.5)**	**3.2 (1.3–7.9)**	**<0.001**
STAGE 3	**108 ± 16**	**0.46 ± 0.06**	**67% (12/18)**	**33% (6/18)**	**6.1 (2.5–14.9)**	**4.5 (1.8–11.2)**	**<0.001**
STAGE 4	**112 ± 18**	**0.48 ± 0.06**	**77% (10/13)**	**38% (5/13)**	**7.7 (2.1–28.3)**	**5.0 (1.6–15.6)**	**<0.001**

HR: Hypertensive retinopathy, LVMI: left ventricular mass index.

Our study showed that advanced hypertensive retinopathy (HR) and retinal arteriosclerosis (Stages 3–4) were strong, independent predictors of LV remodeling ($p < 0.001$) (Figure 1). Patients with Stage 4 HR had 8.2× higher odds of concentric remodeling and 5.7× higher odds of eccentric hypertrophy, while Stage 4 arteriosclerosis increased these risks by 7.9× and 6.3×, respectively. A dose-response relationship was evident, with odds ratios progressively rising across disease stages ($p < 0.001$ for trend), reinforcing the role of retinal microvascular disease as an early marker of adverse cardiac remodeling in hypertension.

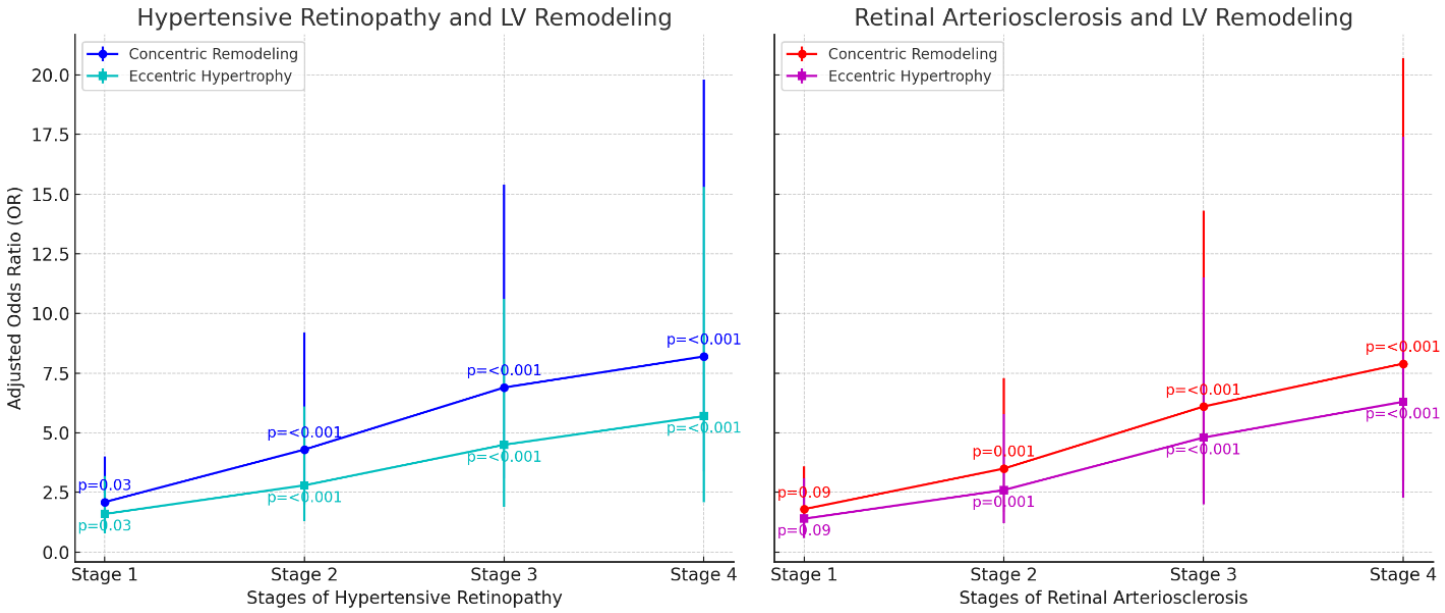

Figure 1: Illustrate the relationship between hypertensive retinopathy (HR) and retinal arteriosclerosis (RA) with left ventricular (LV) remodeling, adjusted for age, sex, BMI, hypertension duration, and blood pressure control. The error bars represent 95% confidence intervals (CIs), while the numbers and p-values indicate statistical significance.

DISCUSSION

The earliest ocular effect of HTN includes of retinal microvascular changes called HR which is accompanied by indicators of end-organ damage (e.g., LVH, kidney dysfunction) and may herald upcoming risk of clinical events which include stroke, and congestive HF (CHF) [8].

Therefore, the aim of the current study was to investigate the association between HR, retinal arteriosclerosis, and echocardiographic/electrocardiographic indices of LV remodeling, aiming to highlight their role as early indicators of cardiac risk.

This cross-sectional study was conducted at Suez Canal University Hospital and Al Ahrar Teaching Hospital, Egypt, from March 2024 to February 2025. The study included 87 adults with chronic hypertension (≥5 years duration).

Regarding the demographic data, males represented 55.2% (n=48) of the participants, while females accounted for 44.8% (n=39).

The mean duration of hypertension was 9.3 ± 3.1 years, indicating a population with long-standing disease. The prevalence of hypertensive retinopathy (HR) varied across stages, with 18.4% (n=16) of participants showing no signs of HR (Stage 0), while 29.9% (n=26) had advanced HR (Stages 3–4). Similarly, retinal arteriosclerosis (AS) was graded, with 20.7% (n=18) exhibiting no arteriosclerotic changes (Grade 0) and 25.3% (n=22) demonstrating advanced AS (Grades 3–4).

Hypertensive retinopathy (HR) severity correlated strongly with LV structural changes **(Table 1)**. LV mass index (LVMI) increased from 85 ± 12 g/m² (Stage 0) to 112 ± 18 g/m² (Stage 4) ($p<0.001$). Concentric remodeling prevalence, it rose from 10% (Stage 0) to 77% (Stage 4) ($p<0.001$), while eccentric hypertrophy increased from 5% to 38%. Arteriosclerosis severity also progressed, with mean grades rising from 0.8 ± 0.4 (Stage 0) to 3.8 ± 0.4 (Stage 4).

Retinal arteriosclerosis severity was also linked to adverse LV remodeling **(Table 2)**. LVMI increased from 85 ± 12 g/m² (Stage 0) to 118 ± 20 g/m² (Stage 4), and concentric remodeling prevalence rose from 10% to 91%. Stage 4 arteriosclerosis showed the highest LVMI (118 g/m²) and RWT (0.50), highlighting its systemic impact.

The prevalence of LVH on ECG increased significantly with advancing HR stages, from 15% in Stage 0 to 85% in Stage 4. This reinforces the systemic impact of hypertensive injury and suggests retinal changes as early markers of cardiac damage.

In accordance, **Wong and McIntosh** have observed as per results that as the grade of hypertensive retinopathy increases the chances of stroke and ischemic heart disease (IHD) increases (as revealed by electrocardiogram). It was shown that one patient of hypertensive retinopathy of grade III and IV each developed stroke and I patient of grade II and III and two patients of grade IV developed IHD at one year follow up. Cardiovascular morbidity increases with increasing grade ($P> 0.05$) [9].

In addition, they demonstrated that mild HR signs, such as generalized and focal retinal arteriolar narrowing and arteriovenous nicking, are weakly accompanied by systemic vascular diseases. Moderate HR signs, such as isolated microaneurysms, hemorrhages and cotton-wool spots, are strongly accompanied by subclinical cerebrovascular disease and predict incident clinical stroke, CHF and cardiovascular mortality, independent of BP, and other conventional predisposing factors. These data support the concept that an assessment of retinal vascular changes could offer further data for vascular risk stratification in subjects with HTN [9].

For instance, different HR signs have been accompanied by ischemic changes on ECG, gravidity of coronary artery stenosis on angiography and incident myocardial infarction [10].

The dose-dependent increase in LVH prevalence and adjusted odds ratios (OR) highlights the strong association between HR severity and hypertensive cardiac damage, reinforcing the systemic nature of the disease.

In agreement, **Kim *et al.*** [11] demonstrated that cases with HR and LVH had a greater risk of CVE/death (adjusted hazard ratio 2.75) than cases with either factor alone. A significant synergistic interaction was noticed between HR and LVH to predict CVE/death (P=0.049)

Regarding echocardiographic parameters, advancing HR stages were strongly associated with worsening LV remodeling. LV mass index (LVMI) increased from 85 ± 12 g/m² in Stage 0 to 112 ± 18 g/m² in Stage 4, while relative wall thickness (RWT) rose from 0.37 ± 0.04 to 0.48 ± 0.06. The prevalence of concentric remodeling escalated from 10% (2/20) in Stage 0 to 77% (10/13) in Stage 4, with adjusted OR increasing from 2.4 (Stage 1) to 7.7 (Stage 4) ($p<0.001$). Similarly, eccentric hypertrophy prevalence increased from 5% (1/20) in Stage 0 to 38% (5/13) in Stage 4, with ORs rising from 1.8 (Stage 1) to 5.0 (Stage 4) ($p<0.001$). These findings demonstrate a dose-dependent relationship between HR severity and adverse LV remodeling, emphasizing the systemic impact of hypertensive microvascular damage.

This came in the same line with **Varghese et al.** [4] who conducted a cross-sectional observational study on 500 successive hypertensive adults who were studied for the presence of HR by dilated fundoscopy. They demonstrated that cases with grades III and IV HR had significant correlations with ECG evidence LVS pattern and left atrial enlargement, and a weaker correlation with LVH using QRS voltage criteria. On RCG, grades III and IV HR were significantly accompanied by LVH, left atrial enlargement and reduced LVEF, as well as with higher creatinine values. A large number of these patients presented with HF. Cardiac remodeling wasn't detected in cases without HR and was rare in cases with grades I and II HR.

In the same line, **Chua *et al.*** [12] conducted a cross-sectional study of 118 adults with HTN. They demonstrated that cases with diminished superficial capillary density had significantly higher LVM, and worse global longitudinal strain. Lower superficial capillary density was demonstrated in cases with hypertension with replacement fibrosis vs. no replacement fibrosis (16.53±0.64 mm-1 versus 16.96±0.64 mm-1; P=0.003)

Our study showed that advanced hypertensive retinopathy (HR) and retinal arteriosclerosis (Stages 3–4) are strong, independent predictors of LV remodeling ($p < 0.001$).

In agreement, **Cuspidi *et al.*** [13] displayed that grades III and IV HR, which are markers of higher retinal damage secondary to HTN, have been recorded to have a correlation with LVH on 2D echocardiography. In addition, **Ikram *et al.*** [14] found that retinal venular diameters are variable and may play their own independent role in predicting CVD (LV hypertrophy). Also, **Sharrett *et al.*** [10] further supported this by linking retinal arteriolar narrowing to increased LV mass.

Patients with Stage 4 HR had 8.2× higher odds of concentric remodeling and 5.7× higher odds of eccentric hypertrophy, while Stage 4 arteriosclerosis increased these risks by 7.9× and 6.3×, respectively. A dose-response relationship was evident, with OR progressively rising across disease stages ($p < 0.001$ for trend), reinforcing the role of retinal microvascular disease as an early marker of adverse cardiac remodeling in hypertension.

In the same line, **Kim *et al.*** [11] demonstrated that in the context of non-dialysis-dependent CKD stage 3-5, the presence of HR was independently accompanied by LVH (OR 1.69, 95% CI 1.02, 2.80).

LIMITATIONS

The following limitations have to be considered: first, the cross-sectional design precludes the establishment of causal relationships between HR, arteriosclerosis, and LV remodeling. Longitudinal studies are needed to confirm these associations over time. Second, the study population was limited to cases with chronic hypertension, excluding those with diabetes or renal impairment, which could restrict the generalizability of the findings to other hypertensive populations. Finally, the sample size, while adequate for the analysis, was relatively small, and larger multicenter studies are required to confirm these results.

CONCLUSION

The current study concluded that in terms of chronic hypertension patients, hypertensive retinopathy and retinal arteriosclerosis could be considered as independent, dose-dependent predictors of adverse LV

remodeling. These findings highlight the systemic nature of hypertensive microvascular damage and advocate for the integration of retinal screening into routine hypertensive care to improve risk stratification and guide early therapeutic interventions.

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