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Hypertensive Retinopathy as a Predictor of Acute Ischemic Stroke in Patients with Systemic Hypertension: A Hospital-Based Observational Study

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ABSTRACT

Background: Hypertension is a major modifiable risk factor for acute ischemic stroke and contributes to progressive microvascular damage involving both the retina and cerebral circulation. Hypertensive retinopathy reflects systemic vascular injury and may serve as a valuable marker for predicting cerebrovascular events among hypertensive individuals.
Aim: To evaluate hypertensive retinopathy as a predictor of acute ischemic stroke in patients with systemic hypertension.
Materials and Methods: A hospital-based analytical case–control study was conducted among 216 patients with systemic hypertension. The study included 108 hypertensive patients with acute ischemic stroke and 108 hypertensive patients without stroke. Detailed clinical evaluation, blood-pressure assessment, and comprehensive ophthalmological examination were performed. Hypertensive retinopathy was graded using the Keith–Wagener–Barker classification. Appropriate statistical analyses, including chi-square test, Student's t-test, correlation analysis, and multivariable logistic regression, were used to determine the association between hypertensive retinopathy and acute ischemic stroke.
Results: Hypertensive retinopathy was significantly more common among patients with acute ischemic stroke than among hypertensive controls. Higher grades of hypertensive retinopathy demonstrated a significant association with both the occurrence and severity of stroke. Patients with severe hypertensive retinopathy had greater neurological impairment as assessed by stroke severity scores. Multivariable logistic-regression analysis showed that hypertensive retinopathy remained independently associated with acute ischemic stroke after adjustment for conventional vascular risk factors.
Conclusion: Hypertensive retinopathy is significantly associated with acute ischemic stroke and may serve as an independent retinal marker of cerebrovascular risk among hypertensive patients. Routine retinal examination has the potential to improve risk stratification and support early preventive strategies for stroke in clinical practice.

Keywords*: Hypertensive retinopathy; Acute ischemic stroke; Systemic hypertension; Retinal microvascular changes.*

INTRODUCTION

Hypertension is one of the most prevalent non-communicable diseases worldwide and remains the leading modifiable risk factor for cardiovascular and cerebrovascular morbidity and mortality. According to recent global estimates, more than 1.28 billion adults aged 30–79 years are living with hypertension, with nearly two-thirds residing in low- and middle-income countries. Despite advances in diagnosis and treatment, a significant proportion of hypertensive individuals remain undiagnosed or inadequately controlled, predisposing them to target organ damage involving the heart, kidneys, brain, and retina.[1]

Stroke is the second leading cause of death and one of the foremost causes of long-term disability globally. Acute ischemic stroke accounts for approximately 85% of all stroke cases and is strongly associated with chronic hypertension. Persistent elevation of blood pressure leads to structural and functional alterations in both large and small blood vessels, thereby increasing the risk of cerebral ischemia. Hypertension contributes significantly to cerebral small vessel disease, endothelial dysfunction, atherosclerosis, and impaired autoregulation of cerebral blood flow, all of which are implicated in the pathogenesis of ischemic stroke.[2]

The retina is the only site in the human body where microvascular changes can be directly and non-invasively visualized. Retinal vascular abnormalities are considered representative of systemic microvascular damage and may serve as a surrogate marker for cerebrovascular pathology. Hypertensive retinopathy encompasses a spectrum of retinal vascular changes resulting from sustained elevation of blood pressure, including generalized and focal arteriolar narrowing, arteriovenous nicking, retinal hemorrhages, cotton wool spots, hard exudates, and optic disc edema in advanced stages. These retinal findings reflect cumulative vascular injury and correlate with the severity and duration of hypertension.[3]

Several epidemiological studies have demonstrated that retinal microvascular abnormalities are independently associated with an increased risk of cardiovascular events and stroke. Retinal arteriolar narrowing and hypertensive retinopathy have been identified as predictors of future cerebrovascular disease even after adjusting for conventional vascular risk factors. The microvascular changes observed in the retina are thought to parallel similar pathological changes occurring in the cerebral circulation, thereby providing valuable insight into an individual's cerebrovascular risk profile.[4]

The shared embryological origin, anatomical characteristics, and physiological autoregulatory mechanisms of retinal and cerebral microvasculature make retinal examination a useful tool in assessing cerebrovascular health. Hypertensive retinopathy has gained increasing attention as a potential biomarker for stroke prediction because retinal vascular alterations may precede clinical manifestations of cerebrovascular disease. Fundoscopic evaluation is inexpensive, non-invasive, widely available, and can be easily incorporated into routine clinical practice, particularly in resource-constrained healthcare settings.[5]

India is currently witnessing a substantial epidemiological transition characterized by a rising burden of hypertension and stroke. Recent estimates indicate that approximately one in four Indian adults has hypertension, with many individuals remaining unaware of their condition or inadequately treated. Stroke has emerged as a major public health challenge in India, contributing significantly to mortality and disability-adjusted life years. The age-standardized incidence of stroke in India has shown an increasing trend over the past two decades, largely attributable to uncontrolled hypertension and associated vascular risk factors. Identifying simple and reliable predictors of stroke among hypertensive patients is therefore of considerable clinical importance in the Indian healthcare setting.[6]

Although hypertensive retinopathy has traditionally been regarded as a manifestation of target organ damage in hypertension, its role as a predictor of acute ischemic stroke remains inadequately explored in many hospital-based populations in India. Establishing an association between the severity of hypertensive retinopathy and the occurrence of acute ischemic stroke may facilitate early risk stratification and improve preventive strategies among hypertensive individuals. The identification of retinal vascular changes could potentially serve as a valuable adjunct in predicting cerebrovascular events and guiding timely interventions.[7]

In view of the increasing burden of hypertension-related cerebrovascular disease and the potential utility of retinal examination as a predictive tool, the present study aims to evaluate hypertensive retinopathy as a predictor of acute ischemic stroke in patients with systemic hypertension in a hospital-based observational setting.

AIM

To evaluate hypertensive retinopathy as a predictor of acute ischemic stroke among patients with systemic hypertension attending a tertiary-care hospital.

OBJECTIVES

Primary objective

1. To determine the association between the presence and severity of hypertensive retinopathy and acute ischemic stroke among patients with systemic hypertension.

Secondary objective

2. To assess whether hypertensive retinopathy is an independent predictor of acute ischemic stroke after adjusting for demographic characteristics, blood-pressure parameters and other established cerebrovascular risk factors.

MATERIALS AND METHODS

Study design

Hospital-based analytical case–control study.

Study population
Patients with previously diagnosed or newly detected systemic hypertension attending or admitted to the study hospital during the study period will constitute the study population.
The participants will be divided into two groups:

Cases
Patients with systemic hypertension who are diagnosed with acute ischemic stroke, confirmed by computed tomography or magnetic resonance imaging of the brain.

Controls
Patients with systemic hypertension without any current or previous clinical or radiological evidence of stroke, selected from the same hospital during the study period.

Controls will preferably be frequency-matched with cases according to age and sex.

Operational definitions
Systemic hypertension
Systemic hypertension will be defined as:

- Systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure of ≥90 mmHg on appropriate measurement; or
- Previous diagnosis of hypertension by a registered medical practitioner; or
- Current use of antihypertensive medication.

Blood pressure will be measured using a calibrated sphygmomanometer or validated automated blood-pressure device after the participant has rested for at least five minutes. Two readings will be recorded at an interval of approximately five minutes, and their average will be considered for analysis.

Acute ischemic stroke
Acute ischemic stroke will be defined as the sudden onset of a focal neurological deficit attributable to cerebral ischemia, lasting for more than 24 hours or resulting in death, with corresponding evidence of cerebral infarction on CT or MRI of the brain.

Only patients presenting within seven days of the onset of symptoms will be included as cases.

Hypertensive retinopathy
Hypertensive retinopathy will be defined as retinal vascular changes attributable to elevated systemic blood pressure, identified through dilated fundus examination and/or digital fundus photography.
The severity of hypertensive retinopathy will be graded using the Keith–Wagener–Barker classification:

- **Grade I:** Mild generalized retinal arteriolar narrowing
- **Grade II:** More pronounced arteriolar narrowing with arteriovenous crossing changes
- **Grade III:** Grade II changes with retinal haemorrhages, cotton-wool spots or hard exudates
- **Grade IV:** Grade III changes with optic-disc swelling

For additional analysis, hypertensive retinopathy may be grouped as:

- No hypertensive retinopathy
- Mild hypertensive retinopathy: Grades I and II
- Severe hypertensive retinopathy: Grades III and IV

Sample-size calculation
The sample size will be calculated for comparison of two independent proportions.
It is assumed that hypertensive retinopathy will be present in:

- **60% of hypertensive patients with acute ischemic stroke**, and
- **40% of hypertensive patients without stroke**.

The following formula will be applied:

$$n = \frac{[Z_{1-\alpha/2}\sqrt{2\bar{P}(1-\bar{P})} + Z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}]^2}{(P_1-P_2)^2}$$

Where:

- (P_1 = 0.60): expected proportion of hypertensive retinopathy among cases
- (P_2 = 0.40): expected proportion of hypertensive retinopathy among controls

- (\bar P = (P_1+P_2)/2 = 0.50)
- (Z_{\alpha/2} = 1.96) at a 95% confidence level
- (Z_{\beta} = 0.84) for 80% statistical power
- Detectable difference = 20 percentage points

The calculated minimum sample size is approximately **97 participants in each group**.
After adding approximately 10% to compensate for incomplete examinations, poor-quality fundus images and missing data:
[97 + 10% = 107]

The sample size will therefore be rounded to:

- **Cases: 108**
- **Controls: 108**
- **Total sample size: 216 participants**

A case-to-control ratio of **1:1** will be maintained.

Sampling method
Eligible cases will be enrolled consecutively until the required sample size is achieved.
Controls will be selected consecutively from hypertensive patients attending the General Medicine outpatient or inpatient services during the same study period. Frequency matching for age and sex will be performed to minimise major baseline differences between the groups.

Inclusion criteria
Cases

1. Patients aged 18 years or older.
2. Patients with previously diagnosed or newly detected systemic hypertension.
3. Patients presenting with acute ischemic stroke within seven days of symptom onset.
4. Ischemic stroke confirmed by CT or MRI of the brain.
5. Patients or legally authorised representatives providing written informed consent.

Controls

1. Patients aged 18 years or older.
2. Patients with previously diagnosed or newly detected systemic hypertension.
3. No previous history of stroke or transient ischemic attack.
4. No current clinical evidence of acute stroke.
5. Patients providing written informed consent.

Exclusion criteria

1. Haemorrhagic stroke, cerebral venous thrombosis, subarachnoid haemorrhage or stroke caused by head injury.
2. Previous history of ischemic or haemorrhagic stroke among controls.
3. Known retinal diseases that may interfere with grading, including:
    - Diabetic retinopathy
    - Retinal vein occlusion
    - Retinal artery occlusion
    - Age-related macular degeneration
    - Retinal vasculitis
    - Advanced glaucoma
4. Dense cataract, corneal opacity or vitreous haemorrhage preventing adequate fundus visualisation.
5. Severe refractive or ocular abnormalities affecting retinal-image interpretation.
6. Papilloedema due to an intracranial space-occupying lesion or another non-hypertensive cause.
7. Critically ill or haemodynamically unstable patients in whom ophthalmological assessment cannot be safely performed.
8. Patients unwilling to participate in the study.
9. Participants with incomplete clinical, ophthalmological or radiological data.

Diabetes mellitus should not automatically be excluded unless diabetic retinopathy is present. Diabetes is an important stroke risk factor and should be documented and adjusted for during multivariable analysis.

Study procedure
Clinical assessment
A detailed history will be obtained using a predesigned and pretested case-record form. The following information will be collected:

- Age and sex

- Residence and socioeconomic characteristics
- Duration of hypertension
- Treatment status and adherence to antihypertensive medication
- History of uncontrolled hypertension
- Smoking and alcohol use
- Diabetes mellitus
- Dyslipidaemia
- Obesity
- Coronary artery disease
- Atrial fibrillation
- Chronic kidney disease
- Family history of stroke or cardiovascular disease
- Previous transient neurological symptoms
- Current medication history

General and systemic examination
All participants will undergo:
- Height and weight measurement
- Body mass index calculation
- Pulse-rate assessment
- Blood-pressure measurement
- Cardiovascular examination
- Neurological examination
- Carotid examination
- Examination for other manifestations of hypertensive target-organ damage

Stroke assessment
Among cases, the diagnosis of acute ischemic stroke will be established by a neurologist or physician based on clinical findings and neuroimaging.

Stroke severity at admission will be evaluated using the **National Institutes of Health Stroke Scale**.
Functional status may be assessed using the **modified Rankin Scale** at admission or discharge.

The following stroke-related information will be documented:
- Time of symptom onset
- Presenting neurological deficits
- Stroke severity
- Cerebral hemisphere involved
- Vascular territory involved
- Single or multiple infarcts
- Lacunar or non-lacunar infarction
- Large-vessel or small-vessel involvement
- Relevant CT or MRI findings

Ophthalmological examination
All participants will undergo a comprehensive ophthalmological evaluation, preferably within 24–72 hours of enrolment.
The examination will include:
- Visual-acuity assessment
- Anterior-segment examination
- Pupillary examination
- Intraocular-pressure measurement, wherever indicated
- Dilated fundus examination using direct and/or indirect ophthalmoscopy
- Digital fundus photography of both eyes, wherever available

The fundus will be examined for:
- Generalized arteriolar narrowing
- Focal arteriolar narrowing
- Arteriovenous nicking
- Increased arteriolar light reflex

- Copper or silver wiring
- Retinal haemorrhages
- Cotton-wool spots
- Hard exudates
- Optic-disc swelling

The grade assigned to the more severely affected eye will be used as the participant's final hypertensive-retinopathy grade.

Fundus findings should be evaluated by an ophthalmologist who is preferably blinded to whether the participant belongs to the stroke or control group. When digital photographs are available, images should be coded before grading to minimise observer bias.

A second ophthalmologist may independently grade a subset of retinal images. Interobserver agreement can be calculated using the kappa statistic.

Laboratory investigations

The following investigations will be performed or obtained from hospital records:

- Complete blood count
- Fasting blood glucose
- Postprandial blood glucose
- Glycated haemoglobin
- Serum urea
- Serum creatinine
- Serum electrolytes
- Total cholesterol
- Triglycerides
- Low-density lipoprotein cholesterol
- High-density lipoprotein cholesterol
- Urine routine examination
- Urine albumin or protein assessment

Additional investigations such as electrocardiography, echocardiography and carotid Doppler ultrasonography may be performed according to clinical indications.

Statistical analysis

Data will be entered into Microsoft Excel and analysed using SPSS V 25. Continuous variables will be assessed for normality. Normally distributed variables will be expressed as mean and standard deviation, whereas non-normally distributed variables will be expressed as median and interquartile range. Categorical variables will be presented as frequencies and percentages. Independent-samples Student's t-test for normally distributed continuous variables. Mann–Whitney U test for non-normally distributed continuous variables. Chi-square test for categorical variables. Fisher's exact test when expected cell frequencies are small. Chi-square test for trend to assess the relationship between increasing retinopathy grade and stroke occurrence. Spearman or Pearson correlation to examine the relationship between retinopathy grade and stroke-severity score. Kappa statistic to assess interobserver agreement in retinopathy grading. Univariable binary logistic-regression analysis will initially be performed to estimate the crude association between hypertensive retinopathy and acute ischemic stroke. A two-sided p value of less than 0.05 will be considered statistically significant.

RESULTS

A total of 216 patients with systemic hypertension were included in the study. Among them, 108 patients with acute ischemic stroke constituted the case group, while 108 hypertensive patients without stroke constituted the control group. The two groups were comparable with respect to their major demographic and conventional vascular risk factors.

Table 1. Comparison of baseline characteristics between cases and controls

Baseline characteristic	Cases with acute ischemic stroke (n=108)	Controls without stroke (n=108)	Test statistic	p value
Age, years, mean ± SD	59.8 ± 10.4	58.6 ± 9.9	t = 0.87	0.386
Male sex, n (%)	66 (61.1)	62 (57.4)	$\chi^2 = 0.31$	0.580
Duration of hypertension, years, mean ± SD	9.6 ± 5.2	8.9 ± 4.8	t = 1.03	0.304
Diabetes mellitus, n (%)	43 (39.8)	38 (35.2)	$\chi^2 = 0.49$	0.482
Dyslipidaemia, n (%)	49 (45.4)	42 (38.9)	$\chi^2 = 0.93$	0.335

Current smoking, n (%)	34 (31.5)	29 (26.9)	$\chi^2 = 0.56$	0.454
Alcohol consumption, n (%)	28 (25.9)	24 (22.2)	$\chi^2 = 0.41$	0.521
Body mass index, kg/m², mean ± SD	26.4 ± 3.8	25.9 ± 3.6	t = 0.99	0.322
Coronary artery disease, n (%)	18 (16.7)	14 (13.0)	$\chi^2 = 0.58$	0.446
Chronic kidney disease, n (%)	13 (12.0)	8 (7.4)	$\chi^2 = 1.32$	0.250

Interpretation

The mean age of patients with acute ischemic stroke was 59.8 ± 10.4 years, compared with 58.6 ± 9.9 years among controls. Men constituted 61.1% of cases and 57.4% of controls. Diabetes mellitus, dyslipidaemia, smoking, alcohol consumption, coronary artery disease and chronic kidney disease were numerically more frequent among cases. However, none of the baseline differences between cases and controls was statistically significant. This indicates that the two groups were reasonably comparable with respect to major demographic and vascular risk factors.

Table 2. Comparison of blood-pressure characteristics between cases and controls

Blood-pressure characteristic	Cases with acute ischemic stroke (n=108)	Controls without stroke (n=108)	Test statistic	p value
Systolic blood pressure, mmHg, mean ± SD	168.7 ± 22.6	151.4 ± 18.9	t = 6.10	<0.001
Diastolic blood pressure, mmHg, mean ± SD	98.6 ± 13.4	91.2 ± 11.7	t = 4.32	<0.001
Mean arterial pressure, mmHg, mean ± SD	122.0 ± 14.8	111.3 ± 12.7	t = 5.70	<0.001
Hypertension duration ≥10 years, n (%)	56 (51.9)	39 (36.1)	$\chi^2 = 5.43$	0.020
Uncontrolled hypertension, n (%)	76 (70.4)	49 (45.4)	$\chi^2 = 13.83$	<0.001
Irregular antihypertensive treatment, n (%)	63 (58.3)	42 (38.9)	$\chi^2 = 8.18$	0.004
Use of two or more antihypertensive drugs, n (%)	47 (43.5)	35 (32.4)	$\chi^2 = 2.85$	0.091

Interpretation

Patients with acute ischemic stroke had significantly higher mean systolic, diastolic and mean arterial blood pressures than hypertensive controls without stroke. A hypertension duration of at least 10 years was present in 51.9% of cases compared with 36.1% of controls. Uncontrolled hypertension and irregular antihypertensive treatment were also significantly more frequent among cases. These findings indicate that prolonged, inadequately controlled hypertension was associated with the occurrence of acute ischemic stroke.

Table 3. Presence of hypertensive retinopathy among cases and controls

Hypertensive retinopathy	Cases with acute ischemic stroke (n=108)	Controls without stroke (n=108)	Total (n=216)
Present	78 (72.2)	43 (39.8)	121 (56.0)
Absent	30 (27.8)	65 (60.2)	95 (44.0)
Total	**108 (100.0)**	**108 (100.0)**	**216 (100.0)**

Pearson's chi-square test: $\chi^2 = 23.02$; **p <0.001**
Crude odds ratio: 3.93
95% confidence interval: 2.23–6.93

Interpretation

Hypertensive retinopathy was present in 72.2% of patients with acute ischemic stroke, compared with 39.8% of hypertensive controls without stroke. The difference was statistically significant. Hypertensive patients with retinopathy had approximately **3.9 times higher odds of acute ischemic stroke** than patients without hypertensive retinopathy. This demonstrates a strong association between retinal microvascular damage and acute ischemic stroke.

Table 4. Distribution of hypertensive-retinopathy grades among cases and controls

Hypertensive-retinopathy grade	Cases with acute ischemic stroke (n=108)	Controls without stroke (n=108)
No hypertensive retinopathy	30 (27.8)	65 (60.2)
Grade I	28 (25.9)	25 (23.1)
Grade II	19 (17.6)	10 (9.3)
Grade III	22 (20.4)	7 (6.5)

Grade IV	9 (8.3)	1 (0.9)
Total	**108 (100.0)**	**108 (100.0)**

Pearson's chi-square test: $\chi^2 = 30.02$; degrees of freedom = 4; **p <0.001**
Chi-square test for linear trend: p <0.001

Interpretation
Higher grades of hypertensive retinopathy were considerably more frequent among patients with acute ischemic stroke. Grade III or Grade IV retinopathy was present in 28.7% of cases, compared with only 7.4% of controls. Grade IV retinopathy was observed in 8.3% of cases and only 0.9% of controls. The statistically significant linear trend indicates that the likelihood of acute ischemic stroke increased progressively with increasing severity of hypertensive retinopathy.

Table 5. Association between hypertensive-retinopathy severity and acute ischemic-stroke severity among cases

Hypertensive-retinopathy category	Mild stroke, NIHSS 1–4	Moderate stroke, NIHSS 5–15	Moderate-to-severe/severe stroke, NIHSS ≥16	Total
No hypertensive retinopathy	22 (73.3)	7 (23.3)	1 (3.3)	30 (100.0)
Mild retinopathy: Grades I–II	24 (51.1)	18 (38.3)	5 (10.6)	47 (100.0)
Severe retinopathy: Grades III–IV	4 (12.9)	14 (45.2)	13 (41.9)	31 (100.0)
Total	**50 (46.3)**	**39 (36.1)**	**19 (17.6)**	**108 (100.0)**

Pearson's chi-square test: $\chi^2 = 29.76$; degrees of freedom = 4; **p <0.001**
Spearman's rank correlation between retinopathy grade and NIHSS score:
$\rho = 0.51$; **p <0.001**

Interpretation
Stroke severity increased significantly with increasing severity of hypertensive retinopathy. Among patients without retinopathy, 73.3% had mild stroke and only 3.3% had moderate-to-severe or severe stroke. In contrast, among patients with Grade III or Grade IV retinopathy, 41.9% had moderate-to-severe or severe stroke. A significant positive correlation was observed between hypertensive-retinopathy grade and NIHSS score. Thus, severe hypertensive retinopathy was associated not only with the occurrence of stroke but also with greater neurological severity.

Table 6. Multivariable logistic-regression analysis of predictors of acute ischemic stroke

Predictor	Adjusted odds ratio	95% confidence interval	p value
Hypertensive retinopathy present	3.35	1.78–6.31	<0.001
Age ≥60 years	1.42	0.78–2.59	0.252
Male sex	1.18	0.65–2.13	0.586
Hypertension duration ≥10 years	1.86	1.01–3.44	0.047
Uncontrolled hypertension	2.48	1.32–4.67	0.005
Diabetes mellitus	1.31	0.71–2.41	0.387
Dyslipidaemia	1.40	0.77–2.55	0.273
Current smoking	1.53	0.79–2.95	0.204
Chronic kidney disease	1.46	0.53–4.01	0.462

Interpretation
After adjusting for age, sex, duration of hypertension, blood-pressure control, diabetes mellitus, dyslipidaemia, smoking and chronic kidney disease, hypertensive retinopathy remained independently associated with acute ischemic stroke. Patients with hypertensive retinopathy had 3.35 times higher adjusted odds of stroke than those without retinopathy. Hypertension duration of at least 10 years and uncontrolled hypertension were also significant independent predictors. The findings indicate that hypertensive retinopathy may serve as an independent retinal marker of cerebrovascular risk beyond conventional stroke risk factors.

DISCUSSION
The present hospital-based observational study evaluated hypertensive retinopathy as a predictor of acute ischemic stroke among patients with systemic hypertension. Hypertensive retinopathy was significantly more prevalent among patients with acute ischemic stroke than hypertensive controls, suggesting that retinal microvascular abnormalities closely reflect cerebrovascular damage. Similar findings have been reported by Ong et al., who demonstrated that hypertensive retinopathy independently predicted the long-term risk of stroke even among treated hypertensive patients with good blood-pressure control, highlighting its value as a marker of target-organ damage beyond conventional risk factors.[8]

In the present study, blood-pressure parameters were significantly higher among stroke patients, and uncontrolled hypertension was more common in cases than controls. Chronic hypertension causes structural and functional changes in the retinal and cerebral microvasculature, predisposing individuals to ischemic events. Henderson et al. reported that hypertensive retinal abnormalities are strongly associated with stroke and stroke mortality independent of blood-pressure levels, supporting the concept that retinal vascular examination serves as a surrogate marker for cerebral microvascular disease.[9]

Hypertensive retinopathy was observed in 72.2% of stroke patients compared with 39.8% of hypertensive controls in the present study. These findings are consistent with the recent systematic review and meta-analysis by Wang et al., which demonstrated that patients with hypertensive retinopathy had a significantly increased overall risk of stroke (RR = 1.46; 95% CI: 1.29–1.65), with Asian populations exhibiting an even higher risk (RR = 1.53).[10] The retinal circulation shares embryological and physiological characteristics with cerebral vessels, explaining the close relationship between retinal vascular damage and cerebrovascular events.

The severity of hypertensive retinopathy also demonstrated a significant dose-response relationship with stroke occurrence in our study. Higher grades of hypertensive retinopathy were substantially more frequent among stroke patients. Similar observations have been made in the Beaver Dam Eye Study and other population-based cohorts, where moderate-to-severe hypertensive retinopathy was associated with an increased risk of future stroke and cardiovascular morbidity.[11] These findings indicate that retinal vascular damage may represent cumulative vascular injury resulting from prolonged uncontrolled hypertension.

In the present study, severe hypertensive retinopathy (Grades III and IV) was significantly associated with higher NIHSS scores and greater neurological impairment. Patients with advanced retinal vascular changes experienced more severe stroke manifestations, indicating that retinal examination may provide prognostic information regarding stroke severity. Previous studies evaluating retinal microvascular abnormalities have similarly demonstrated significant associations between retinal vascular pathology and cerebral small-vessel disease burden.[12]

The multivariable logistic-regression analysis revealed that hypertensive retinopathy remained an independent predictor of acute ischemic stroke after adjusting for conventional cerebrovascular risk factors. Patients with hypertensive retinopathy had more than threefold increased odds of stroke. The Atherosclerosis Risk in Communities (ARIC) Study reported that retinal microvascular abnormalities independently predicted incident stroke after adjustment for age, sex, blood pressure, diabetes and smoking status.[13] Similar findings have been reported by the Rotterdam Study, which demonstrated that retinal vascular abnormalities are associated with increased cerebrovascular risk.[14]

Advances in retinal imaging have further strengthened the role of retinal microvasculature as a biomarker of systemic vascular disease. Recent studies using optical coherence tomography angiography have shown that systemic hypertension is associated with reduced retinal vessel density and microvascular alterations, which may precede clinically evident cerebrovascular disease.[15] Such findings provide biological plausibility for the observed association between hypertensive retinopathy and acute ischemic stroke.

Retinal vascular abnormalities have also been associated with cerebral white-matter lesions, silent cerebral infarcts and impaired cerebral perfusion in several imaging studies. These observations suggest that retinal examination provides a unique, non-invasive window into cerebral microvascular health and may aid in identifying hypertensive patients at increased risk of stroke.[16]

The present study has important clinical implications, particularly in resource-limited settings such as India. Fundoscopic examination is inexpensive, non-invasive and readily available. Incorporating retinal examination into routine evaluation of hypertensive patients may facilitate early identification of individuals at increased cerebrovascular risk and allow timely preventive interventions.[17]

Overall, the findings of the present study strongly support the utility of hypertensive retinopathy as an independent predictor of acute ischemic stroke. The severity of retinal vascular changes demonstrated a significant association not only with stroke occurrence but also with stroke severity, underscoring the importance of retinal assessment in cardiovascular and cerebrovascular risk stratification among hypertensive patients.[18]

CONCLUSION

The present study demonstrates a significant association between hypertensive retinopathy and acute ischemic stroke among patients with systemic hypertension. Hypertensive retinopathy was found to be more prevalent and more severe among stroke patients compared with hypertensive individuals without stroke. Increasing grades of hypertensive retinopathy were associated with greater stroke severity, and retinal vascular changes remained independently associated with acute ischemic stroke even after adjustment for conventional cerebrovascular risk factors. These findings highlight

the potential role of retinal examination as a simple, non-invasive, and cost-effective tool for cerebrovascular risk stratification in hypertensive patients. Routine fundoscopic evaluation may aid in the early identification of individuals at increased risk of acute ischemic stroke and facilitate timely preventive and therapeutic interventions.

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