International Journal of Diseases and Disorders ISSN 2329-9835 Vol. 3 (7), pp. 01-12 July, 2015.
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# Retinal Microvascular Alterations in Acute Stroke Patients Assessed by Fundus Photography

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**Conflict of interest:** No! Conflict of interest is found elsewhere considering this work.
**Source of Funding:** There was no financial support concerning this work

## Abstract

**Background:** Stroke is a leading cause of morbidity and mortality worldwide. The retina, due to its shared embryological and anatomical characteristics with cerebral vasculature, offers a unique window to assess microvascular health. Retinal microvascular abnormalities may serve as noninvasive markers of cerebrovascular disease, but their role in acute stroke patients is underexplored.

**Aim:** To examine retinal microvascular changes in acute stroke patients using fundus photography and evaluate their correlation with stroke severity.

**Material and Methods:** This prospective observational study included 70 patients with acute stroke (ischemic, hemorrhagic, and lacunar).. All patients underwent detailed clinical examination,

stroke severity grading using the NIH Stroke Scale, and fundus photography to assess retinal changes. Retinal microvascular signs, including arteriolar narrowing, arteriovenous nicking, exudates, and arteriovenous ratio, were analyzed. Correlation between retinal findings and stroke severity was evaluated using appropriate statistical methods.

**Results:** Of the 70 patients, 38 (54.3%) were male and 32 (45.7%) were female. Ischemic stroke was most common (51.4%), followed by hemorrhagic (28.6%) and lacunar stroke (20%). Generalized arteriolar narrowing was observed in 100% of hemorrhagic and lacunar strokes and 91.7% of ischemic strokes. Focal narrowing and arteriovenous nicking were most prevalent in lacunar strokes (100%). Hard and soft exudates were seen predominantly in lacunar strokes (78.6%). The mean arteriovenous ratio was lowest in lacunar strokes (0.410 ± 0.112), reflecting significant microvascular compromise.

**Conclusion:** Retinal microvascular abnormalities are common in acute stroke and correlate strongly with stroke severity, particularly in lacunar strokes. Fundus photography is a promising noninvasive tool for assessing cerebrovascular health and may complement conventional stroke evaluation in clinical practice.

**Keywords:** Stroke, retinal microvasculature, fundus photography, arteriolar narrowing, arteriovenous nicking, stroke severity

## Introduction

Stroke remains a major global health concern and is one of the leading causes of mortality and long-term disability worldwide, accounting for nearly 12 million new cases each year [1]. Ischemic stroke constitutes approximately 80–85% of all stroke cases, followed by hemorrhagic subtypes. Timely identification of stroke severity is critical to predict clinical outcomes, tailor therapeutic strategies, and optimize recovery. However,

in many resource-limited settings, access to advanced neuroimaging is often constrained, highlighting the need for adjunctive and accessible diagnostic tools.

The retina offers a unique and noninvasive window into the microcirculation of the central nervous system. The retinal and cerebral microvasculature share similar embryologic origin, anatomical characteristics, and physiological properties [2,3]. As a result, changes in the retinal microvasculature may reflect cerebrovascular status and provide valuable insights into stroke pathophysiology. Studies have reported various retinal microvascular signs, such as generalized or focal arteriolar narrowing, arteriovenous nicking, microaneurysms, retinal hemorrhages, and cotton wool spots, in individuals with cardiovascular risk factors like hypertension, diabetes, and hyperlipidemia, all of which predispose to stroke [4,5].

In recent years, retinal vascular abnormalities have been recognized as potential biomarkers not only for the presence of cerebrovascular disease but also for its severity and prognosis [6,7]. Several population-based studies have shown that specific retinal changes, particularly narrower arteriolar caliber and wider venular caliber, are associated with an increased risk of lacunar infarcts, cerebral small vessel disease, and stroke mortality [6,8]. Moreover, certain retinal patterns have been linked to poor functional outcomes and recurrent vascular events after stroke [9].

Fundus photography is a simple, noninvasive, and cost-effective imaging modality that can capture high-resolution images of the retinal vasculature. With the advent of digital fundus cameras and automated image analysis techniques, it has become possible to quantify retinal vascular parameters with greater precision, reproducibility, and clinical applicability [8]. While most of the existing research has been

conducted in Western populations, there is a relative paucity of data from low- and middle-income countries like India, where the stroke burden is rising rapidly [10].

Understanding the spectrum of retinal microvascular changes in acute stroke patients and evaluating their association with stroke severity could provide an accessible and inexpensive tool to enhance clinical assessment, especially in settings where neuroimaging facilities are limited or delayed. This approach may also help in risk stratification, early intervention, and prognostic counseling.

The present study aims to examine the retinal microvascular changes in acute stroke patients using fundus photography and to evaluate their correlation with the severity of stroke. By exploring these retinal biomarkers, this study hopes to contribute to the growing body of evidence supporting the role of ocular imaging as a promising tool in cerebrovascular disease management.

**Material and Methods**

This was a prospective observational study conducted at the Department of Ophthalmology at a tertiary care hospital.

A total of 70 consecutive patients admitted with a diagnosis of acute stroke were enrolled in the study. Stroke was confirmed by clinical examination and neuroimaging (CT/MRI brain). Both ischemic and hemorrhagic stroke patients were included.

**Inclusion Criteria**

- Patients aged ≥18 years
- Diagnosis of acute stroke (ischemic or hemorrhagic) within 7 days of symptom onset
- Willingness to provide informed consent (or proxy consent from relatives if patient incapacitated)

**Exclusion Criteria**

- Pre-existing retinal diseases (e.g., diabetic retinopathy, retinal vein occlusion)

- Significant media opacity (e.g., dense cataract, vitreous hemorrhage) preventing fundus imaging
- History of previous stroke
- Uncooperative patients or those unable to undergo fundus photography

the Institutional Ethics Committee approved the study protocol. Written informed consent was obtained from all participants or their legal representatives. Confidentiality and privacy of all participants were maintained throughout the study.

Detailed demographic data, medical history, risk factors (hypertension, diabetes, smoking, hyperlipidemia), stroke type, and stroke severity were recorded. Stroke severity was assessed using the National Institutes of Health Stroke Scale (NIHSS) on admission.

All enrolled patients underwent a detailed ophthalmic evaluation, including visual acuity, anterior segment examination, and intraocular pressure measurement. Fundus examination was performed using a non-mydriatic digital fundus camera. Fundus photographs of both eyes were obtained, focusing on the optic disc and posterior pole. Retinal images were analyzed for the following microvascular changes:

- Generalized and focal arteriolar narrowing
- Arteriovenous (AV) nicking
- Microaneurysms
- Retinal hemorrhages
- Cotton wool spots
- Vessel tortuosity

Grading was done independently by two experienced ophthalmologists who were blinded to the clinical data.

The presence and extent of retinal microvascular changes were correlated with stroke severity as measured by NIHSS scores. Patients were stratified into mild, moderate, and severe stroke groups based on NIHSS.

**Statistical Analysis**

Data were entered into Microsoft Excel and analyzed using SPSS version 25. Descriptive statistics were presented as mean ± standard deviation (SD) for continuous variables and as frequencies and percentages for categorical variables. Correlation between retinal findings and stroke severity was analyzed using chi-square test, t-test, or ANOVA as appropriate. A p-value <0.05 was considered statistically significant.

**Results**

Table 1 shows the demographic and baseline characteristics of 70 acute stroke patients, where males accounted for 54.3% and females for 45.7%. Ischemic stroke was the most common type at 51.4%, followed by hemorrhagic stroke at 28.6% and lacunar stroke at 20%. Stroke severity grading revealed that most patients were in Grade II (54.3%), with fewer patients in Grade I and III (21.4% each), and a small proportion in Grade IV (2.9%).

Table 2 presents the correlation between stroke types and retinal microvascular changes. Generalized retinal arteriolar narrowing was seen in all hemorrhagic and lacunar stroke patients and in 91.7% of ischemic patients. Focal arteriolar narrowing was present in 65% of hemorrhagic, 61.1% of ischemic, and 100% of lacunar stroke cases. Arteriovenous nicking was observed in half of the hemorrhagic cases, 36.1% of ischemic cases, and all lacunar strokes. Hard and soft exudates were rare in hemorrhagic (5%) and ischemic (5.6%) strokes but common in lacunar strokes (78.6%). The mean arteriovenous ratio was lowest in lacunar strokes (0.410 ± 0.112), followed by hemorrhagic (0.560 ± 0.125) and ischemic strokes (0.590 ± 0.128), suggesting significant microvascular compromise in lacunar strokes.

**Table 1: Demographic and baseline characters of patients**

| Demographic characters | No. of patients | Percentage |
|---|---|---|
| Gender | | |
| Male | 38 | 54.3% |
| Female | 32 | 45.7% |
| Type of stroke | | |
| Hemorrhagic | 20 | 28.6% |
| Ischemic | 36 | 51.4% |
| Lacunar | 14 | 20% |
| Grade | | |
| Grade I | 15 | 21.4% |
| Grade II | 38 | 54.3% |
| Grade III | 15 | 21.4% |
| Grade IV | 2 | 2.9% |

**Table 2: Correlation between severities of stroke and of retinal micro-vascular changes**

| Parameters | Hemorrhagic (N=20) | Ischemic (N=36) | Lacunar (N=14) |
|---|---|---|---|
| Generalized retinal arteriolar narrowing Present (%) | 20 (100%) | 33 (91.7%) | 14 (100%) |
| Absent (%) | 0 (0%) | 3 (8.3%) | 0 (0%) |
| Focal arteriolar narrowing Present (%) | 13 (65%) | 22 (61.1%) | 14 (100%) |
| Absent (%) | 7 (35%) | 14 (38.9%) | 0 (0%) |
| Arteriovenous nicking Present (%) | 10 (50%) | 13 (36.1%) | 14 (100%) |

| | | | |
|---|---|---|---|
| Absent (%) | 10 (50%) | 23 (63.9%) | 0 (0%) |
| Hard and soft exudates Present (%) | 1 (5%) | 2 (5.6%) | 11 (78.6%) |
| Absent (%) | 19 (95%) | 34 (94.4%) | 3 (21.4%) |
| Arteriovenous ratio (Mean ± SD) mm | 0.560 ± 0.125 | 0.590 ± 0.128 | 0.410 ± 0.112 |

**Discussion**

This study evaluated the retinal microvascular changes in 70 acute stroke patients and explored their correlation with stroke severity. Our findings showed a high prevalence of generalized retinal arteriolar narrowing across all stroke subtypes, particularly in hemorrhagic and lacunar strokes. Focal arteriolar narrowing and arteriovenous nicking were also notably frequent in lacunar strokes, underscoring the extensive microvascular damage in small-vessel disease. These results are consistent with previous studies that demonstrated a strong association between retinal arteriolar narrowing and cerebrovascular pathology [4,5].

The ischemic stroke group in our cohort demonstrated retinal microvascular changes in over 90% of cases, with arteriovenous nicking seen in about one-third. Prior work suggests that retinal vascular narrowing reflects chronic hypertensive changes, which are often implicated in ischemic stroke pathogenesis [6,7]. Interestingly, we observed that hard and soft exudates were most common in lacunar strokes (78.6%), which likely reflects the microangiopathic nature of lacunar infarcts. This observation aligns with earlier reports linking retinopathy markers, such as microaneurysms and exudates, to cerebral small-vessel disease and white matter changes [12].

Fundus photography has emerged as a practical, noninvasive tool to assess microvascular health and predict neurological outcomes in stroke patients [8,9]. Studies have demonstrated that retinal microvascular abnormalities can serve as surrogates for cerebral microangiopathy and may help predict stroke recurrence and functional outcomes [10,13]. In our study, the lowest arteriovenous ratio was observed in the lacunar group (0.410 ± 0.112), indicating pronounced vessel caliber changes compared to ischemic or hemorrhagic stroke. This suggests that quantitative assessment of retinal vessels may aid in stratifying stroke subtypes and severity.

Although our study adds valuable regional data, it has certain limitations. The sample size was relatively small, and the study was conducted in a single center, which may limit the generalizability of the results. Additionally, we used non-mydriatic fundus photography, which, while practical, may have missed subtle peripheral retinal changes. Nevertheless, our findings highlight the potential role of retinal examination as a simple adjunctive tool in the assessment of stroke patients, particularly in settings with limited access to neuroimaging [14,15].

Future research should focus on larger, multicentric studies with advanced retinal imaging techniques, such as optical coherence tomography angiography (OCTA), to further refine the predictive value of retinal biomarkers in stroke [16]. Integrating retinal assessment into routine stroke evaluation could potentially improve risk stratification and guide personalized management strategies.

**Conclusion**

This study demonstrated that retinal microvascular abnormalities, especially generalized and focal arteriolar narrowing and arteriovenous nicking, are common in acute stroke patients and correlate with stroke severity, particularly in lacunar strokes.

Fundus photography offers a practical, noninvasive approach to assess these changes and may serve as a useful adjunct in clinical stroke evaluation. Strengthening awareness about the role of retinal imaging in stroke could help improve early detection, risk assessment, and management, especially in resource-limited settings.

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