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Original Article

Evaluation of Doppler Parameters of Ophthalmic Artery and Central Retinal Artery in Type 2 Diabetes Mellitus for Early Detection of Diabetic Retinopathy with Fundoscopic Correlation

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ABSTRACT

Background: Ophthalmic artery Doppler assessment provides a non-invasive method to evaluate orbital and cerebral microvascular changes. Alterations in Peak Systolic Velocity (PSV) and resistance indices may reflect early vascular dysfunction in systemic diseases.
Objectives: To compare Doppler parameters of the ophthalmic artery across three groups and determine the extent of vascular changes with disease progression.
Methods: This observational study included three groups of participants. Ophthalmic artery PSV was measured using standardized color Doppler ultrasonography. Mean values, standard deviations, and percentage changes between groups were calculated and compared.
Results: A progressive decline in ophthalmic artery PSV was observed from Group I (31.92 ± 6.69 cm/s) to Group II (31.69 ± 8.55 cm/s), and further to Group III (28.53 ± 14.90 cm/s). The percentage reduction was −0.72% from Group I to II and −9.97% from Group II to III, indicating increasing vascular resistance and impaired blood flow with disease severity.
Conclusion: Ophthalmic artery Doppler parameters demonstrate measurable deterioration across patient groups, suggesting early microvascular involvement. Doppler ultrasonography may serve as a useful adjunct for detecting vascular changes and monitoring disease progression. Further large-scale studies are warranted to strengthen these findings.

Keywords*: Ophthalmic artery, Doppler ultrasonography, Peak systolic velocity (PSV), Microvascular changes, Vascular resistance, Orbital blood flow, Disease progression, Non-invasive imaging.*

INTRODUCTION

Diabetic retinopathy (DR) is one of the most common microvascular complications of type 2 diabetes mellitus (T2DM) and remains a leading cause of preventable visual impairment and blindness in adults worldwide. The global prevalence of DR among individuals with diabetes is estimated to be approximately 35%, with vision-threatening retinopathy affecting nearly 10% of diabetic patients *[1]*. The burden continues to rise due to increasing life expectancy, urbanisation, sedentary lifestyles, and earlier onset of diabetes *[2]*.

Diabetic retinopathy is characterized by progressive retinal microangiopathy resulting from chronic hyperglycemia, oxidative stress, endothelial dysfunction, and capillary basement membrane thickening *[3,4]*. Conventionally, diagnosis and staging of DR rely on fundoscopic evaluation and retinal imaging. However, structural changes in retinal vasculature often occur only after significant microvascular damage has already taken place. Thus, identifying early functional vascular alterations is crucial for timely detection and prevention of irreversible vision loss *[5]*.

Color Doppler ultrasonography (CDU) has emerged as a non-invasive, cost-effective, and reliable imaging modality for assessing orbital vascular hemodynamics. It enables measurement of arterial blood flow parameters such as peak systolic velocity (PSV), end-diastolic velocity (EDV), and resistive index (RI) in vessels including the ophthalmic artery (OA)

and the central retinal artery (CRA) *[6]*. Several studies have reported that Doppler parameters progressively worsen with increasing severity of diabetic retinopathy, reflecting underlying microvascular compromise *[7,8]*. Increased RI and decreased EDV in CRA and OA have been strongly associated with advancing stages of DR and may serve as early biomarkers of retinal ischemia even before clinical retinopathy becomes apparent *[9]*.

Early identification of hemodynamic alterations in orbital vessels can therefore provide an opportunity for timely intervention, closer ophthalmic follow-up, and improved visual outcomes. Despite growing evidence, Doppler evaluation remains underutilised in routine diabetic screening, particularly in developing countries.

The present study aims to evaluate Doppler parameters of the ophthalmic artery and central retinal artery in patients with type 2 diabetes mellitus, with fundoscopic correlation, to determine their role in early detection of diabetic retinopathy.

MATERIALS AND METHODS

Source of Data

The study was conducted in the **Department of Radio-diagnosis**, Vydehi Institute of Medical Sciences and Research Centre (VIMS & RC), Bangalore, in collaboration with the **Department of Ophthalmology**.
The study population consisted of three groups:

Group I: Controls
Non-diabetic individuals referred to the Department of Radiodiagnostics for non-ocular imaging and having normal blood glucose levels.

Group II: Diabetic Patients Without Retinopathy / Mild–Moderate NPDR
Diabetic patients confirmed by haematological investigations and showing no retinopathy or mild to moderate non-proliferative diabetic retinopathy on fundus examination.

Group III: Diabetic Patients With Retinopathy
Diabetic patients presenting with moderate–severe NPDR or proliferative diabetic retinopathy (PDR), confirmed on ophthalmological evaluation.

Study Duration
May 2023 to December 2024

Study Design
Prospective observational study

Sample Size Calculation
The sample size was determined using the effect size of the difference in the Resistive Index (RI) between diabetic patients with and without retinopathy, based on previously published data (Madhpuriya et al., 2022).
Formula:

$$n_i = 2\left(\frac{Z_{1-\alpha/2} + Z_{1-\beta}}{ES}\right)^2$$

Where:

- $Z_{1-\alpha/2}$=1.96for 95% confidence interval
- $Z_{1-\beta}$=0.84for 80% power
- Effect Size (ES) = 0.67
  (from reference study: RI = 0.75 ± 0.03 vs 0.73 ± 0.03)

Substitution yielded:

$$n_i = 2(1.96+0.84/0.67)^2 = 32$$

Thus, **32 participants were required in each group**, giving a total sample size of 96 participants.

Data Collection
Data were collected from three categories of participants:

- Diabetic patients without retinopathy
- Diabetic patients with diabetic retinopathy (NPDR/PDR)
- Non-diabetic control participants

For each participant, **Color Doppler ultrasound (CDU)** evaluation of orbital vessels was performed to obtain the following hemodynamic parameters:

- **Peak Systolic Velocity (PSV)**

- **End-Diastolic Velocity (EDV)**
- **Resistive Index (RI)**

All measurements were recorded, analyzed, and compared across the three study groups.

Method of Evaluation

1. Determination of Diabetic Status

Diabetes mellitus was diagnosed using documented hematological test results including:

- Fasting plasma glucose
- Random or postprandial plasma glucose
- Glycosylated hemoglobin (HbA1c)

Classification into diabetic or non-diabetic category followed the **American Diabetes Association (ADA)** diagnostic criteria.

2. Ophthalmic Evaluation

All diabetic patients were examined by an ophthalmologist.
The evaluation included:

- Slit-lamp examination
- Dilated fundus examination using 90D lens
- Grading of diabetic retinopathy based on ETDRS criteria

Participants were categorized as:

- **Group II:** No DR or mild–moderate NPDR
- **Group III:** Moderate–severe NPDR or PDR

3. Color Doppler Ultrasonography

Color Doppler ultrasonography of the orbital vasculature was performed in the Department of Radio-diagnosis.
Equipment:

- **Samsung V6 Ultrasound System**
- **Samsung V8 Ultrasound System**

Transducer:

- Linear array probe
- Frequency range: **5–12 MHz**

Procedure:

- Participants were examined in the **supine position** with **30° head elevation**.
- A coupling gel was applied, and the probe was gently placed over the **closed upper eyelid**.
- Excessive pressure on the globe was avoided to prevent alteration in blood flow.
- Patients were instructed to look upward to optimize visualization.
- Spectral Doppler waveforms were recorded from:
  - **Ophthalmic Artery (OA)**
  - **Central Retinal Artery (CRA)**

Parameters Measured:

- **PSV (cm/s)**
- **EDV (cm/s)**
- **Resistive Index (RI)**, calculated as:

$$RI = \frac{PSV\text{-}EDV}{PSV}$$

Measurements were obtained bilaterally, and average values were used for analysis.

Inclusion Criteria

- Non-diabetic healthy individuals
- Diagnosed diabetic patients with documented blood glucose and HbA1c
- Diabetic patients with fundus-confirmed diabetic retinopathy

Exclusion Criteria

Participants were excluded if they had:

- Ocular infections, inflammation, or anatomical abnormalities
- History of glaucoma, high myopia (>6D), retinal vascular occlusion

- Previous ocular surgeries or pan-retinal photocoagulation
- Systemic conditions affecting ocular circulation, including:
    - Dyslipidemia
    - Diabetic nephropathy
    - Cardiovascular disease

Ethical Considerations

Ethical clearance for this study was obtained from the **Institutional Ethics Committee (IEC)** of Vydehi Institute of Medical Sciences and Research Centre.

- Detailed information about the study procedure was provided to all participants.
- Written informed consent was obtained before enrolment.
- All participant data were anonymised and handled confidentially.
- The study adhered to the ethical principles outlined in the **Declaration of Helsinki**.

Equipment Used

- **Samsung V6 Ultrasound Machine with linear probe**
- **Samsung V8 Ultrasound Machine with linear probe**

Figure. 1: Samsung V6 ultrasound machine and linear probe

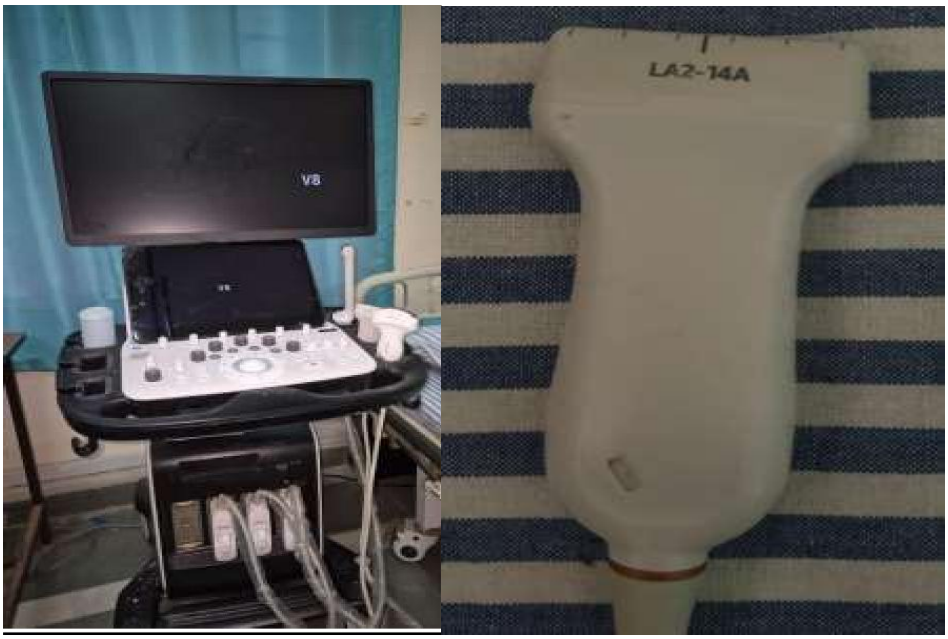

Figure. 2: Samsung V8 ultrasound machine and linear probe

RESULTS AND OBSERVATIONS

The study comprised a total of 96 subjects, who were divided into three groups with a sample size of 32 in each group: Group I (non-diabetic), Group II (Diabetic without retinopathy and with mild to moderate NPDR), and Group III (diabetic with retinopathy). The average age ranged from 40 to 65 years.

Table 1: Age-wise distribution in the study group

AGE GROUP	FREQUENCY	PERCENTAGE (%)
41-50 years	22	22.91 %
51- 60 years	32	33.33 %
>60 years	42	43.75 %
Total	96	100 %

The study included 96 participants, ranging in age from 40 to 65 years, with a median age of 59. They were divided into three age groups: 40 - 60 years (22 patients, 22.91%), between 51 and 60 years (32 patients, 33.3%), and greater than 60 years (42 patients, 43.75 %).

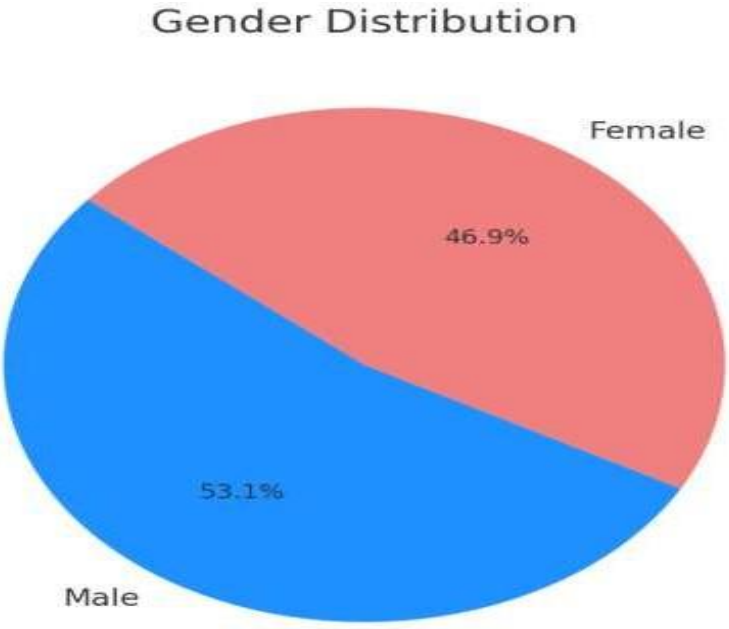

Figure3: Distribution of Gender in the study group

Table 2: Distribution based on clinical parameters of the study population

Parameter	Group I	Group II	Group III
Mean age of diabetes mellitus	0	3	10
Glycosylated Hb(%)	5.81±0.29	9.09±2.13	10.86±2.33

Table 2 compares three groups based on the Mean Age of Diabetes Onset and HbA1c levels. Group I shows no diabetes (0 years) with normal HbA1c (5.81%), while Group II (3 years) and Group III (10 years) have progressively higher HbA1c levels (9.09% and 10.86%), indicating worsening glycemic control with increasing diabetes duration

Table 3: Distribution based on affected side in the study group III

Symptom – blurring ofvision	Frequency	Percentage
Left	8	21.88%
Right	7	25.00%
Bilateral	17	53.12%
Total	32	100%

Table 3 presents the frequency and percentage of blurring of vision in a sample of32 individuals. Bilateral blurring (both eyes) is the most common symptom (53.12%), affecting more than half of the cases. Isolated right eye blurring occurs in 25.00%, while isolated left eye blurring is the least common at 21.88%. This distribution suggests that blurred vision more frequently affects both eyes rather than just one.

Table 4: Comparison of the Mean and the Standard Deviation in RI of central retinal artery

Group	Mean ± SD of RI	Percentage change
Group I	0.77 ± 0.07	2.60 % (Group I à Group II)
Group II	0.79 ± 0.15	7.59 % (Group II à Group III)
Group III	0.85 ± 0.13	10.39% (Group I à Group III)

Table 4 shows the Central Retinal Artery Resistive Index (CRA RI) across three groups, with corresponding percentage changes. Group I starts at 0.77, with a 2.60% increase to Group II (0.79), indicating mild vascular resistance. Group III (0.85) shows a 7.59% rise from Group II and a 10.39% total increase, suggesting progressive vascular impairment. The increasing RI trend may indicate worsening microvascular health, potentially due to conditions like diabetes

Table 5: Comparison of the Mean and the Standard Deviation in PSV of central retinal artery

Group	Mean ± SD ofPSV(cm/sec)	Percentage change
Group I	12.77 ± 4.19	32.18 %(Group I à Group II)
Group II	8.66 ± 4.88	1.39%(Group II à Group III)
Group III	8.54 ± 2.76	33.12%(Group I à Group III)

Table 5 presents the Mean ± SD of CRA PSV across three groups, along with percentage changes between them. From Group I to Group II, there is a sharp 32.18% decrease, indicating a significant drop in blood flow velocity. The change from Group II to Group III is minimal (1.39%), suggesting stabilization at lower PSV levels. Overall, Group I to Group III shows a total 33.12% decline, reflecting a progressive reduction in retinal blood circulation.

Table 6: Comparison of the Mean and the Standard Deviation in EDV of central retinal artery

Group	Mean ± SD of EDV(cm/sec)	Percentage change
Group I	2.74 ± 1.16	-7.30% (Group I à Group II)
Group II	2.54 ± 1.05	-16.54% (Group II à Group III)
Group III	2.12 ± 1.06	-22.63% (Group I à Group III)

Table 6 shows a progressive decline in the end-diastolic velocity (EDV) of the central retinal artery across the three groups. From Group I to Group II, there is a 7.30% decrease, indicating a mild reduction in blood flow. The decline becomes more pronounced with a 16.54% decrease from Group II to Group III, highlighting worsening vascular compromise. Overall, the cumulative reduction from Group I to Group III is 22.63%, suggesting a significant deterioration in blood circulation, potentially linked to advancing stages of diabetic retinopathy

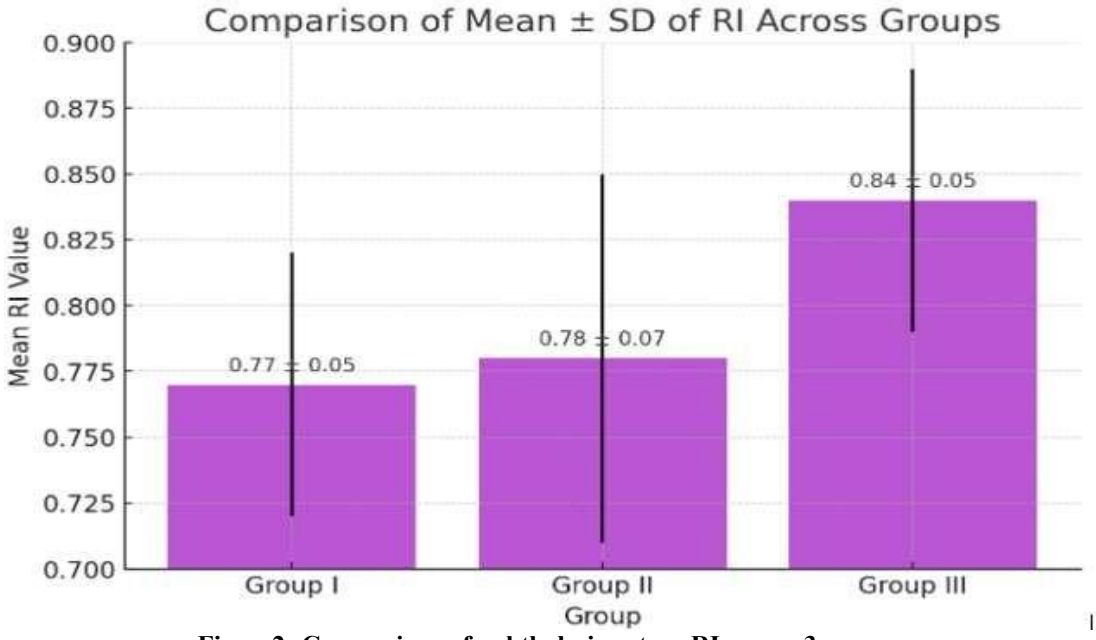

Figure2: Comparison of ophthalmic artery RI across 3 groups

Table:7 Comparison of PSV and EDV of Ophthalmic Artery Across Groups

Group	PSV (cm/sec) Mean ± SD	% Change (PSV)	EDV (cm/sec) Mean ± SD	% Change (EDV)
Group I	31.92 ± 6.69	-0.72% (Group I → II)	7.26 ± 2.51	-18.73% (Group I → II)
Group II	31.69 ± 8.55	-9.97% (Group II → III)	5.90 ± 2.98	-20.17% (Group II → III)
Group III	28.53 ± 14.90	-10.62% (Group I → III)	4.71 ± 4.08	-35.12% (Group I → III)

Both PSV and EDV show a progressive decline from Group I to Group III. The reduction in PSV is moderate, indicating gradually decreasing systolic blood flow. In contrast, EDV shows a much larger drop, reflecting significant impairment in diastolic retinal perfusion. This pattern suggests worsening ophthalmic artery hemodynamics and increasing microvascular dysfunction across the groups.

DISCUSSION

The present study evaluated Doppler hemodynamic parameters of the ophthalmic artery (OA) and the central retinal artery (CRA) in type 2 diabetic patients and correlated them with the presence and severity of diabetic retinopathy (DR). The findings revealed a **progressive increase in Resistive Index (RI)** and a **significant decline in both Peak Systolic Velocity (PSV) and End-Diastolic Velocity (EDV)** from non-diabetic individuals (Group I) to diabetics without retinopathy (Group II), and further to diabetics with retinopathy (Group III). These observations support the hypothesis that orbital Doppler changes precede and accompany microvascular damage in DR.

In the present study, **CRA RI increased from 0.77 to 0.85**, showing a total rise of 10.39%, while CRA EDV decreased by 22.63% from Group I to Group III. Similar trends have been consistently reported. Dimitrova & Kato demonstrated that CRA RI rises significantly as DR progresses, reflecting increased downstream resistance caused by capillary basement membrane thickening, pericyte loss, and microaneurysm formation *[12]*. Erdoğan et al. also observed that CRA EDV was markedly lower in PDR compared to NPDR, linking reduced diastolic flow to worsening retinal ischemia *[13]*. Our findings strengthen these earlier conclusions by showing a clear, quantifiable progression in RI and EDV across the three groups.

The study also recorded a **32.18% sharp decline in CRA PSV from controls to early diabetic patients**, followed by stabilization at lower levels in advanced DR. Reduced PSV suggests impaired systolic perfusion due to vessel wall rigidity and endothelial dysfunction. Previous studies by Goebel & Kretzchmar-Gross reported lower CRA PSV in diabetics and attributed it to narrowing of precapillary arterioles and increased vascular impedance *[7,18]*. Similar findings by Tripathi et al. further support that PSV reduction correlates with worsening glycemic control and microvascular compromise *[10]*.

For the ophthalmic artery, although PSV declined only modestly (10.62%), OA EDV showed a substantial drop (35.12%) between Group I and Group III. EDV is the most sensitive marker of distal vascular resistance, and its reduction suggests progressive impairment of perfusion in smaller retinal arterioles. Aburn & Sergott previously demonstrated that OA Doppler parameters reflect early changes in orbital vasculature, even before clinically detectable DR develops *[6]*. Our study supports this by showing measurable OA flow abnormalities in Group II (diabetics without DR/mild NPDR), highlighting the role of CDU in early detection.

The strong correlation between **duration of diabetes, elevated HbA1c levels, and Doppler abnormalities** observed in this study is well documented in literature. The UKPDS showed that chronic hyperglycemia leads to cumulative endothelial injury and microvascular dysfunction *[17]*. Higher HbA1c levels in Group III (10.86%) corresponded with marked deterioration in Doppler flow parameters, supporting findings by Bhanushali et al., who linked poor glycemic control to increased RI and reduced CRA velocities *[11]*.

The underlying mechanisms for reduced flow include chronic hyperglycemia-induced oxidative stress, thickening of the capillary basement membrane, loss of pericytes, endothelial damage, and eventual capillary occlusion *[3,4]*. These pathophysiological changes collectively increase peripheral vascular resistance and reduce perfusion in both CRA and OA, explaining the trends observed in this study.

Overall, the results confirm that **orbital Doppler sonography is a sensitive, non-invasive method for detecting early hemodynamic changes in diabetic eyes**. As Doppler abnormalities were observed even in diabetics without visible DR, its use may help identify high-risk individuals before fundoscopic changes appear. This has significant clinical value in screening, risk stratification, and timely referral for ophthalmic evaluation.

However, the study has certain limitations. The cross-sectional design does not allow assessment of temporal progression or predictive accuracy of Doppler parameters. Additionally, factors such as intraocular pressure, systemic hypertension, and autonomic neuropathy—which can affect ocular blood flow—were not measured. Future longitudinal studies with larger sample sizes and multimodal imaging (OCT-A, fluorescein angiography) may further clarify the clinical role of Doppler indices.

In summary, the present study shows that **CRA and OA Doppler parameters deteriorate progressively with increasing severity of diabetic retinopathy**, and that RI and EDV are particularly sensitive indicators of early microvascular dysfunction. Color Doppler ultrasonography, therefore, represents a valuable adjunct tool for early detection and monitoring of diabetic retinal vascular changes.

CONCLUSION

In this study, progressive worsening of ophthalmic artery Doppler parameters was observed from Group I to Group III, indicating declining orbital vascular function. The reduction in PSV and rise in vascular resistance suggest early microvascular compromise associated with disease severity. These findings highlight the potential role of ophthalmic artery Doppler as a non-invasive tool for detecting subtle vascular alterations and monitoring progression. Further studies with larger samples are needed to validate its diagnostic and prognostic value.

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