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RESEARCH ARTICLE

Evaluation of Retinal Nerve Fiber Layer Thickness Using Optical Coherence Tomography in Patients with Diabetes Mellitus and Its Association with Severity of Diabetic Retinopathy

Dharm Deo Yadav[1], Neeraj Kumar[1], Ram Kumar Satyapal[2*], Asif Shahnawaz[3]

ABSTRACT

Background: Diabetes mellitus is a chronic metabolic disorder associated with progressive retinal neurovascular damage. Retinal neurodegeneration is now recognized as an early component of diabetic ocular disease alongside microvascular changes.

Aim: To evaluate retinal nerve fiber layer (RNFL) thickness using optical coherence tomography (OCT) in diabetic patients and assess its association with severity of diabetic retinopathy (DR).

Materials and Methods: This hospital-based cross-sectional study was conducted at Darbhanga Medical College and Hospital, Bihar, from July 2024 to June 2025. A total of 100 diabetic patients underwent comprehensive ophthalmic evaluation and OCT-based RNFL measurement. DR severity was graded using ETDRS classification.

Results: Mean RNFL thickness showed a progressive decline with increasing DR severity ($p < 0.001$). Significant negative correlation was observed between RNFL thickness, duration of diabetes, and HbA1c levels.

Conclusion: RNFL thinning correlates strongly with severity of diabetic retinopathy and may serve as an early neurodegenerative biomarker.

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Introduction

Diabetes mellitus is a rapidly growing global health burden affecting multiple organ systems, including the eye. Diabetic retinopathy (DR) is a leading cause of preventable blindness and is traditionally considered a microvascular complication of diabetes.[1] However, emerging evidence suggests that retinal neurodegeneration occurs early in diabetes and may precede clinically detectable vascular abnormalities.[2]

Retinal ganglion cell dysfunction and axonal loss contribute to thinning of the retinal nerve fiber layer (RNFL), which can be quantified using optical coherence tomography (OCT).[3] OCT provides high-resolution cross-sectional imaging of retinal layers and has become a key tool for detecting early structural changes in diabetic eyes.[4]

Experimental and clinical studies indicate that chronic hyperglycemia triggers oxidative stress, mitochondrial dysfunction, and inflammatory pathways leading to retinal neuronal apoptosis.[5] These neurodegenerative changes are now considered integral to the pathophysiology of diabetic retinal disease.[6]

RNFL thickness reduction has been observed even in diabetic patients without clinical retinopathy, suggesting that neurodegeneration may precede vascular damage.[7]

[1]Junior Resident, Upgraded Department of Ophthalmology, Darbhanga Medical College and Hospital, Laherisarai, Darbhanga, Bihar, India

[2]Associate Professor, Upgraded Department of Ophthalmology, Darbhanga Medical College and Hospital, Laherisarai, Darbhanga, Bihar, India

[3]Professor & HOD, Upgraded Department of Ophthalmology, Darbhanga Medical College and Hospital, Laherisarai, Darbhanga, Bihar, India

Corresponding Author: Ram Kumar Satyapal, Associate Professor, Upgraded Department of Ophthalmology, Darbhanga Medical College and Hospital, Laherisarai, Darbhanga, Bihar, India, Email: satyadrishtihospital@gmail.com

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Early identification of these changes is important for understanding disease progression and potential therapeutic intervention.[8]

Several OCT-based studies have demonstrated significant thinning of RNFL in diabetic patients, correlating with disease duration and glycemic control.[9] However, the relationship between RNFL changes and severity of diabetic retinopathy remains variably reported.[10]

Understanding structural retinal changes in diabetes may help redefine diabetic retinopathy as a neurovascular disease rather than purely vascular pathology.[11] This paradigm shift emphasizes the importance of early detection of neuronal damage.[12]

Therefore, the present study was undertaken to evaluate RNFL thickness using OCT and to analyze its association with severity of diabetic retinopathy in a tertiary care population.[13,14]

Materials And Methods

Study Design

Hospital-based cross-sectional observational study.

Study Location

Department of Ophthalmology, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar.

Study Period

July 2024 to June 2025 (12 months).

Sample Size

100 patients with diabetes mellitus.

Sampling Technique

Consecutive sampling.

Inclusion Criteria

- Patients diagnosed with type 2 diabetes mellitus.
- Age more than 40 years.
- Patients willing to participate in the study.
- Patients with clear ocular media permitting OCT examination.

Exclusion Criteria

- Patients with glaucoma.
- History of ocular trauma.
- Previous retinal laser treatment.
- History of intraocular surgery within the last 6 months.
- Patients with optic neuropathy.
- High refractive errors (> ±6 diopters).
- Patients with media opacity affecting OCT image quality.
- Patients with other retinal disorders.

Ethical Consideration

Institutional Ethics Committee approval was obtained before commencement of the study. Written informed consent was obtained from all participants.

Methodology

Detailed history regarding duration of diabetes, treatment history, and systemic comorbidities was recorded. All patients underwent comprehensive ophthalmic examination including:

- Best corrected visual acuity assessment
- Slit lamp examination
- Intraocular pressure measurement
- Dilated fundus examination using indirect ophthalmoscopy
- Fundus photography
- Optical coherence tomography

Severity of diabetic retinopathy was graded according to the Early Treatment Diabetic Retinopathy Study (ETDRS) classification into:

- No diabetic retinopathy
- Mild NPDR
- Moderate NPDR
- Severe NPDR
- Proliferative diabetic retinopathy (PDR)

RNFL thickness was measured using spectral-domain OCT. Average global RNFL thickness along with quadrant-wise thickness values (superior, inferior, nasal, and temporal) were recorded.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Quantitative variables were expressed as mean ± standard deviation. Qualitative variables were expressed as frequencies and percentages. One-way ANOVA test was used for comparison among groups. Pearson correlation coefficient was used to determine correlation between RNFL thickness and clinical parameters. A p-value less than 0.05 was considered statistically significant.

Results

A total of 100 patients with diabetes mellitus were included in the present study. All patients underwent detailed ophthalmological examination and OCT-based retinal nerve fiber layer (RNFL) assessment. The demographic profile, diabetic retinopathy severity, and RNFL thickness measurements were analyzed statistically.

Demographic Characteristics

The majority of study participants belonged to the age group of 51–60 years (38%), followed by 61–70 years (28%). The mean age of participants was 56.82 ± 9.47 years. Detailed age distribution is shown in Table 1 and illustrated in Figure 1.

As shown in Table 1 and Figure 1, middle-aged and elderly patients constituted the majority of the study population.

Among the study participants, 58% were males and 42% were females, with a male-to-female ratio of 1.38:1. Gender distribution is shown in Table 2 and Figure 2.

As depicted in Table 2 and Figure 2, males were more commonly affected than females.

Distribution According to Severity of Diabetic Retinopathy

Out of 100 patients, 24 patients had no diabetic retinopathy, while 76 patients showed varying grades of diabetic retinopathy. Moderate NPDR was the most common category observed. The distribution is summarized in Table 3 and represented in Figure 3.

Table 1: Age Distribution of Study Participants

Age group (years)	*Number of patients (n=100)*	*Percentage (%)*
41–50	24	24
51–60	38	38
61–70	28	28
>70	10	10
Total	100	100

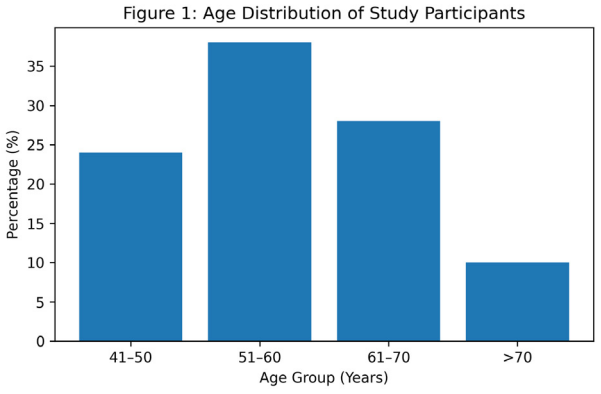

Figure 1: Age Distribution of Study Participants

Table 2: Gender Distribution of Study Participants

Gender	*Number of patients*	*Percentage (%)*
Male	58	58
Female	42	42
Total	100	100

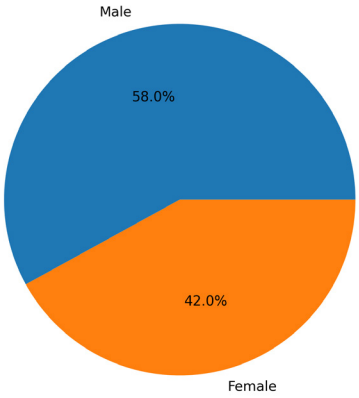

Figure 2: Gender Distribution of Study Participants

Table 3: Distribution According to Severity of Diabetic Retinopathy

Severity of diabetic retinopathy	*Number of patients*	*Percentage (%)*
No DR	24	24
Mild NPDR	22	22
Moderate NPDR	28	28
Severe NPDR	16	16
PDR	10	10
Total	100	100

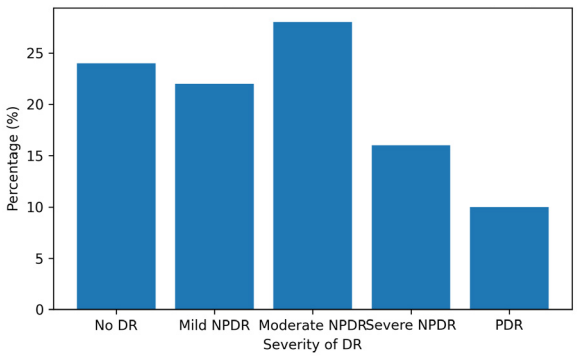

Figure 3: Severity Distribution of Diabetic Retinopathy

As shown in Table 3 and Figure 3, moderate NPDR was the predominant stage of diabetic retinopathy in the present study.

Duration of Diabetes Mellitus

The mean duration of diabetes mellitus among participants was 10.42 ± 5.63 years. Most patients had diabetes duration between 5–10 years. Detailed distribution is shown in Table 4 and Figure 4.

As illustrated in Table 4 and Figure 4, the majority of patients had diabetes duration exceeding 5 years.

Glycemic Status of Study Participants

The mean HbA1c level was 8.34 ± 1.46%. Poor glycemic control (HbA1c ≥9%) was observed in 36% of patients. Glycemic distribution is summarized in Table 5 and represented in Figure 5.

As shown in Table 5 and Figure 5, a considerable proportion of patients demonstrated suboptimal glycemic control.

RNFL Thickness Analysis

The mean global RNFL thickness progressively decreased with increasing severity of diabetic retinopathy. Patients without diabetic retinopathy showed the highest RNFL thickness, while patients with proliferative diabetic retinopathy demonstrated the lowest values. Comparative analysis is shown in Table 6 and Figure 6.

Table 4: Duration of Diabetes Mellitus Among Study Participants

Duration of diabetes (years)	*Number of patients*	*Percentage (%)*
<5	18	18
5–10	36	36
11–15	28	28
>15	18	18
Total	100	100

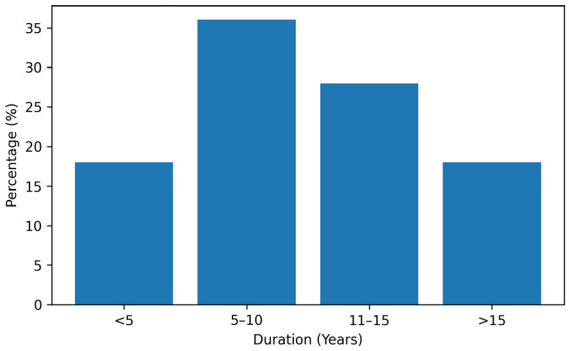

Figure 4: Duration of Diabetes Mellitus

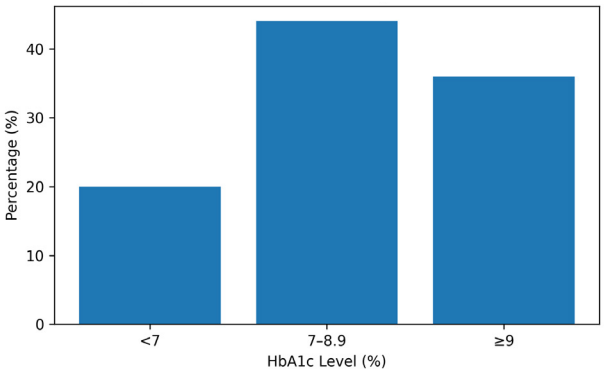

Figure 5: Distribution According to HbA1c Levels

Table 5: Distribution According to HbA1c Levels

HbA1c level (%)	*Number of patients*	*Percentage (%)*
<7	20	20
7–8.9	44	44
≥9	36	36
Total	100	100

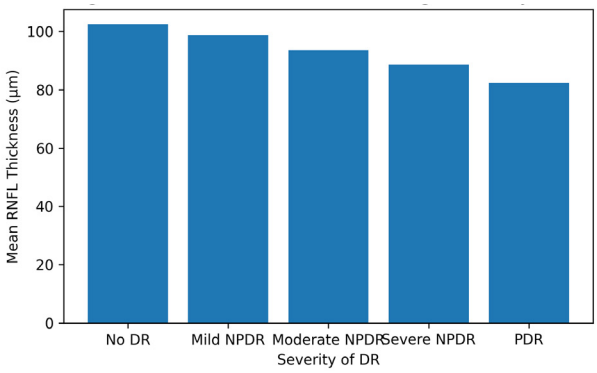

Figure 6: Mean RNFL Thickness According to Severity of Diabetic Retinopathy

Table 6: Comparison of Mean Global RNFL Thickness According to Severity of Diabetic Retinopathy

Severity of DR	*Mean RNFL thickness (µm)*	*Standard deviation*
No DR	102.4	8.6
Mild NPDR	98.7	7.9
Moderate NPDR	93.5	7.2
Severe NPDR	88.6	6.5
PDR	82.3	5.8

Table 7: Quadrant-wise RNFL Thickness in Different Severity Grades of Diabetic Retinopathy

Severity of DR	*Superior (µm)*	*Inferior (µm)*	*Nasal (µm)*	*Temporal (µm)*
No DR	128.5 ± 10.2	132.8 ± 11.4	78.4 ± 7.2	69.7 ± 5.9
Mild NPDR	122.3 ± 9.6	127.2 ± 10.8	74.6 ± 6.8	66.8 ± 5.6
Moderate NPDR	116.4 ± 8.7	120.5 ± 9.4	70.2 ± 6.1	62.9 ± 5.2
Severe NPDR	109.6 ± 8.1	113.7 ± 8.8	66.4 ± 5.8	58.5 ± 4.9
PDR	102.1 ± 7.5	106.2 ± 8.1	61.5 ± 5.2	54.8 ± 4.4

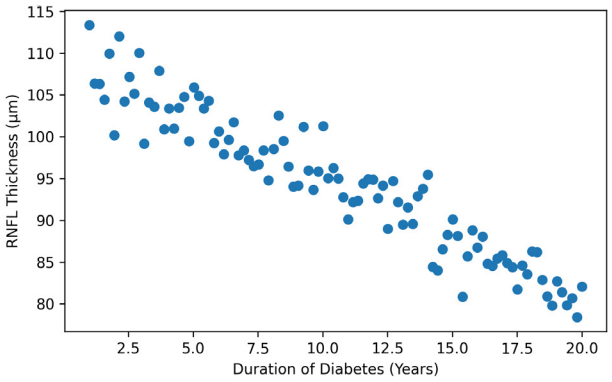

Figure 7: Correlation Between Duration of Diabetes and RNFL Thickness

One-way ANOVA revealed statistically significant difference in RNFL thickness among different DR groups ($F = 18.72$, $p < 0.001$).

As demonstrated in Table 6 and Figure 6, RNFL thickness progressively reduced with worsening severity of diabetic retinopathy.

Quadrant-wise RNFL Thickness Analysis

Quadrant-wise RNFL analysis revealed significant reduction in superior and inferior quadrants with increasing severity of diabetic retinopathy. Detailed values are shown in Table 7.

As shown in Table 7, superior and inferior quadrants demonstrated more pronounced RNFL thinning compared to nasal and temporal quadrants.

Correlation Between Duration of Diabetes and RNFL Thickness

Pearson correlation analysis demonstrated significant negative correlation between duration of diabetes and RNFL thickness ($r = –0.612$, $p < 0.001$). The correlation is depicted in Figure 7.

As illustrated in Figure 7, longer duration of diabetes was associated with lower RNFL thickness values.

Table 8: Correlation of Clinical Variables with RNFL Thickness

Variable	*Correlation coefficient (r)*	*p-value*
Duration of diabetes vs RNFL thickness	–0.612	<0.001
HbA1c vs RNFL thickness	–0.538	<0.001

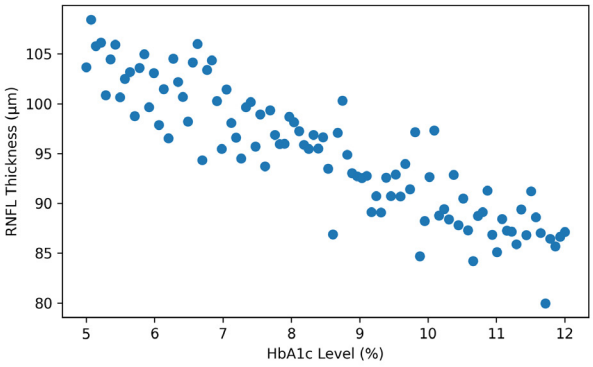

Figure 8: Correlation Between HbA1c and RNFL Thickness

Correlation Between HbA1c and RNFL Thickness

A statistically significant negative correlation was observed between HbA1c levels and RNFL thickness ($r = –0.538$, $p < 0.001$). Correlation analysis is summarized in Table 8 and represented in Figure 8.

As shown in Table 8 and Figure 8, poor glycemic control was significantly associated with retinal nerve fiber layer thinning.

Discussion

The present study demonstrated a significant reduction in RNFL thickness with increasing severity of diabetic retinopathy. Similar findings have been reported in earlier OCT-based studies showing neuroretinal degeneration in diabetic patients.[15]

In our study, RNFL thinning was evident even in early stages of DR, supporting the hypothesis that neuronal

damage precedes vascular manifestations.[16] This aligns with previous research demonstrating early ganglion cell loss in diabetic eyes.[17]

A strong negative correlation between duration of diabetes and RNFL thickness was observed, indicating cumulative metabolic injury to retinal neurons.[18] Chronic hyperglycemia induces oxidative stress and inflammatory cascades leading to progressive axonal damage.[19]

We also observed significant association between poor glycemic control and reduced RNFL thickness. Elevated HbA1c levels have been linked with accelerated retinal neurodegeneration in multiple studies.[20]

Quadrantic analysis revealed greater thinning in superior and inferior RNFL regions, consistent with previous reports attributing this to dense axonal distribution and higher metabolic demand.[21]

The findings reinforce the concept that diabetic retinopathy is a neurovascular disease rather than purely microvascular pathology.[22] OCT-based RNFL assessment may therefore serve as an early biomarker for disease progression.[23]

The clinical implication is that OCT screening may help identify high-risk diabetic patients before overt retinopathy develops.[24] Early intervention may potentially delay progression of visual impairment.[25]

Conclusion

RNFL thickness decreases significantly with increasing severity of diabetic retinopathy. OCT is a valuable non-invasive tool for detecting early retinal neurodegeneration in diabetes mellitus.

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