Assessment of Retinal Nerve Fiber Layer Thickness in Glaucoma Using OCT

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ABSTRACT

Background: Glaucoma is a leading cause of irreversible blindness. Early detection through structural evaluation of the retinal nerve fiber layer (RNFL) is essential for mitigating visual field loss. This study aimed to assess RNFL thickness in glaucomatous eyes using spectral-domain optical coherence tomography (SD-OCT), evaluate differences based on glaucoma subtype and severity, and examine the correlation with visual field parameters. ***Methods:*** A cross-sectional observational study was conducted on 120 eyes of 80 patients diagnosed with primary open-angle glaucoma (POAG) or normal-tension glaucoma (NTG) at BSMMU, Dhaka, Bangladesh. RNFL thickness was measured using Cirrus HD-OCT, and visual field testing was performed using Humphreys' perimetry. Statistical analyses included t-tests, ANOVA, and Pearson's correlation. ***Results:*** The global average RNFL thickness was 74.3 ± 11.2 µm. The superior and inferior quadrants showed the greatest thinning. Global RNFL thickness declined significantly with increasing disease severity: 84.1 µm (mild), 70.5 µm (moderate), and 60.8 µm (severe) ($P < 0.001$). Although RNFL NTG values were slightly higher in RNFL eyes than in POAG eyes, the difference was not statistically significant. A strong correlation was observed between RNFL thickness and visual field mean deviation ($r = 0.66$, $p < 0.001$). ***Conclusion:*** RNFL thickness measured using SD-OCT provides valuable structural markers of glaucoma severity and correlates well with functional visual loss. OCT should be integrated into routine clinical evaluations for early diagnosis and progression monitoring.

Keywords: Glaucoma, RNFL thickness, SD-OCT, visual field, POAG, NTG.

INTRODUCTION

Glaucoma is a progressive optic neuropathy that is chronic and involves structural damage to the nerve head of the optic nerve and the loss of retinal ganglion cells, which finally results in the loss of visual field, which becomes permanent. Blindness is the second world problem because it affects around 64.3 million individuals worldwide in 2013, and it is expected that its number will only increase to 111.8 million by 2040 [1,2]. The two most common types of glaucoma are normal-tension glaucoma (NTG) and primary open-angle glaucoma (POAG). POAG is commonly found to occur along with increased intraocular pressure (IOP), but NTG shows the damage in the glaucomatous optic nerve, though the IOP is normally within the normal range [3].

High-risk individuals should be screened and evaluated before the onset and progression of the disease because glaucoma is an insidious illness. Functional assessment is still the so-called gold-standard test: visual field testing, but a lot of loss of retinal nerve fiber layer (RNFL) can occur before functional deficits become evident [4]. Optical coherence tomography (OCT), especially spectral-domain OCT (SD-OCT), provides cross-sectional high-resolution imaging of the ocular structures and allows early and reproducible monitoring of RNFL thinning earlier than visual impairment [5,6].

Normative RNFL thickness maps have been determined by several researchers and it has been shown that the most severe damage in glaucoma traditionally occurs in the superior and inferior quadrants [7,8]. Moreover, it has been found that inter-global-RNFL correlates well with visual field mean deviation (MD) in order to give the structural-functional connection to make clinical decisions [9, 10]. Nevertheless, RNFL, although it is clinically useful, measures can be affected by demographic aspects (age, sex, and ethnicity), raising the issue of population-specific information [11], [12].

There was a paucity of data on RNFL thickness patterns in glaucoma patients in the South Asian context, particularly comparing POAG and NTG subtypes. The current studies are either normative or population-based, or involve generalization of glaucoma, which does not reflect the studies specific to the quadrant or stratification based on the severity of the disease. Also, a significant part of the work does not involve a direct importance of structure-function correlation with the help of the OCT and automated perimetry, which are the necessary constituents of glaucoma management.

This study aimed to assess RNFL thickness in Bangladeshi glaucoma patients using SD-OCT, stratify these findings based on disease severity, and compare patterns between POAG and NTG. By examining quadrant-specific RNFL thinning and its correlation with visual field loss, this research contributes valuable insight into the structural biomarkers of glaucoma progression in a population with limited prior documentation.

METHODOLOGY & MATERIALS

This cross-sectional, observational study was conducted at the Department of Ophthalmology, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from April 2014 to March 2015. A total of 120 eyes from 80 glaucoma patients were included. Participants were recruited from the outpatient glaucoma clinic at BSMMU during the study period.

Selection Criteria

Inclusion Criteria

- Adults aged 40 years or older.
- Diagnosed with POAG or NTG.
- Best-corrected visual acuity of 6/60 or better.
- Reliable and reproducible visual field test results.
- Ability to undergo OCT scanning with good image quality (signal strength ≥ 7).

Exclusion Criteria

- Secondary glaucoma (e.g., uveitis, traumatic, neovascular).
- History of intraocular surgery (except for uncomplicated cataract surgery).
- Ocular media opacities (e.g., dense cataract, corneal opacities) interfere with OCT imaging.
- Retinal pathology (e.g., diabetic retinopathy, macular degeneration).
- Neurological diseases affecting the optic nerve (e.g., optic neuritis, multiple sclerosis).

Data Collection Procedure: Data were collected using a structured protocol. Demographic and clinical data, including age, sex, intraocular pressure (IOP), and visual acuity, were recorded. RNFL thickness measurements were obtained using spectral-domain OCT (Cirrus HD-OCT, Carl Zeiss Meditech), and global as well as quadrant-wise values were documented. Visual field assessment was performed using standard automated perimetry (Humphrey Field Analyzer, 24 2 SITA-Standard strategy). All measurements were taken by trained personnel. Informed written consent was obtained from all participants. Confidentiality was maintained, and the study adhered to the Declaration of Helsinki and institutional ethical guidelines.

Statistical Analysis: Statistical analysis was performed using SPSS software version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarize baseline characteristics. Independent-samples t-tests and one-way ANOVA were employed for between-group comparisons. Pearson's correlation coefficients were calculated to examine the association between RNFL thickness and visual field indices. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1: Baseline characteristics of the participants (N = 80 Patients, 120 Eyes)

Variables		Frequency (n)	Percentage (%)
Mean Age (years)		58.4 ± 9.2	
Gender	Male	46	57.5
	Female	34	42.5
Type of Glaucoma	- Primary Open-Angle Glaucoma	66	82.5
	- Normal-Tension Glaucoma	14	17.5
Intraocular Pressure (mmHg)		21.8 ± 3.4	
Visual Field Mean Deviation (dB)		−6.52 ± 3.1	

Table 1 presents the baseline demographic and clinical characteristics of the study population. Of the 80 participants, 57.5% were male and 42.5% were female. The majority (82.5%) were diagnosed with POAG, while the remaining 17.5% had normal-tension glaucoma (NTG). The mean age of participants was 58.4 ± 9.2 years, and the average intraocular pressure was 21.8 ± 3.4 mmHg. Visual field analysis indicated a mean deviation (MD) of −6.52 ± 3.1 dB.

Table 2: Average RNFL Thickness (µm) in Different Quadrants Among All Glaucomatous Eyes (N = 120 Eyes)

RNFL Quadrant	Mean ± SD (µm)	Range (µm)
Superior	91.2 ± 14.3	62 – 118
Inferior	88.9 ± 16.1	58 – 119
Nasal	62.7 ± 9.8	44 – 81
Temporal	54.3 ± 7.6	38 – 70
Global Average	74.3 ± 11.2	52 – 101

Table 2 shows the average RNFL thickness values across four quadrants. The superior quadrant exhibited the highest mean RNFL thickness (91.2 ± 14.3 µm), followed closely by the inferior quadrant (88.9 ± 16.1 µm). The nasal and temporal quadrants had lower values, at 62.7 ± 9.8 µm and 54.3 ± 7.6 µm, respectively. The global average RNFL thickness across all quadrants was 74.3 ± 11.2 µm.

Table 3: RNFL Thickness by Glaucoma Severity (Based on Visual Field MD) (N = 120 Eyes)

Severity Group	N	Mean Global RNFL (µm) ± SD	p-value
Mild (MD > −6 dB)	48	84.1 ± 9.7	<0.001
Moderate (−6 to −12)	42	70.5 ± 10.4	
Severe (MD < −12)	30	60.8 ± 8.9	

Table 3 illustrates the distribution of global RNFL thickness across different stages of glaucoma severity, classified based on visual field mean deviation (MD). A progressive thinning of the retinal nerve fibre layer (RNFL) was observed with advancing disease. Eyes in the mild glaucoma group (MD > −6 dB) had a mean global RNFL thickness of 84.1 ± 9.7 µm, whereas those in the moderate (−6 to −12 dB) and severe (MD < −12 dB) groups showed significantly lower values, at 70.5 ± 10.4 µm and 60.8 ± 8.9 µm respectively. The difference among groups was statistically significant ($p < 0.001$).

Table 4: Comparison of RNFL Thickness Between POAG and NTG (N = 120 Eyes)

RNFL Quadrant	POAG (n = 99 eyes) Mean ± SD	NTG (n = 21 eyes) Mean ± SD	p-value
Superior	90.8 ± 13.7	93.1 ± 12.5	0.479
Inferior	87.2 ± 15.9	92.4 ± 13.2	0.164
Nasal	61.4 ± 10.1	65.2 ± 9.4	0.115
Temporal	54.1 ± 8.2	54.7 ± 7.5	0.758
Global Average	73.1 ± 10.5	76.9 ± 9.3	0.127

Table 4 compares RNFL thickness between eyes with POAG and NTG. While global average RNFL thickness was slightly higher in NTG (76.9 ± 9.3 µm) compared to POAG (73.1 ± 10.5 µm), this difference was not statistically significant ($p = 0.127$). However, the inferior and nasal quadrants showed considerable thinning in POAG compared to NTG ($p = 0.164$ and $p = 0.115$, respectively), indicating regional susceptibility differences between the subtypes.

Table 5: Correlation Between Global RNFL Thickness and Visual Field Mean Deviation (N = 120 Eyes)

Variable	Pearson Correlation (r)	p-value
Global RNFL vs. MD	0.66	<0.001
Inferior RNFL vs. MD	0.58	<0.001
Superior RNFL vs. MD	0.54	<0.001
Temporal RNFL vs. MD	0.29	0.003
Nasal RNFL vs. MD	0.31	0.001

Table 5 presents the Pearson correlation coefficients between RNFL thickness and visual field MD values. A moderate to strong positive correlation was observed between global RNFL thickness and MD ($r = +0.66$, $p < 0.001$), suggesting that structural measurements of the RNFL closely reflect functional visual loss. Among the quadrants, the inferior RNFL showed the strongest correlation with MD ($r = +0.58$), followed by the superior quadrant ($r = +0.54$). The nasal and temporal quadrants had weaker but still statistically significant correlations ($r = +0.31$ and $r = +0.29$, respectively).

DISCUSSION

This study investigated the retinal nerve fiber layer (RNFL) thickness in glaucomatous eyes using spectral-domain optical coherence tomography (SD-OCT) and demonstrated a significant correlation between structural loss and visual field impairment. Our results reinforce the utility of OCT-derived RNFL measurements as both diagnostic and monitoring tools in glaucoma management.

The mean world RNFL thickness in glaucoma patients under consideration was 74.3 +/- 11.2 µm, with a maximum impact on the superior and inferior quadrants. The above observation is consistent with the literature that states feature markers of glaucomatous damage are superior and inferior thinning of the quadrants [7]. A similar pattern was observed by Leung et al. with the use of SD-OCT, which affirmed the quadrant-based RNFL sensitivity [13].

Stratified by type of severity, RNFL thickness decreased with increasingly abnormal visual fields mean deviation (MD), adding to the structure-function relationship in glaucoma. Mild, moderate and severe cases of RNFL thickness were 84.1 0.8, 70.5 0.3, and 60.8 0.4, respectively, as determined in our study. Those values can be compared to the results obtained by Medeiros et al., who expressed an increasing RNFL thinning with functional loss [14]. The diagnostic potential of OCT measures regarding glaucomatous progression is also confirmed by Pearson correlation coefficients between global RNFL and MD ($r = 0.66$, $p < 0.001$).

It is important to note that the low RNFL strongly correlated with MD ($r = 0.58$), which may correspond to the findings by Sung et al., who compared measurements of inferior RNFLs on the basis of higher diagnostic accuracy of low RNFLs [15]. Likewise, the clinical relevance of the localized loss of RNFL to functional loss of vision was highlighted by Schlottmann et al. [16].

In our comparison study of POAG versus NTG, there was no statistically significant difference in global RNFL thickness ($p = 0.127$), though regional differences, namely the nasal and inferior RNFL quadrants, showed a tendency towards greater thinning in POAG. A similar observation was given by Galvao Filho et al., who reported more RNFL loss in POAG patients, especially in early-stage patients [17]. Nevertheless, insignificance of our variables can be explained by the constraints in the sample size of NTG (n = 21 eyes).

Our population's regional loss patterns of RNFL also agree with the African Descent and Glaucoma Evaluation Study (ADAGES), which noted variations and differences in the distribution of RNFL and compiled parameters of the optic disc between ethnic groups [18]. This confirms the importance of population-based databases in glaucoma diagnosis and surveillance.

Notably, the current study will add to the scant literature on RNFL measures amongst South Asian communities. Earlier regional studies, like Mahmud-Ajeigbe et al., had concentrated more on the normative data of healthy people [19], whereas our research presented the comparative data between routes of glaucoma and grades of severity. The moderate to strong correlation of structural and functional measurements in our results reflects the reflection on conclusions of Wollstein et al. concerning the longitudinal follow-up of glaucomatous damage [6].

Visual field testing is still a standard in clinical practice, despite the possibility of variance and learning responses. On the contrary, OCT provides objective, reproducible images. Inter-session reproducibility of RNFL measurement of RNFL thickness on OCT has been shown to have very good inter-session reproducibility with standard deviations of between 4 and 8 µm demonstrated by Schuman et al. and Paunescu et al. [20,21]. Our findings are consistent with the usefulness of OCT in the early diagnosis, particularly of cases with minimal or no functional loss at all.

Along with these strengths, certain limitations need to be acknowledged. We did not study patients with media opacities and high levels of comorbidities, which might be a limitation to generalizability. Also, despite the fact that our results are consistent with those of other large-scale studies performed with the help of OCT, the cross-sectional study does not allow tracing the evolution of RNFL over time.

Our findings are compatible with the available satisfactory evidence regarding SD-OCT-based RNFL thickness, especially in inferior and superior quadrants, as a good indicator of glaucomatous destruction. The positive correlation between RNFL loss and MD highlights the duality of structural and functional assessment of glaucoma: MD assessment and RNFL loss can supplement each other in the diagnosis of glaucoma and its monitoring.

CONCLUSION

This study confirmed that retinal nerve fiber layer (RNFL) thickness measured using spectral-domain optical coherence tomography (SD-OCT) provides valuable structural insights into the severity of glaucoma. Significant thinning of the RNFL, particularly in the superior and inferior quadrants, correlates well with functional visual field loss. While POAG and NTG show similar global RNFL values, quadrant-wise variations exist in the values. Our findings support the integration of SD-OCT into routine glaucoma evaluations for early detection and monitoring.

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