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ORIGINAL ARTICLE

Assessment of Peripapillary Retinal Nerve Fibre Layer and Ganglion Cell Layer Thickness by Spectral Domain Optical Coherence Tomography in Primary Open-Angle Glaucoma Patients-A One-Year Cross-Sectional Study

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Abstract:

Introduction: Glaucoma is a chronic, progressive optic neuropathy characterised by degeneration of retinal ganglion cells (RGCs) and their axons, leading to characteristic visual field defects and irreversible blindness if untreated. Traditionally, glaucoma diagnosis and monitoring relied on functional assessment using standard automated perimetry. However, structural changes in the retinal nerve fibre layer (RNFL) and ganglion cell layer (GCL) precede detectable visual field loss

Methodology: A hospital-based cross-sectional observational study was conducted at KLE's Dr. Prabhakar Kore Hospital, Belagavi, over one year (April 2023-March 2024). Thirty-four patients with POAG aged over 18 years underwent a detailed ocular examination and SD-OCT imaging. RNFL and GC-IPL thicknesses were measured in superior and inferior quadrants. Statistical analyses included ANOVA, Spearman's correlation, and post-hoc tests.

Results: Spectral-domain optical coherence tomography (SD-OCT) revealed significant thinning of the peripapillary retinal nerve fibre layer (RNFL) with increasing severity of glaucoma. The superior RNFL thickness was recorded as 118 ± 15 µm in early glaucoma, 80 ± 24 µm in moderate glaucoma, and 92 ± 29 µm in advanced glaucoma. Assessment of macular ganglion cell layer (GCL) thickness showed a declining trend across the severity spectrum.

Conclusion: The integration of SD-OCT parameters into clinical evaluation enhances diagnostic precision, enables earlier detection of structural alterations preceding visual field loss, and facilitates better risk stratification and disease management.

Keywords: Primary open-angle glaucoma, Spectral domain optical coherence tomography, Peripapillary retinal nerve fibre layer thickness, Ganglion cell layer thickness

INTRODUCTION

Glaucoma is a chronic, progressive optic neuropathy characterised by degeneration of retinal ganglion cells (RGCs) and their axons, leading to characteristic visual field defects and irreversible blindness if untreated. Among its subtypes, primary open-angle glaucoma (POAG) is the most prevalent form globally, often asymptomatic until significant visual loss occurs (1). It is estimated that by 2040, nearly 111.8 million individuals will be affected worldwide, with a substantial disease burden in Asia and Africa (2). The disease pathophysiology involves a complex interplay of elevated intraocular pressure (IOP), vascular dysregulation, oxidative stress, and genetic susceptibility, all contributing to axonal damage at the optic nerve head (3).

Traditionally, glaucoma diagnosis and monitoring relied on functional assessment using standard automated perimetry. However, structural changes in the retinal nerve fibre layer (RNFL) and ganglion cell layer (GCL) precede detectable visual field loss (4). This emphasizes the importance of early structural evaluation to prevent progression and vision loss. The advent of spectral-domain optical coherence tomography (SD-OCT) has revolutionized glaucoma diagnostics by enabling high-resolution, quantitative imaging of the RNFL and macular layers, providing objective and reproducible measurements (5,6).

Several studies have demonstrated that thinning of the peripapillary RNFL and macular GCL-inner plexiform layer (GC-IPL) correlates strongly with glaucoma severity and visual field defects (7,8). The superior and inferior quadrants of the RNFL are particularly susceptible to early glaucomatous damage due to the arrangement of retinal nerve fibres (9). Similarly, the macular GC-IPL complex, containing over 50% of all retinal ganglion cells, offers an additional sensitive parameter for detecting early neuroretinal damage (10). Comparative analyses have shown that structural parameters obtained from SD-OCT, especially the RNFL

and GC-IPL thickness, can predict functional loss and serve as biomarkers of disease progression (11–13).

Given the chronic nature of POAG and the irreversible nature of visual impairment, early detection through structural biomarkers is paramount. Therefore, the present study aims to assess the peripapillary RNFL and macular GCL thickness using SD-OCT in patients with varying stages of POAG and to evaluate their correlation with disease severity. Such data are crucial for establishing robust structure–function relationships and optimizing individualized management strategies in glaucoma care.

MATERIAL AND METHODS

Methodology: A hospital-based cross-sectional study was conducted from April 2023 to March 2024 in the Department of Ophthalmology, KLE's Dr. Prabhakar Kore Hospital, Belagavi. It included patients over 18 years diagnosed with primary open-angle glaucoma (POAG) who gave consent. Patients with BCVA <20/40, media opacities, anterior segment anomalies, prior intraocular surgery, secondary glaucoma, or retinal diseases affecting retinal thickness or visual fields were excluded.

A minimum sample size of 34 was calculated using a prevalence of 74% for early to moderate glaucoma, 5% significance, and 20% allowable error. Participants were selected by convenience sampling. After ethical clearance and consent, each underwent detailed ophthalmic evaluation including visual acuity testing, slit-lamp examination, gonioscopy, applanation tonometry, and optic disc assessment with a 90D lens following dilation with tropicamide 0.8% and phenylephrine 5%. Indirect ophthalmoscopy was performed to rule out other retinal disorders.

Structural imaging was performed using the Topcon-Maestro 3D Spectral Domain Optical Coherence Tomography (SD-OCT), which provided measurements of peripapillary retinal nerve fibre layer (RNFL) thickness and macular ganglion cell-inner plexiform layer (GC-IPL) thickness in superior and inferior quadrants.

Statistical Analysis: Statistical analysis was conducted using SPSS version 21.0 and Microsoft Excel. Continuous data were expressed as mean ± standard deviation. Categorical variables were presented as frequencies and percentages. Depending on distribution, comparisons between groups were performed using Student's t-test, one-way ANOVA and non-parametric tests. Post hoc analysis was conducted using Tukey's test. Correlations between structural and functional parameters were assessed using Spearman's rho test. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 34 patients diagnosed with primary open-angle glaucoma (POAG) were included in the study, with a mean age of 60.38 ± 12.96 years. The study population showed a clear male predominance, with 82.4% males and 17.6% females. A family history of glaucoma was present in 14.7% of the participants. Among systemic comorbidities, hypertension was the most common, affecting 35.1% of the subjects, followed by diabetes mellitus in 21.6%.

Visual acuity assessment revealed that 50% of participants had a presenting visual acuity between 6/6 and 6/12, while 47.1% had visual acuity ranging from 6/12 to 6/60. A relative afferent pupillary defect (RAPD) was detected in only one patient (2.9%), indicating optic nerve dysfunction in that case.

Evaluation of the optic nerve head (ONH) showed that 58.8% of participants had a cup-to-disc (C:D) ratio between 0.3 and 0.6, while 38.2% had ratios ranging from 0.7 to 0.9. These findings suggest that a considerable proportion of patients exhibited moderate to advanced optic nerve cupping. Additional optic disc changes included thinning of the neuroretinal rim in 16.7% of eyes, bayonetting in 16.7%, splinter haemorrhages in 11%, laminar dot sign in 11%, and temporal pallor in 22.2% of cases. The mean intraocular pressure (IOP) measured by applanation tonometry was 22.1 ± 7.3 mmHg. Gonioscopic evaluation confirmed open angles in all eyes.

Structural analysis using spectral-domain optical coherence tomography (SD-OCT) revealed significant thinning of the peripapillary retinal nerve fibre layer (RNFL) with increasing severity of glaucoma. The superior RNFL thickness was recorded as 118 ± 15 µm in early glaucoma, 80 ± 24 µm in moderate glaucoma, and 92 ± 29 µm in advanced glaucoma.

Similarly, the inferior RNFL thickness measured 124 ± 17 µm, 86 ± 26 µm, and 89 ± 36 µm in early, moderate, and advanced glaucoma, respectively. These findings demonstrated a statistically significant difference in RNFL thickness among the different severity groups ($p < 0.001$). Post-hoc analysis further confirmed that the differences in RNFL thickness between early and both moderate and advanced groups were statistically significant.

Assessment of macular ganglion cell layer (GCL) thickness showed a declining trend across the severity spectrum. Superior GCL thickness was 62.96 ± 17.09 µm in early glaucoma, 66.17 ± 16.26 µm in moderate, and 56 ± 12.93 µm in advanced glaucoma. Inferior GCL thickness showed a similar trend, with values of 65.65 ± 15.18 µm, 66.17 ± 17.43 µm, and 56.7 ± 9.81 µm in early, moderate, and advanced glaucoma, respectively. Correlation analysis revealed a significant relationship

between GCL thickness and glaucoma stage, particularly in advanced disease (p = 0.019).

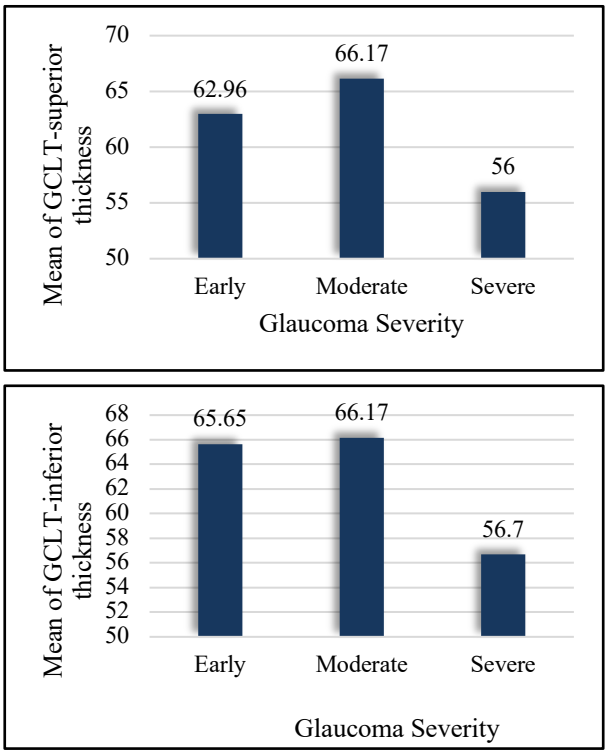

Figure 1: Mean Ganglion cell layer-superior and inferior layer thickness

DISCUSSION

In the present study, structural analysis using spectral-domain optical coherence tomography (SD-OCT) revealed a significant reduction in peripapillary retinal nerve fibre layer (RNFL) and macular ganglion cell layer (GCL) thickness in patients with primary open-angle glaucoma (POAG). The superior and inferior RNFL quadrants demonstrated the most pronounced thinning, consistent with the characteristic pattern of glaucomatous damage. These findings are in agreement with previous reports highlighting the strong relationship between structural loss and glaucoma severity (1,3).

Structural analysis using SD-OCT revealed significant thinning of the peripapillary RNFL across all stages of glaucoma. Superior and inferior RNFL thicknesses decreased progressively from early to advanced disease, with statistically significant differences between early and advanced groups ($p < 0.001$). The mean superior RNFL thickness decreased from 118 µm in early glaucoma to 80 µm and 92 µm in moderate and advanced glaucoma, respectively, indicating a clear trend of structural deterioration with disease progression. Braeu et al. reported similar results, observing that RNFL loss becomes more prominent with increasing disease severity and may precede detectable functional deficits (8). Additionally, Vazquez and Huang demonstrated that RNFL thickness, particularly in the inferior and superior quadrants, serves as a reliable biomarker for glaucomatous optic nerve damage and disease staging (5,14).

The inferior and superior regions of the RNFL are anatomically predisposed to early glaucomatous damage due to the distribution and arrangement of retinal nerve fibres entering the optic disc (9). These regions contain densely packed axons from the macular and arcuate areas, rendering them more susceptible to intraocular pressure (IOP)-related stress and vascular compromise (4). This topographical pattern explains the early appearance of arcuate scotomas and nasal steps in the visual field, which correspond to structural loss in these quadrants.

Our study also demonstrated a decline in macular GCL thickness with increasing glaucoma severity. Although intergroup differences were not statistically significant in isolation, the overall correlation between GCL thinning and disease stage was significant ($p = 0.019$). This finding underscores the diagnostic relevance of macular imaging in glaucoma. Marie et al. observed a similar decline in GC-IPL thickness with disease severity, emphasizing its value in early detection (15). Acosta et al. also confirmed a strong correlation between GCL thickness and moderate stages of glaucoma ($p < 0.001$), supporting the use of macular structural parameters as complementary tools in glaucoma evaluation (12).

The macular GC-IPL complex contains over 50% of all retinal ganglion cells, and its evaluation provides a sensitive indicator of neuronal loss even before perimetric changes appear. Mwanza et al. demonstrated that macular GC-IPL measurements using SD-OCT show high reproducibility and diagnostic accuracy in differentiating normal from glaucomatous eyes (6). However, some variability exists in reported associations between GCL thickness and disease stage. Hou et al. found no statistically significant correlation between GCL thinning and glaucoma severity ($p = 0.586$), possibly due to device algorithm differences, population variability, or sample size limitations (13).

A combined assessment of peripapillary RNFL and macular GCL thickness may offer a more comprehensive evaluation of glaucomatous damage. San Pedro et al. found a strong correlation between these two parameters in both glaucoma suspects and confirmed cases, indicating their complementary diagnostic value (7). While RNFL analysis primarily reflects axonal damage, GCL measurement captures neuronal loss at the macular level, enhancing the sensitivity of glaucoma detection, especially in early disease stages (11).

The results of the present study also align with the structure–function relationship described by Hood and Kardon, where structural changes in the RNFL and GCL precede functional loss on standard automated perimetry

(9). Hence, OCT-based measurements can facilitate earlier diagnosis and more effective monitoring of progression, even before visual field defects manifest.

In conclusion, our findings reinforce the clinical utility of SD-OCT-derived parameters, particularly peri-papillary RNFL and macular GCL thickness, as reliable structural biomarkers in POAG. Integrating newer imaging modalities such as swept-source OCT and OCT angiography may further enhance diagnostic precision by evaluating microvascular changes in the optic nerve head and macula.

CONCLUSION

The present study highlights the crucial role of spectral-domain optical coherence tomography (SD-OCT) in the structural assessment of glaucomatous optic neuropathy. A significant reduction in peripapillary retinal nerve fibre layer (RNFL) and macular ganglion cell layer (GCL) thickness was observed with increasing severity of primary open-angle glaucoma (POAG). The superior and inferior RNFL quadrants exhibited the greatest degree of thinning, consistent with the characteristic pattern of glaucomatous damage. Furthermore, the observed correlation between GCL thickness and disease stage emphasizes the importance of macular analysis in detecting early neuroretinal changes.

These findings reaffirm that both peripapillary RNFL and macular GCL measurements provide complementary and objective structural biomarkers for diagnosing and monitoring glaucoma. The integration of SD-OCT parameters into clinical evaluation enhances diagnostic precision, enables earlier detection of structural alterations preceding visual field loss, and facilitates better risk stratification and disease management.

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