ORIGINAL RESEARCH PAPER
Volume - 14 | Issue - 03 | March - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

EVALUATION OF RETINAL NERVE FIBER LAYER AND GANGLION CELL-INNER PLEXIFORM LAYER THICKNESS IN GLAUCOMA: A PROSPECTIVE STUDY USING OPTICAL COHERENCE TOMOGRAPHY

Ophthalomology

Dr Suhail Fayaz Postgraduate Student, Postgraduate Department Of Ophthalmology. Govt Medical College, Srinagar. Kashmir

Dr Asima Hassan* Senior Resident, Postgraduate Department Of Ophthalmology. Govt Medical College, Srinagar. Kashmir *Corresponding Author

Prof. (Dr) Sajad Bashir Khanday Professor, Postgraduate Department Of Ophthalmology. Govt Medical College, Srinagar. Kashmir

ABSTRACT

Purpose: This study aims to assess the structural changes in retinal nerve fiber layer (RNFL) and ganglion cell-inner plexiform layer (GCIPL) thickness across different stages of glaucoma and evaluate their correlation with functional visual field (VF) to understand disease progression and diagnostic utility. **Methods:** A cross-sectional study was conducted on 100 glaucoma patients categorized into early (n=55), moderate (n=25), and advanced (n=20) stages. Optical coherence tomography (OCT) was used to measure RNFL and GCIPL thickness, while VF were assessed using standard automated perimetry. Data analysis was performed using IBM SPSS 23, with ANOVA and Pearson's correlation tests applied to compare groups and assess relationships between structural and functional parameters. **Results:** Significant progressive thinning of RNFL and GCIPL was observed with increasing glaucoma severity ($p < 0.001$). RNFL showed the greatest thinning in the superior and inferior quadrants, with average thickness declining from 80.3 µm in early glaucoma to 62.5 µm in advanced stages. GCIPL also showed marked thinning, with average thickness reducing from 74.0 µm to 59.8 µm. Strong correlations between RNFL ($r = 0.477$, $p < 0.001$) and GCIPL ($r = 0.397$, $p < 0.001$) with VF parameters were evident in early to moderate glaucoma. In advanced stages, superior GCIPL exhibited the strongest correlation with VF indices ($r = 0.495$, $p < 0.001$), overcoming the floor effect observed in average RNFL and GCIPL measurements. **Conclusion:** GCIPL analysis provides valuable diagnostic insights, especially in advanced glaucoma, where RNFL measurements are less reliable. OCT-based RNFL and GCIPL evaluations are indispensable tools for early detection and monitoring of glaucoma progression.

KEYWORDS

Glaucoma, Retinal Nerve Fiber Layer, Ganglion Cell-Inner Plexiform Layer, Optical Coherence Tomography, Visual Field, Disease Progression, Diagnostic Utility.

INTRODUCTION

Glaucoma is a chronic, progressive optic neuropathy and a leading cause of irreversible blindness worldwide(Lucy & Wollstein, 2016). It is characterized by structural and functional damage to the optic nerve, primarily resulting from the selective loss of retinal nerve fibers and ganglion cells(Tieger et al., 2017). The disease often begins with subtle structural changes in the retina, such as thinning of the retinal nerve fiber layer (RNFL) and ganglion cell-inner plexiform layer (GCIPL)(Ungar et al., 2012).

These changes occur before measurable functional deficits like visual field loss, which appear in later disease stages.The pathophysiology of glaucoma primarily involves the degeneration of ganglion cell axons, which are compressed and deformed at the optic disc lamina(Allison et al., 2020). This damage is often attributed to elevated intraocular pressure (IOP), although other factors such as vascular dysregulation and genetic predisposition also play a role(Osborne et al., 1999). Early detection and monitoring of glaucoma rely on the identification of structural changes in the retina, which reflect the natural history of the disease.(Kim et al., 2010)

Structural Markers In Glaucoma: RNFL And GCIPL

The RNFL reflects retinal ganglion cell axons, while the GCIPL includes their soma and dendrites, offering a more specific analysis (Scuderi et al., 2020). Unlike the GCC, GCIPL thinning precedes RNFL changes in early glaucoma, aligning with the degeneration sequence (Tieger et al., 2017). Monitoring GCIPL provides critical insights for early detection and intervention.

Advancements In Optical Coherence Tomography

The advent of OCT has transformed ophthalmology with non-invasive, high-resolution imaging of retinal structures) (Shiga et al., 2023). Advances in spectral-domain and swept-source OCT enable precise RNFL and GCIPL measurements, critical for glaucoma diagnosis, monitoring, and treatment evaluation. Modern OCT devices use automated segmentation algorithms for consistent GCIPL analysis, and trend-based monitoring detects subtle progression over time, enhancing glaucoma management.

Importance Of GCIPL Analysis In Glaucoma

While RNFL analysis is key for glaucoma assessment, GCIPL analysis complements it by detecting early glaucomatous changes, strongly correlating with visual field defects (Shiga et al., 2023). GCIPL analysis is especially valuable in advanced glaucoma, where RNFL measurements may reach a "floor effect," offering crucial insights into disease progression..

Rationale For The Study

While GCIPL analysis is gaining recognition, further research is needed to clarify its role in monitoring glaucoma progression. Unlike GCC, targeting GCIPL alone isolates the layers most impacted by glaucomatous damage. This study evaluates RNFL and GCIPL changes during early follow-ups, offering insights into disease progression and clinical practice..

Aims And Objectives

The aim of this study is to investigate the progression and patterns of retinal nerve fiber layer thickness and macular ganglion cell- inner plexiform layer thickness in order to assess the structural damage during the progression of glaucoma.

MATERIAL AND METHOD

This was a hospital-based, observational, prospective study conducted at the Postgraduate Department of Ophthalmology, GMC Srinagar, over a period of one year and six months. In the first six months, patients were enrolled in the study, and subsequently followed up at 6 months and 12 months from the day of recruitment.

Participants: A total of 100 glaucoma patients participated in the study.

Inclusion Criteria:

Age > 18 years, Primary open-angle glaucoma patients, Steroid-induced glaucoma, Pseudo-exfoliative glaucoma

Exclusion Criteria: Angle closure glaucoma/suspect, Intraocular diseases, Ocular trauma, Neurological disease affecting optic nerve, Patients not willing to participate in the study for any reason

Data Analysis Statistical Analysis:

Data analysis was performed using SPSS version 28.0, The normality of continuous variables was assessed using the Shapiro-Wilk test. Continuous variables are presented as mean ± standard deviation. Categorical variables are expressed as frequencies and percentages.

For comparison of continuous variables across the three groups (early, moderate, and advanced glaucoma), one-way analysis of variance (ANOVA) was used for normally distributed data, and the Kruskal-Wallis test was applied for non-normally distributed data. Post-hoc analysis was performed using Tukey's HSD test for ANOVA and Dunn's test with Bonferroni correction for Kruskal-Wallis test. Categorical variables were compared using the Chi-square test.

OCT parameters including retinal nerve fiber layer (RNFL) thickness and ganglion cell-inner plexiform layer (GCIPL) thickness measurements were analyzed using one-way ANOVA followed by Tukey's post-hoc test.

The relationship between visual field MD and OCT parameters was assessed using Spearman's correlation coefficient (r) due to non-normal distribution of the data. Correlation analysis was performed separately for combined early to moderate glaucoma group (n=80) and advanced glaucoma group (n=20) to evaluate potential differences in structure-function relationships across disease severity.

For all statistical tests, a two-tailed p-value <0.05 was considered statistically significant. Statistical power was calculated using G*Power version 3.1.9.7, and the study achieved >80% power for detecting differences in primary outcome measures

Table 1. Demographic And Baseline Characteristics Of Study Participants

Characteristic	Early Glaucoma (n=55)	Moderate Glaucoma (n=25)	Advanced Glaucoma (n=20)	P-value
Age (years)*	53 ± 12	53 ± 10	60 ± 13	<0.001
Gender				
Male, n (%)	30 (54.5)	14 (56.0)	9 (45.0)	0.399
Female, n (%)	25 (45.5)	11 (44.0)	11 (55.0)	

*Values are presented as mean ± standard deviation

The study included 100 participants distributed across three stages of glaucoma severity (Table 1). The mean age was significantly higher in the advanced glaucoma group (60 ± 13 years) compared to both early (53 ± 12 years) and moderate (53 ± 10 years) groups (p<0.001). Gender distribution was comparable across all groups, with no significant differences observed (p=0.399).

Table 2. Clinical Characteristics of Study Participants

Parameter	Early Glaucoma (n=55)	Moderate Glaucoma (n=25)	Advanced Glaucoma (n=20)	P-value
Spherical Equivalent (D)*	-1.65 ± 2.31	-1.53 ± 2.61	-2.07 ± 3.18	0.232
IOP (mmHg)*	16.8 ± 3.2	17.1 ± 3.5	17.5 ± 3.8	0.089

*Values are presented as mean ± standard deviation

As shown in Table 2, there were no statistically significant differences in spherical equivalent among the three groups (p=0.232). Similarly, intraocular pressure (IOP) measurements showed a slight increasing trend from early to advanced stages (16.8 ± 3.2 mmHg to 17.5 ± 3.8 mmHg) but did not reach statistical significance (p=0.089).

Table 3. OCT Parameters - Retinal Nerve Fiber Layer Thickness

RNFL Parameter (µm)*	Early Glaucoma (n=55)	Moderate Glaucoma (n=25)	Advanced Glaucoma (n=20)	P-value
Average	80.3 ± 9.5	70.5 ± 8.9	62.5 ± 8.9	<0.001
Superior Quadrant	95.2 ± 12.4	85.3 ± 10.8	75.4 ± 11.2	<0.001
Inferior Quadrant	92.8 ± 13.2	82.6 ± 11.5	73.2 ± 10.8	<0.001
Nasal Quadrant	72.5 ± 11.8	65.4 ± 10.2	58.3 ± 9.8	<0.001
Temporal Quadrant	65.8 ± 10.5	58.7 ± 9.8	52.4 ± 9.2	<0.001

*Values are presented as mean ± standard deviation

Analysis of OCT parameters (Table 3) revealed significant thinning of the retinal nerve fiber layer (RNFL) across all quadrants with disease progression. Average RNFL thickness decreased from 80.3 ± 9.5 µm in early glaucoma to 62.5 ± 8.9 µm in advanced cases (p<0.001). The superior and inferior quadrants showed the greatest absolute reduction in thickness, consistent with the typical pattern of glaucomatous damage.

Table 4. OCT Parameters - Macular Ganglion Cell-Inner Plexiform Layer Thickness

GCIPL Parameter (µm)*	Early Glaucoma (n=55)	Moderate Glaucoma (n=25)	Advanced Glaucoma (n=20)	P-value
Average	74.0 ± 6.3	69.1 ± 5.4	59.8 ± 14.0	<0.001
Superior	75.2 ± 6.8	70.3 ± 5.9	61.4 ± 13.8	<0.001
Inferior	72.8 ± 6.5	67.9 ± 5.7	58.2 ± 14.2	<0.001

*Values are presented as mean ± standard deviation

Table 4 demonstrates significant thinning of the ganglion cell-inner plexiform layer (GCIPL) with increasing disease severity. Average GCIPL thickness decreased from 74.0 ± 6.3 µm in early glaucoma to 59.8 ± 14.0 µm in advanced cases (p<0.001). Both superior and inferior regions showed similar patterns of progressive thinning (p<0.001).

Table 5. Correlation Between Visual Field MD and OCT Parameters

Parameter	Early to Moderate Glaucoma (n=80)	Advanced Glaucoma (n=20)
Average RNFL	0.477 (<0.001)	0.198 (0.177)
Average GCIPL	0.345 (<0.001)	0.093 (0.528)
Superior GCIPL	0.159 (0.012)	0.495 (<0.001)
Inferior GCIPL	0.397 (<0.001)	0.342 (0.020)

*Values are presented as mean ± standard deviation

The correlation analysis between visual field mean deviation and OCT parameters (Table 5) revealed significant associations in early to moderate glaucoma, with the strongest correlation observed for average RNFL thickness (r=0.477, p<0.001). Interestingly, in advanced glaucoma, the superior GCIPL showed the strongest correlation with MD (r=0.495, p<0.001), while average RNFL and GCIPL correlations were not significant, suggesting a possible floor effect in advanced disease stages.

DISCUSSION

This study evaluated the structural changes in retinal nerve fiber layer (RNFL) and ganglion cell-inner plexiform layer (GCIPL) thickness across different stages of glaucoma and their correlation with functional visual field (VF) loss. The results demonstrated significant progressive thinning of both RNFL and GCIPL as glaucoma severity increased, with key differences in their diagnostic utility at various stages.

Structural Changes In RNFL And GCIPL

RNFL analysis showed significant thinning from 80.3 µm in early glaucoma to 62.5 µm in advanced stages ($p < 0.001$), with the superior and inferior quadrants most affected. Similarly, GCIPL thickness declined from 74.0 µm to 59.8 µm ($p < 0.001$), indicating diffuse ganglion cell loss. The superior GCIPL remained strongly correlated with functional parameters ($r = 0.495$, $p < 0.001$), highlighting its value in tracking late-stage progression.

Correlations Between Structural And Functional Changes

The study found strong correlations between OCT parameters and VF indices in early to moderate glaucoma, with RNFL thickness ($r = 0.477$, $p < 0.001$) and inferior GCIPL ($r = 0.397$, $p < 0.001$) showing high diagnostic value. In advanced stages, these correlations weakened due to the floor effect, but the superior GCIPL remained a reliable marker ($r = 0.495$, $p < 0.001$) for monitoring progression..

Implications For Clinical Practice

RNFL analysis is vital for detecting early glaucomatous changes, while GCIPL analysis helps identify subtle structural changes, especially in regions correlating with functional loss. Quadrant-specific GCIPL analysis is valuable for tracking progression in advanced stages. The study highlights OCT as a reliable, non-invasive tool for glaucoma diagnosis and management.

Limitations Of The Study

The small sample size in the advanced glaucoma group (n = 20) limits generalizability, and the cross-sectional design restricts insight into longitudinal changes in RNFL and GCIPL thickness. Larger, standardized longitudinal studies incorporating additional functional measures, like multifocal electroretinography, are needed to validate and expand these findings..

CONCLUSION

This study highlights the progressive thinning of RNFL and GCIPL in glaucoma and their varying diagnostic utilities at different disease stages. While RNFL is a key marker in early glaucoma, GCIPL analysis offers complementary and, in some cases, superior diagnostic value, particularly in advanced stages. Incorporating both RNFL and GCIPL parameters into routine clinical practice can enhance early detection, improve disease monitoring, and optimize patient outcomes. Future research should focus on larger, longitudinal studies and explore advanced imaging techniques to refine diagnostic and monitoring strategies further.

REFERENCES

1. Allison, K., Patel, D., & Alabi, O. (2020). Epidemiology of Glaucoma: The Past, Present, and Predictions for the Future. Cureus, 12(11). https://doi.org/10.7759/cureus.11686
2. Kim, J. S., Ishikawa, H., Gabriele, M. L., Wollstein, G., Bilonick, R. A., Kagemann, L., Fujimoto, J. G., & Schuman, J. S. (2010). Retinal nerve fiber layer thickness measurement comparability between time domain optical coherence tomography (OCT) and spectral domain OCT. Investigative Ophthalmology and Visual Science, 51(2), 896–902. https://doi.org/10.1167/iovs.09-4110
3. Lucy, K. A., & Wollstein, G. (2016). Structural and functional evaluations for the early detection of glaucoma. Expert Review of Ophthalmology, 11(5), 367–376. https://doi.org/10.1080/17469899.2016.1229599
4. Osborne, N. N., Ugarte, M., Chao, M., Chidlow, G., Bae, J. H., Wood, J. P. M., & Nash, M. S. (1999). Neuroprotection in relation to retinal ischemia and relevance to glaucoma. Survey of Ophthalmology, 43(6 SUPPL.), 102–128. https://doi.org/10.1016/S0039-6257(99)00044-2
5. Scuderi, G., Fragiotta, S., Scuderi, L., Iodice, C. M., & Perdicchi, A. (2020). Ganglion cell complex analysis in glaucoma patients: What can it tell us? Eye and Brain, 12, 33–44. https://doi.org/10.2147/EB.S226319
6. Shiga, Y., Nishida, T., Jeoung, J. W., Di Polo, A., & Fortune, B. (2023). Optical coherence tomography and optical coherence tomography angiography: essential tools for detecting glaucoma and disease progression. Frontiers in Ophthalmology, 3. https://doi.org/10.3389/fopht.2023.1217125
7. Tieger, M. G., Hedges, T. R., Ho, J., Erlich-Malona, N. K., Vuong, L. N., Athappilly, G. K., & Mendoza-Santiesteban, C. E. (2017). Ganglion cell complex loss in chiasmal compression by brain tumors. Journal of Neuro-Ophthalmology, 37(1), 7–12. https://doi.org/10.1097/WNO.0000000000000424
8. Ungar, A. K., Wollstein, G., & Schuman, J. S. (2012). Optical coherence tomography in glaucoma. Diagnostic Technologies in Ophthalmology, 6(April 2012), 113–143. https://doi.org/10.2174/978160805133511201010113