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Longitudinal comparison of RNFL and mGCC thickness as predictors of assessing functional visual impairment in papilledema secondary to idiopathic intracranial hypertension

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Abstract

Background: Idiopathic intracranial hypertension (IIH) is marked by elevated intracranial pressure, which is evidenced by papilledema and imaging results, occurring without a discernible causal factor and the main objective of this study is to evaluate and compare the predictive value of retinal nerve fiber layer (RNFL) and macular ganglion cell complex (mGCC) thickness for best corrected visual acuity (BCVA), visual field index (VFI), pattern standard deviation (PSD) outcomes across three visits in both eyes.

Methods: Retrospective analysis conducted on 69 idiopathic intracranial hypertension patients over 3 visits at 0, 1, 3 months with examination of RNFL, mGCC thickness from optical coherence tomography (OCT) and BCVA, VFI, PSD from HVF 30-2 analysis. Linear regression models assessed the relationship between RNFL and mGCC thickness with VFI, PSD, BCVA. Predictive strength was evaluated using adjusted R^2 and regression coefficients.

Results: RNFL thickness consistently demonstrated higher adjusted R^2 values and stronger coefficients for predicting VFI, PSD, BCVA compared to mGCC. In the first visit RNFL predicted BCVA with an adjusted R^2 Value of 0.51 in right eye and 0.31 in left eye outperforming mGCC.

Conclusion: Longitudinal analysis reaffirms that, RNFL and mGCC thickness demonstrate significant associations with functional visual outcomes, while mGCC consistently shows stronger correlation with BCVA and comparable or slightly better predictive strength for PSD, particularly in second and third visits. RNFL remains a reliable predictor of VFI. mGCC may serve as more sensitive marker for central visual function, while RNFL maintains its robustness in broader functional assessments. Bilateral, sustained trends strengthen the evidence for integrating the structural parameters in clinical evaluation with mGCC, potentially offering insights into disease progression. Both markers should be considered complementary in longitudinal monitoring of papilledema.

Keywords: RNFL, mGCC thickness, visual impairment, papilledema

Introduction

Idiopathic intracranial hypertension (IIH) is characterized by increased intracranial pressure, manifested by papilledema and radiological findings, in the absence of an identifiable casual factor [1]. The primary symptoms include headache, vision loss, and pulsatile tinnitus, and are recognized to have profound impacts on quality of life and visual function [2]. Idiopathic intracranial hypertension is becoming one of the most common conditions causing papilledema leading to functional vision impairment ranging from decreased best corrected visual acuity (BCVA), decreased field of vision and pattern standard deviation (PSD) [3]. Depending on the severity of the condition, the change in BCVA or VFI, PSD may be transient to permanent. Multiple biomarkers and investigations have been used to diagnose and determine the severity of papilledema and for subsequent prediction of functional visual impairment including utilization of clinical 90 D examination of optic nerve and visual field examination but are characterized by interobserver variability and subjective variability respectively [4]. Recent utilization of structural optical coherence tomography (OCT) markers like RNFL thickness, mGCC evaluation has helped in estimating the severity of papilledema and also to correlate to the functional impairment of BCVA and Visual field Indices like VFI and PSD in IIH patients [5].

Although both show correlations with visual function, their Longitudinal Predictive value especially comparing both eyes has not been widely studied. Current study aims to compare RNFL and mGCC thickness as predictors for assessing functional visual impairment in papilledema secondary to idiopathic intracranial hypertension.

Materials and Methods

Study Design

A longitudinal retrospective study was conducted involving 136 eyes (comprising both right and left eyes) from 68 patients with idiopathic intracranial hypertension (IIH), representing various genders and age groups. The analysis utilized optical coherence tomography (OCT) to assess markers such as retinal nerve fiber layer (RNFL) thickness and macular ganglion cell complex (mGCC) thickness. Additionally, functional indicators were evaluated, including best corrected visual acuity and visual field indices from the humphrey visual field (HVF) 30-2 test, specifically the visual field index (VFI) and pattern standard deviation (PSD), across three separate visits at 0, 1, and 3 months. Using a Cirrus SD-OCT (Carl Zeiss Meditec), scans were performed in all the patients at baseline and at subsequent follow-ups and well-focused, uniformly illuminated images were obtained. The laser scanned a 6 × 6 mm area, capturing the data of the optic disc cube 200 × 200 (×2) consisting of 200 A-scans from 200 linear B-scans of 2 mm per A-scan. The HD 5-line raster scan, consisting of five speckles reduced B-scans of 9 mm long, each consisting of 1024 A-scans (each with an axial depth of 2 mm and 1024 pixels per A-scan) was performed. Using software provided with the SD-OCT the average retinal nerve fiber layer (RNFL) thickness for the total circumference was calculated.

Statistical Analysis

Linear Regression was used to model each outcome (BCVA, VFI, PSD) using RNFL and mGCC thickness as predictors for each visit and eye. Adjusted R^2 Values, Regression Coefficients were reported and P<0.005 is considered significant.

Results

A total of 3 visits were analyzed for both right eye and left eye, with corresponding structural and functional parameters recorded. The primary structural indicators were RNFL and mGCC thickness, and the functional correlates included visual field index (VFI), pattern standard deviation (PSD), best corrected visual acuity (BCVA).

The correlation coefficients between RNFL and mGCC thickness and functional parameters are presented in Table 1. RNFL Thickness demonstrated a moderate to strong positive correlation with VFI across all three visits in both eyes. This indicates that higher RNFL thickness is associated with better preservation of the visual field. mGCC thickness showed a stronger correlation compared to RNFL with BCVA, particularly in visit 2 and 3, suggesting that macular structural integrity may be a better predictor of central visual acuity. Correlation with PSD was moderate and negative for both RNFL and mGCC thickness, which is expected, as lower RNFL/mGCC thickness corresponds to higher PSD values (indicating greater localized visual field loss). Notably, mGCC displayed slightly higher correlation coefficients overall than RNFL, especially in the later visits, implying that mGCC may be a more sensitive structural maker for functional changes over time.

Figure 1 illustrates the mean RNFL and mGCC thicknesses at each of the three visits for both eyes. A gradual decrease in thickness was observed over time in both RNFL and mGCC, consistent with disease progression. The mGCC values declined more sharply than RNFL between visits 1 and 3 in both eyes, especially the left eye. When comparing both eyes, the left eye has exhibited more pronounced thinning, especially in mGCC values, indicating possible asymmetrical progression. This visualization reinforces the quantitative findings in the correlation table and supports the hypothesis that mGCC may serve as a more dynamic and responsive marker in monitoring the disease over time.

Figure 2 shows comparison of RNFL and mGCC predictive strengths for BCVA across three visits in both eyes. It shows a steady increase in mGCC in the left eye by visit 3 highlighting its sensitivity. Figure 3 shows a predictive strength for VFI and shows how RNFL consistently predicts VFI better than mGCC in both eyes over time. Figure 4 shows predictive strength for PSD and mGCC and showing stronger correlation with PSD than RNFL, especially by the third visit in the left eye.

Discussion

Papilledema secondary to idiopathic intracranial hypertension is characterized by decrease in visual acuity, visual field involvement in the acute stages which can be transient or permanent depending on the severity of papilledema. Clinical examination of papilledema was characterized by inter observer variability and visual field examination as a sole indicator for severity of disease progression is not reliable. Periodic structural evaluation of optic nerves provides us with a measure of objectivity and can also be used to assess the severity and progression of the disease.

SD-OCT measures the RNFL thickness and is a useful technique for assessing the structure of the optic disc in glaucoma and other optic neuropathies. It has also been used in the diagnosis and management of disc edema by quantifying a peripapillary RNFL thickness [6,7]. Retinal nerve fiber layer thickness is sensitive for monitoring acute IIH and evaluating treatment effect. Increased rim area and rim thickness and decreased optic cup volume are reliable parameters that indicate persistently increased CSF pressure and risk of relapse. OCT measures are sensitive and reliable for diagnosing subtle IIH even in the absence of papilledema [8].

However, some patients had an increase in RNFL thickness without a significant decrease in best corrected visual acuity (BCVA) in the acute and treatment phases of papilledema giving rise to a question whether it can be used as a sole marker to assess the functional impairment in visual acuity. In previous studies it has been identified that severe papilledema also affects the macular ganglion cells leading to a slightly more severe decrease in Best Corrected Visual Acuity [9].

Hence, macular optical coherence tomography (OCT) is an essential imaging modality for assessing central RGCs. Detection of OCT changes may provide an opportunity to initiate or escalate treatment to prevent irreversible VF loss. Therefore, by monitoring areas of the macula that have the greatest effects on the central VF, clinicians could then monitor the central VF to detect earlier loss and determine the need for additional therapy [10]. Even though multiple studies have established that both RNFL and mGCC can both affect BCVA, Visual Field Indices. Our study demonstrates that while RNFL generally performs as a reliable predictor of VFI, mGCC exhibits superior and more consistent associations with BCVA and PSD, particularly over time.

The results show that RNFL's anatomical proximity to the optic nerve head and its representation of the broader retinal architecture lend it the robustness in predicting generalized visual field loss, as reflected in stronger adjusted R2 Values for VFI in both eyes which is supported by previous studies such as Berry DE *et al*., which found that early RNFL thinning correlates with long-term visual field decline in glaucoma patients [11].

However, as demonstrated in our study, mGCC outperforms RNFL in predicting BCVA and shows comparable or higher correlation with PSD, especially in the later visits. This aligns with the findings of Mahmoudinezhad *et al*., who reported that accelerated mGCC thinning was significantly associated with central visual field deterioration. Given that BCVA represents central vision and that mGCC directly reflects macular ganglion cell integrity, this structural-functional relationship is physiologically plausible [12].

Furthermore, our results reveal a progressive decline in both RNFL and mGCC values over time, with mGCC demonstrating a steeper decline, especially in OS. This trend indicates the potential of mGCC as a more dynamic marker in the early detection of functional changes, particularly in the central visual field. Anraku *et al*., previously highlighted the prognostic value of inferior mGCC thickness for predicting visual field progression, which supports our observations [13].

Interestingly, our data reveal that while RNFL consistently correlates with VFI across all visits, mGCC becomes increasingly predictive of BCVA and PSD in the second and third visits. This temporal evolution of predictive strength suggests a possible stage-dependent role of these parameters, where RNFL is more relevant early on, and mGCC assumes a more critical role as disease progresses. This observation aligns with Pham *et al*., who suggested that RNFL is more diagnostic in early glaucoma, whereas GC-IPL measurements (comparable to mGCC) are more predictive in advanced stages [14].

In light of these findings, we propose that both RNFL and mGCC serve complementary roles in clinical monitoring. RNFL remains crucial for evaluating peripheral field integrity and generalized optic nerve damage, while mGCC offers enhanced sensitivity for central vision assessment and early localized damage. Our study's strengths include a bilateral and longitudinal design with three-point follow-up, enhancing robustness. However, limitations include its retrospective nature and sample size. Future prospective studies with larger cohorts and longer follow-up are recommended to validate these trends and investigate the applicability of combined RNFL-mGCC metrics in predictive modeling.

Table 1: The correlation coefficients between RNFL and mGCC thickness and functional parameters

Eye	Visit	Predictor	Outcome	Adjusted r^2	Coefficient	P-Value
RE	First	RNFL thickness	VFI	0.318	0.4261	<0.001
			PSD	0.417	-0.1003	<0.001
			BCVA	0.512	-0.0029	<0.001
	Second	RNFL thickness	VFI	0.496	0.4566	<0.001
			PSD	0.496	-0.1059	<0.001
			BCVA	0.512	-0.0029	<0.001
	Third	RNFL thickness	VFI	0.507	0.4570	<0.001
			PSD	0.507	-0.1060	<0.001
			BCVA	0.523	-0.0029	<0.001
	First	Macular GCC thickness	VFI	0.277	0.5588	<0.001
			PSD	0.342	-0.1278	<0.001
			BCVA	0.435	-0.0040	<0.001
	Second	Macular GCC thickness	VFI	0.440	0.6498	<0.001
			PSD	0.470	-0.1555	<0.001
			BCVA	0.435	-0.0040	<0.001
	Third	Macular GCC thickness	VFI	0.440	0.6500	<0.001
			PSD	0.470	-0.1560	<0.001
			BCVA	0.435	-0.0040	<0.001
LE	First	RNFL Thickness	VFI	0.338	0.5552	<0.001
			PSD	0.175	-0.0609	<0.001
			BCVA	0.315	-0.0030	<0.001
	Second	RNFL Thickness	VFI	0.372	0.6071	<0.001
			PSD	0.196	-0.0749	<0.001
			BCVA	0.510	-0.0043	<0.001
	Third	RNFL Thickness	VFI	0.407	0.7178	<0.001
			PSD	0.252	-0.0921	<0.001
			BCVA	0.499	-0.0053	<0.001
LE	First	Macular GCC Thickness	VFI	0.258	0.7011	<0.001
			PSD	0.210	-0.0952	<0.001
			BCVA	0.417	-0.0056	<0.001
	Second	Macular GCC Thickness	VFI	0.280	0.7058	<0.001
			PSD	0.224	-0.1061	<0.001
			BCVA	0.589	-0.0069	<0.001
	Third	Macular GCC Thickness	VFI	0.304	0.7807	<0.001
			PSD	0.252	-0.1152	<0.001
			BCVA	0.718	-0.0084	<0.001

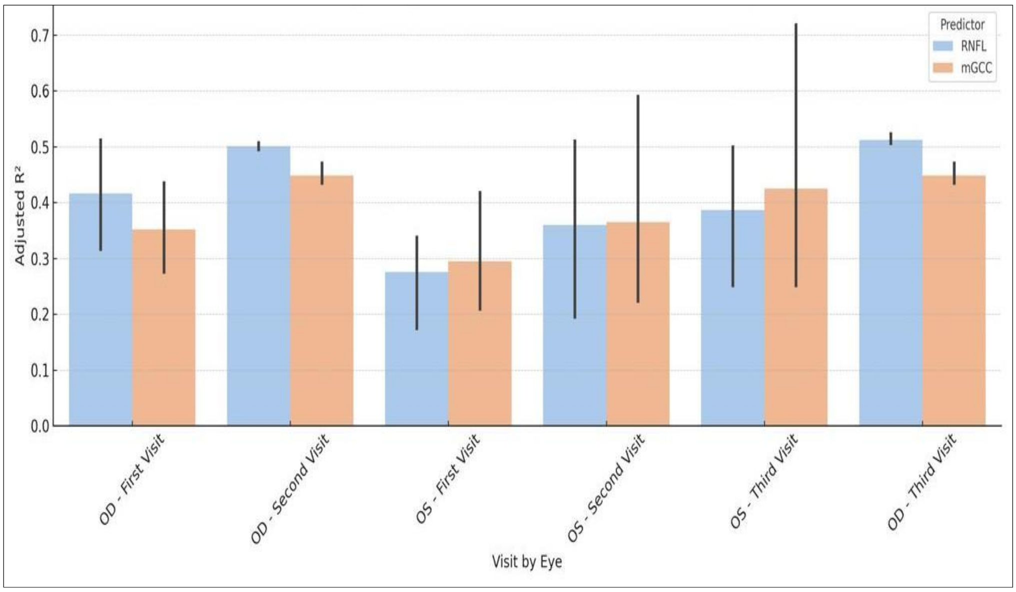

Fig 1: Mean RNFL and mGCC thicknesses at each of the three visits.

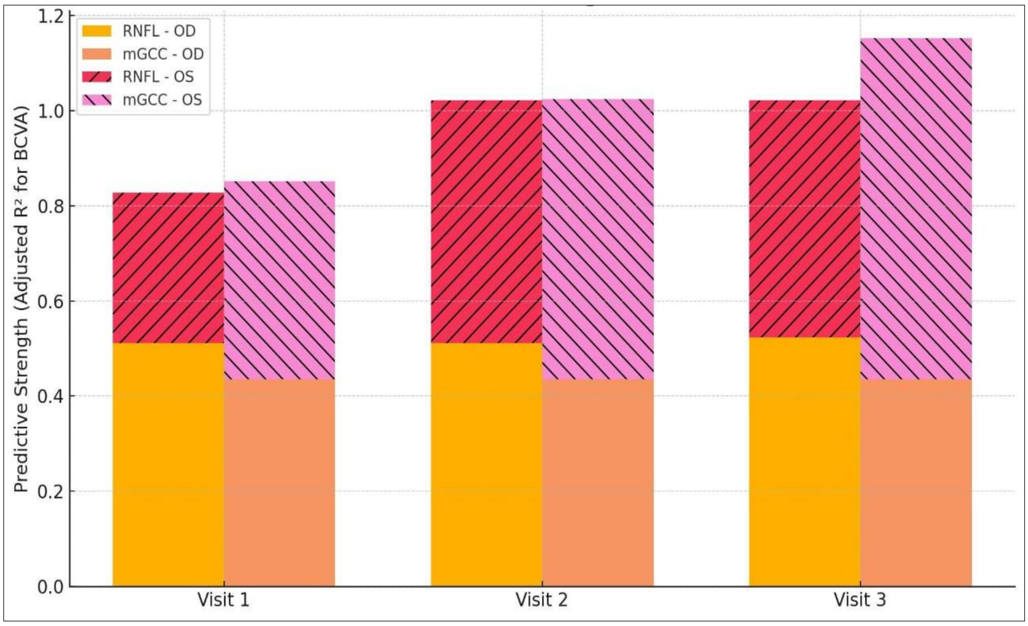

Fig 2: RNFL and mGCC predictive strength over visits (OD&OS).

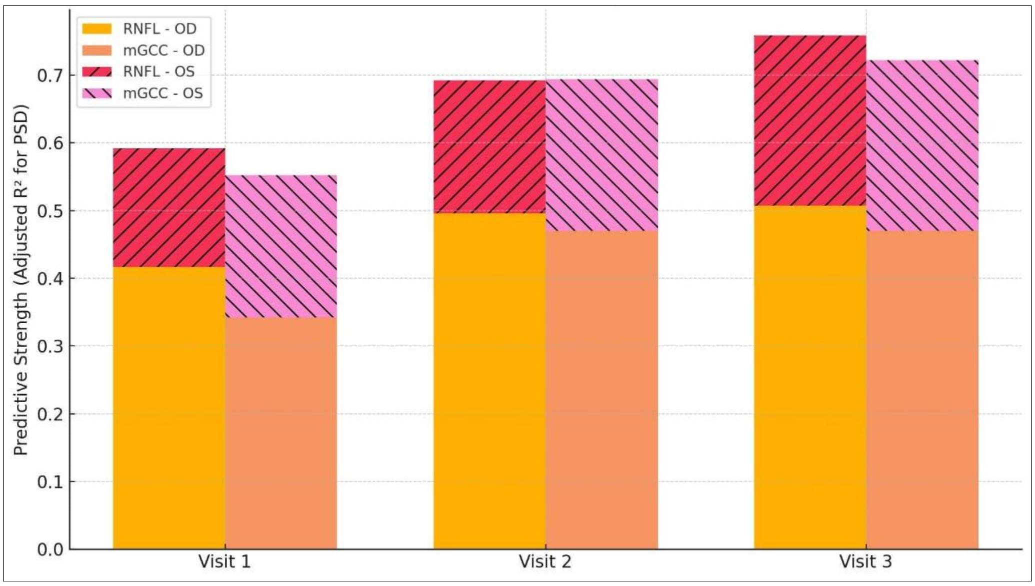

Fig 3: RNFL and mGCC predictive strength for PSD (OD&OS).

Fig 4: RNFL and mGCC predictive strength for VFI (OD&OS).

Conclusion

This Longitudinal analysis reaffirms that while both RNFL and mGCC thickness demonstrate significant associations with functional visual outcomes, mGCC consistently shows stronger correlation with BCVA and comparable or slightly better predictive strength for PSD, particularly in the second and third visits. RNFL, on the other hand, remains a reliable predictor of VFI. These findings suggest that mGCC may serve as a more sensitive marker for central visual function, while RNFL maintains its robustness in broader visual field assessments. The bilateral and sustained trends observed over time strengthen the evidence for integrating both structural parameters in clinical evaluation, with mGCC potentially offering earlier insights into disease progression. Both markers should be considered complementary in longitudinal glaucoma monitoring.

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Conflicts of Interest statement

None Declared.

Ethical approval

Not required

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