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Original Research

Evaluation of Ganglion Cell Layer Thickness in Early Open-Angle Glaucoma Using Swept-Source Optical Coherence Tomography

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ABSTRACT

Background: Primary Open-Angle Glaucoma (POAG) is a progressive optic neuropathy and a leading cause of irreversible blindness worldwide. Early detection of retinal ganglion cell (RGC) loss is crucial in preventing vision loss. Swept-source optical coherence tomography (SS-OCT) enables high-resolution imaging of the macular ganglion cell layer (GCL), which may aid in detecting early glaucomatous changes.

Methods: This hospital-based, cross-sectional observational study was conducted from February 2021 to January 2022. Patients aged 40 years or older, diagnosed with early POAG, were included. Exclusion criteria comprised patients with angle-closure glaucoma, significant refractive error, or a history of intraocular surgery. SS-OCT was used to measure GCL thickness in six sectors, while visual field testing was done using the Humphrey Field Analyzer (HFA) with 24-2 SITA Standard protocols. Data were analyzed using ANOVA for intergroup comparisons

.**Results:** A total of 96 eyes from 96 participants were analyzed, with 48 diagnosed with early POAG and 48 as controls. Significant thinning was observed in the GCL's inferior and inferonasal sectors in the POAG group ($p = 0.046$ and $p < 0.001$, respectively) compared to the control group. A moderate correlation between GCL thinning and visual field loss was found in the inferior sector ($p < 0.001$).

Conclusion: Macular GCL thinning, especially in the inferior and inferonasal sectors, serves as an early marker of glaucomatous damage in POAG patients. SS-OCT is effective in detecting early structural changes, which could facilitate earlier diagnosis and better management of glaucoma.

Introduction

Primary open-angle glaucoma (POAG) is a chronic and progressive optic neuropathy characterised by the selective loss of retinal ganglion cells (RGCs) and their axons, which leads to structural changes in the optic nerve head and corresponding functional loss in the visual field. It is one of the leading causes of irreversible blindness globally, with the damage often remaining unnoticed until advanced stages due to the asymptomatic nature of the disease in its early phases**[1],[2],[3],[4],[5],[6].**

Early detection of POAG is crucial to prevent irreversible visual loss. In recent years, optical coherence tomography (OCT) has emerged as a powerful diagnostic tool for evaluating the structural changes associated with glaucoma. OCT enables high-resolution imaging of the retinal nerve fibre layer (RNFL) and the ganglion cell complex (GCC), which includes the ganglion cell layer (GCL) and inner plexiform layer (IPL). Swept-source OCT (SS-OCT), with its ability to provide deeper and faster imaging, has further enhanced the detection of early glaucomatous changes**[7][8].**

Given that more than 50% of retinal ganglion cells are located within the central 10 degrees of the macula, measuring the thickness of the ganglion cell layer in this region provides a direct indication of early glaucomatous damage. While visual field tests like the 24-2 pattern are commonly used, they often miss early central visual field defects that are detectable through 10-2 visual field testing. This structural-functional correlation between ganglion cell layer thickness and

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visual field sensitivity is vital in diagnosing POAG at an early stage**[9][10][11] [12][13]**

This study aims to evaluate ganglion cell layer thickness changes in patients with early open-angle glaucoma using Swept-Source OCT, emphasizing the correlation between GCL thickness and early visual field changes. This can aid in enhancing the early diagnosis and management of glaucoma.

Materials and Methods

Thishospital-based, cross-sectional study lasted from February 2021 to January 2022 and included patients diagnosed with early primary open-angle glaucoma (POAG) The study followed the Declaration of Helsinki, and written informed consent was obtained from all participants

Patients aged 40 years or above with a diagnosis of early POAG were included in the study. Early POAG was defined based on the European Glaucoma Society guidelines, which classify visual field loss as mild (mean deviation of less than -6 dB)

The following exclusion criteria were applied. Angle-closure glaucoma, History of intraocular surgery or significant media opacity that could affect imaging quality, Refractive error greater than ±5.0 diopters,and Patients unwilling to provide informed consent All participants underwent a comprehensive ophthalmic examination, including Best-corrected visual acuity (BCVA) assessment, Applanation tonometry for intraocular pressure (IOP) measurement, Gonioscopy to confirm open angles, Central corneal thickness (CCT) measurement using an ultrasonic pachymeter Fundus examination with a slit-lamp bio microscopy and a 90D lens. Swept-source OCT (SS-OCT, DRI OCT-1; Topcon, Tokyo, Japan) was used to measure ganglion cell layer thickness at the macula. The macular scan covered a 6x6 mm area, and the ganglion cell layer–inner plexiform layer (GC-IPL) thickness was evaluated in the supero-temporal, supero-nasal, infero-temporal, infero-nasal, superior, and inferior sectors.Visual field testing was performed using the Humphrey Field Analyzer (HFA) with 24-2 SITA Standard protocols. The data were analyzed using ANOVA for intergroup comparisons.

Results

A total of 96 eyes from 96 participants were included in the final analysis. The participants were divided into two groups: 48 with early primary open-angle glaucoma (POAG) and 48 as controls. The mean age of the participants was 55.00 ± 9.88 years in the POAG group and 49.75 ± 9.60 years in the control group, with a statistically significant difference observed among the groups ($p < 0.001$).

Table 1: Intergroup comparison of age of the study population

SN	Age Group	Group 1(POAG)		Group 2(control)	
		No.	%	No.	%
1	≤ 40 years	6	12.5	4	8.3
2	41-50 years	16	33.3	12	25.0
3	51-60 years	16	33.3	16	33.3
4	61-70 years	8	16.7	16	33.3
5	≥ 71 years	2	4.2	0	0.0
		Mean	**SD**	**Mean**	**SD**
		53.46	9.88	55.54	9.60

The majority of patients in group 1(66.6%) were aged from 1to60years, while a majority of controls were aged between 51 and 70years(66.6%). On comparing statistically, a significant difference was observed among the groups for age ($p<0.001$)

Table 2: Intergroup comparison of Gender of the study population

SN	Gender	Group 1(Early POAG)		Group 2(Control)	
		No.	%	No.	%
1	Female	26	54.2	21	43.8
2	Male	22	45.8	27	56.3

χ^2=4.233;p=0.12 Though most patients in group 1 were Female (54.2%) and majority of patients in group 2 were males (group 2: 66.7%, group 3: 56.3%). However, on comparing statistically, the gender of the patients was comparable among the groups ($p>0.05$)

Table 3: Intergroup comparison of Ganglion layer thickness in different sectors

Sector	Early glaucoma (mean +/- SD)	Normal (mean+/- SD)	P value
Supero-temporal	71.19 ± 1.22	70.52 ± 1.14	0.443

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Superior	69.79 ± 1.32	70.56 ± 1.30	0.160
Supero-nasal	70.98 ± 1.41	71.56 ± 1.12	0.577
Infero-temporal	70.42 ± 1.25	70.56 ± 1.20	0.975
Inferior	67.71 ± 1.89	69.88 ± 1.15	0.046
Infero-nasal	67.92 ± 1.73	71.83 ± 1.40	< 0.001

The ganglion cell layer (GCL) thickness was analyzed in six sectors. In the POAG group, there was significant thinning observed in the inferior ($p = 0.046$) and infero-nasal ($p < 0.001$) sectors compared to controls. The other sectors showed no statistically significant differences between the two groups.

Table 4: Correlation of ganglion cell layer thickness in each sector(um) with Mean Deviation(dB) 24-2 visual field in early primary open-angle glaucoma

	24-2Visual Field	
	Pearson Correlation	**p-Value**
Superotemporal	0.141	0.340
Superior	0.036	0.809
Supronasal	-0.026	0.859
Inferotemporal	-0.204	0.164
Inferior	0.531	<0.001
Inferonasal	0.236	0.107

A weak or no correlation was observed between 24-2 Visual field and ganglion layer thickness in all sectors except Inferior sector, while a moderate correlation was observed for Inferior sectors. Statistically, only Inferior sector ganglion thickness was significantly correlated with 24-2 visual field

Discussion

This study aimed to evaluate ganglion cell layer (GCL) thickness in patients with early primary open-angle glaucoma (POAG) using Swept-Source Optical Coherence Tomography (SS-OCT). The primary finding was a significant thinning of the GCL in specific sectors, particularly the inferior and inferonasal regions, in patients with early POAG compared to normal subjects. These results are consistent with previous studies that demonstrated early glaucomatous damage affects the retinal ganglion cells, which are critical in the pathophysiology of POAG **[14][15][16][18][19][20][21][22][23][24][25]**

The macular region, which contains a high density of retinal ganglion cells, plays a pivotal role in early glaucoma detection. The thinning of the GCL, particularly in the inferior sectors, is a known hallmark of early glaucomatous damage. In our study, the GCL thinning observed in the inferonasal and inferior sectors aligns with the literature, which suggests that the damage in these regions correlates with early visual field defects **[16][17].** The relationship between structural changes, as detected by SS-OCT, and functional loss, as observed in visual field testing, underscores the importance of early structural evaluation in glaucoma diagnosis **[26][27][28][29][30][31][32]**

Swept-source OCT has been shown to have superior capabilities compared to other imaging techniques like spectral-domain OCT (SD-OCT), especially in measuring deeper structures and larger volumes of ocular tissue. The higher speed and deeper penetration of SS-OCT enabled us to capture detailed images of the GCL and inner retinal layers, facilitating the detection of subtle changes that are not always apparent in traditional visual field tests **[7][8][10]**

In our study significant correlation between GCL thickness and visual field loss was found. It further supports the structural-functional relationship in early POAG. Similar to other studies, we found that thinning in the GCL was most pronounced in the inferior and inferonasal sectors, which correspond to the superior visual field defects seen in early glaucoma. This suggests that early structural damage in these regions may serve as an important marker for diagnosing and tracking disease progression in patients with primary open-angle glaucoma**.[33][34][35][36][37][38][39]**

Conclusion

This study showed that ganglion cell layer thickness analysis is effective in detecting early ganglion cell layer (GCL) thinning in primary open-angle glaucoma (POAG). Significant thinning in the inferior and inferonasal sectors of the GCL was observed, suggesting their importance in early diagnosis.

High-resolution imaging can detect structural damage before a functional loss occurs, making it a valuable tool for early POAG detection. The correlation between GCL thinning and visual field defects underscores the importance of combining GCL thickness analysis with visual field testing for better glaucoma management.

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