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Study on glaucoma staging system with macular visual field measurements

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Abstract
Background: Glaucoma, a leading cause of irreversible blindness, is characterized by progressive optic nerve damage, often leading to visual field loss, with early detection critical for effective management and prevention of vision impairment.
Aims: To study the glaucoma staging system with macular visual field measurements.
Methods: A cross-sectional study was conducted in the Ophthalmology Department at Government Medical College, Kota, Rajasthan, from May 2016 to December 2024. Forty glaucoma patients (20 males, 20 females) diagnosed with Primary Open-Angle Glaucoma (POAG) or Normal-Tension Glaucoma (NTG) were enrolled. Exclusion criteria included Primary
Angle-Closure Glaucoma (PACG), secondary glaucomas, congenital glaucoma, and patients who had undergone intraocular surgeries. Participants underwent a comprehensive ocular examination, including 24-2 and 10-2 perimetry, Spectral Domain Optical Coherence Tomography (SD-OCT) imaging, and clinical assessments. Glaucoma severity was classified using the Hodapp-Parrish-Anderson (HPA) staging system, and macular damage was analyzed using 10-2 perimetry and SD-Oct.
Results: The study revealed that macular involvement was detected in all glaucoma patients using the 10-2 perimetry test, whereas the 24-2 perimetry missed macular damage in 17.5% of cases SD-OCT showed macular abnormalities in 77.5% of the patients, with significant thinning of the retinal ganglion cell complex (GCC) and inner plexiform layer (IPL) correlated with increasing disease severity. The correlation between functional loss (as measured by visual field tests) and structural damage (GCC and IPL thinning) was strong, suggesting that macular testing provides valuable insights into glaucoma progression.
Conclusion: This study emphasizes the importance of incorporating macular visual field testing and SD-OCT in the routine glaucoma workup. The findings suggest that 10-2 perimetry and SD-OCT offer a more comprehensive approach to detecting early glaucomatous damage, particularly in the macula, which is often overlooked by conventional testing methods.
Integrating these tools into clinical practice can improve early diagnosis, disease staging, and individualized treatment strategies, ultimately enhancing patient outcomes and preserving vision in glaucoma patients.

Keywords: Small incision cataract surgery, trabeculectomy, glaucoma, intraocular pressure

Introduction

Glaucoma is one of the leading causes of irreversible blindness globally, with an estimated 60 million people affected worldwide, a number expected to rise significantly due to the aging population. [1] It is primarily characterized by progressive optic neuropathy, often associated with elevated intraocular pressure (IOP), which leads to optic nerve damage and visual field loss. However, glaucoma can also occur in individuals with normal IOP, known as normal-tension glaucoma, which makes early detection challenging. As a result, glaucoma is often referred to as the "silent thief of sight," because individuals may not notice vision loss until it becomes significant.

Early detection and accurate staging are crucial to prevent vision loss, making staging systems an essential part of glaucoma management. Traditionally, glaucoma staging systems have focused on peripheral visual field loss and optic nerve head changes, which are the hallmark signs of the disease. However, recent advancements have shown that the macula, which is responsible for central vision, may be affected in the early stages of glaucoma, even before peripheral vision loss occurs. [2]

Macular visual field measurements have become increasingly important in detecting early glaucomatous damage that may go unnoticed in peripheral field tests. Technologies such as Optical Coherence Tomography (OCT) and Humphrey Visual Field Analyzer (HVF) have

enabled high-resolution macular mapping, offering more sensitive detection of central vision loss. The incorporation of macular visual field testing into traditional glaucoma staging systems can significantly improve the accuracy of early diagnosis and enable more tailored treatment plans to preserve vision.[3]

With glaucoma affecting a significant portion of the global population, the integration of macular testing into glaucoma staging offers a more comprehensive approach to managing the disease, improving patient outcomes, and preventing irreversible blindness. As our understanding of glaucoma deepens, the role of macular visual field measurements will continue to be essential in early detection and progression monitoring.

Materials and Methods

This hospital-based, cross-sectional observational study was conducted at the Outpatient Department of Ophthalmology, Government Medical College and Associated Hospitals, Kota, Rajasthan, from May 2016 to December 2024. The study was approved by the Institutional Ethical Committee. The study included patients diagnosed with primary open-angle glaucoma (POAG) and normal-tension glaucoma (NTG), while patients with primary angle-closure glaucoma (PACG), secondary glaucomas, congenital glaucoma, or those who had undergone intraocular surgeries were excluded. A minimum of 40 patients were enrolled after obtaining informed consent.

Patients underwent a detailed clinical evaluation, including visual acuity measurement (Snellen's chart), refractive status, anterior segment evaluation via slit-lamp biomicroscopy, and intraocular pressure (IOP) measurement using the Schiotz tonometer. Gonioscopy was performed to exclude angle-closure, and fundus examination was conducted using an indirect ophthalmoscope with a 20D lens. Macular evaluation was done with Zeiss Cirrus Spectral Domain Optical Coherence Tomography (SD-OCT), and visual field testing was conducted with the Humphrey Field Analyzer. For severity classification, 24-2 perimetry was performed, and Hodapp-Parrish-Anderson (HPA) and Glaucoma Visual Field Staging System (GVFSS) were used for staging. Macular damage was assessed through 10-2 SAP and SD-OCT, with results compared to conventional glaucoma staging methods. Data analysis was conducted using SPSS software (version 29.0), including Pearson or Spearman correlations, Chi-square test, and McNemar's Test for paired proportions.

Ethical considerations were strictly followed throughout the study. The study was approved by the Institutional Ethical Committee, and informed written consent was obtained from all participants, ensuring they understood the study's purpose, procedures, and potential risks. Patient confidentiality was maintained, and participation was voluntary.

Results

The study aimed to investigate the demographic, clinical, and functional characteristics of glaucoma patients, with a focus on macular damage and its association with glaucoma severity. The cohort consisted of 40 participants, equally distributed between males and females, with a mean age of 61.00±7.52 years. A significant proportion of the patients (57.5%) had a positive family history of glaucoma, indicating a genetic predisposition. Systemic comorbidities, such as diabetes mellitus (30%), hypertension (25%), and smoking (37.5%), were commonly observed, with hypertension and smoking being more prevalent in the moderate and advanced stages of glaucoma. These findings suggest that systemic health factors could play a role in the progression of glaucoma.

The glaucoma severity was assessed using the Hodapp-Parrish-Anderson (HPA) staging system, which classified 30% of the patients as mild, 45% as moderate, and 25% as advanced. Notably, the mean intraocular pressure (IOP) of the cohort was within normal limits (17.28±4.23 mmHg), suggesting that IOP alone is not an adequate marker for glaucoma severity. Visual field testing showed a significant decline in functional vision with advancing glaucoma severity. The 24-2 Mean Deviation (MD), Pattern Standard Deviation (PSD), and the 10-2 parameters all exhibited progressively worse values with advancing disease, correlating with the decline in Visual Field Index (VFI): 96.25% in mild, 83.67% in moderate, and 56.7% in advanced cases.

The macular damage was evaluated using both 24-2 and 10-2 perimetry. The 10-2 perimetry detected macular damage in all 40 eyes (100%), whereas 24-2 perimetry identified damage in only 33 eyes (82.5%), missing 7 cases that were detected by 10-2. This demonstrates the superior sensitivity of the 10-2 test in identifying macular damage, especially in early-stage glaucoma where central vision is more affected. The study also incorporated Spectral Domain Optical Coherence Tomography (SD-OCT), which revealed abnormal findings indicating macular loss in 77.5% of patients, with 23.5% showing normal OCT results. The ganglion cell complex (GCC) and inner plexiform layer (IPL) thicknesses were found to progressively decline with disease severity, with GCC thickness being a consistent marker of glaucomatous damage.

The relationship between HPA staging and macular damage was further explored, and the findings showed a progressive decline in VFI and structural changes (GCC and IPL thinning) with worsening disease stages. The VFI in mild glaucoma was 96.2%, in moderate glaucoma was 83.6%, and in advanced glaucoma was 56.7%, highlighting the increasing loss of visual function as the disease progressed. These findings suggest that incorporating 10-2 perimetry and SD-OCT in the assessment of glaucoma may provide a more comprehensive and accurate evaluation, especially in detecting early macular damage and improving disease staging.

Additionally, systemic comorbidities such as hypertension, diabetes mellitus, and a family history of glaucoma were associated with more severe forms of glaucoma, indicating that these factors could contribute to glaucoma progression. These findings underscore the importance of an integrated approach to glaucoma management, which includes addressing systemic health factors, regular monitoring using advanced diagnostic tools like 10-2 perimetry and SD-OCT, and early intervention strategies to prevent or manage glaucomatous damage effectively. The study emphasizes the critical role of macular evaluation in glaucoma detection and staging, suggesting that it may be underrepresented in traditional glaucoma management if macular damage is not specifically assessed.

Table 1: Comparative Analysis of Glaucoma Parameters across HPA Stages

Parameter	Mild (Mean ± SD)	Moderate (Mean ± SD)	Advanced (Mean ± SD)	Total (Mean ± SD)
IOP	16±3	15±2.87	22.9±1.76	17.28±4.23
24-2_MD	-3.4±0.38	-10.6±0.61	-15.07±1.6	-10.17±3.69
10-2_MD	-4.69±0.68	-8.58±0.91	-12.88±0.92	-8.49±3.14
24-2_PSD	2.25±0.62	7.34±0.73	10.48±0.69	6.84±2.86
10-2_PSD	2.59±0.6	5.91±0.83	9.29±0.76	5.76±2.59
VFI	96.25±0.92	83.67±3.97	56.7±6.89	80.7±15.48
GCC	96.66±1.44	81.11±2.21	66.4±3.83	80.98±10.12
IPL	48.08±1.85	40.22±2.57	29.7±2.1	39.95±7.16

SD= Standard deviation; IOP= Intraocular Pressure; MD= Mean Deviation; PSD= Pattern Standard Deviation; VFI= Visual field index; GCC= Ganglion Cell Complex; IPL= inner plexiform layer

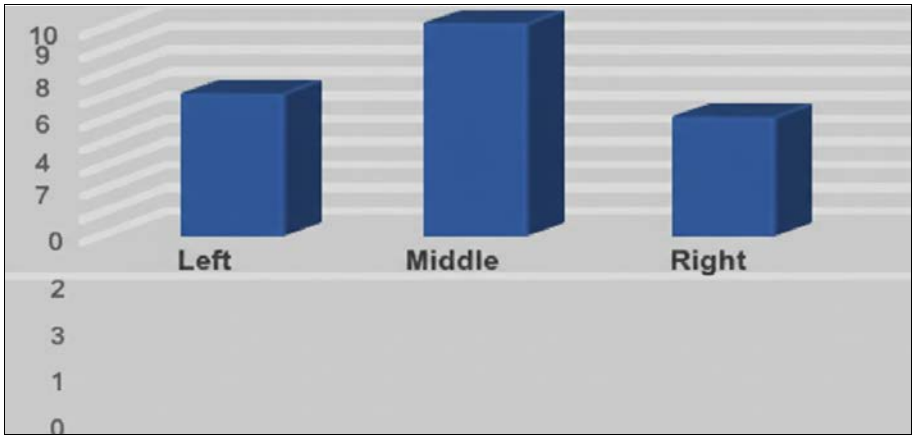

Fig 1: Graphical Distribution of Patients According to HPA Stage

Table 2: Macular Damage Detection Status (24-2 vs 10-2)

Macular Damage	Detection Status (24-2)	Detection Status (10-2)
Present	33 (82.50%)	40 (100.00%)
Absent	7 (17.50%)	0 (0.00%)
Total	40 (100%)	40 (100%)

Table 3: Relationship between HPA Stage and Macular Damage with Mean VFI (%)

HPA Stage	Macular Damage Present	Mean VFI (%)±SD
Mild	12	96.2±12.5
Moderate	18	83.6±7.3

Advanced 10 56.7±14.1

Discussion

The present study aimed to evaluate the association between macular visual field measurements and the severity of glaucoma, with a focus on primary open-angle glaucoma (POAG) and normal-tension glaucoma (NTG). Conducted at the Outpatient Department of Ophthalmology at Government Medical College and Associated Group of Hospitals, Kota, Rajasthan, the study spanned over 15 months after obtaining ethical approval. The study followed a cross-sectional design, with 40 glaucoma patients diagnosed with either POAG or NTG enrolled in the study. Exclusion criteria included patients with other types of glaucoma, those who had undergone intraocular surgeries or laser treatments, and patients with ocular conditions that could mimic glaucomatous visual field defects.

The study's key objective was to assess macular damage in glaucoma patients using 10-2 perimetry and spectral domain optical coherence tomography (SD-OCT), and to determine the correlation of these findings with established glaucoma severity classifications. The results revealed that macular involvement was present even in the early stages of open-angle glaucoma. This observation is consistent with Hood *et al.*[4], who demonstrated that macular damage, particularly in the papillomacular bundle, can occur early in glaucoma and may be missed with conventional 24-2 testing due to its sparse central grid. In this study, 10-2 perimetry, which includes 68 test points in the central 10° of the visual field, showed superior sensitivity in detecting central field loss compared to 24-2 perimetry, which only includes four test points within the central 8°. [4]

Our study cohort had a mean age of 61.00±7.52 years, which is consistent with findings from large epidemiological studies of POAG, such as the Baltimore Eye Survey and the Blue Mountains Eye Study, which reported similar age distributions. [5] The gender distribution was equal, with 50% male and 50% female, consistent with previous studies, such as those by Mitchell *et al.* [6], who found no significant gender difference in POAG prevalence. The study also observed a high prevalence of systemic comorbidities, including diabetes mellitus (40%), hypertension (25%), and smoking (37.5%), which have been linked to worsened glaucoma prognosis due to their effects on ocular blood flow and optic nerve head ischemia. Additionally, a positive family history of glaucoma was found in 57.5% of participants, supporting the heritable component of POAG, as noted by genetic studies on glaucoma. [7]

From a functional perspective, 24-2 perimetry showed a worsening in mean deviation (MD) and pattern standard deviation (PSD) values with increasing glaucoma severity, reaffirming the utility of this staging scale. [4] However, this method failed to detect early macular involvement, which was identified by 10-2 perimetry even in patients classified as having mild to moderate glaucoma by the 24-2 test. These findings are in line with those of Blumberg *et al.* [8], who highlighted that 10-2 perimetry better correlates with vision-related quality of life (QoL) measures than 24-2 perimetry, as it more accurately reflects central field defects, which are essential for activities like reading and face recognition.

The SD-OCT imaging revealed that macular damage was

present in 77.5% of the patients, with 23.5% showing normal OCT findings. Ganglion cell complex (GCC) thickness measurements demonstrated a progressive thinning with increasing glaucoma severity, with 96.66 µm in mild cases, 81.11 µm in moderate cases, and 66.4 µm in advanced cases, reflecting the structural changes associated with glaucomatous damage. [9] The thinning of the inner plexiform layer (IPL) was similarly observed, although there was more variability in moderate cases. This variability could be attributed to segmentation artifacts or regional differences in macular degeneration, as noted by Kim *et al*. [10], who pointed out that IPL thinning may be less reliable than GCC thinning due to measurement difficulties.

These findings support the use of 10-2 perimetry and SD-OCT in routine glaucoma management, as they provide a more comprehensive assessment of disease severity, particularly in detecting macular involvement, which may be underestimated by conventional 24-2 perimetry. The study's results also suggest that systemic factors such as hypertension, diabetes, and family history significantly influence glaucoma progression, and these factors should be addressed in the overall management of glaucoma patients.

The study findings have important clinical implications. In practice, patients with early-stage glaucoma may appear stable on 24-2 perimetry, yet suffer from significant central field loss, which affects their daily visual tasks. The inclusion of 10-2 perimetry and macular OCT scans can help detect these early macular changes and prevent underdiagnosis or undertreatment of glaucoma. These tools should be incorporated into routine clinical practice to improve diagnostic accuracy, guide treatment decisions, and monitor disease progression more effectively. Future studies with larger sample sizes and longer follow-up periods will be necessary to further validate these findings and refine glaucoma staging protocols.

Conclusion

This study highlights the importance of incorporating macular visual field assessment in glaucoma diagnosis and staging. Traditional tests like 24-2 may miss early central vision loss due to sparse sampling, while the 10-2 perimetry test, with its denser grid, more effectively detects macular damage. This is crucial as early glaucoma often affects the macula, vital for tasks like reading. Spectral Domain Optical Coherence Tomography (SD-OCT) provides high-resolution imaging, revealing thinning of the retinal ganglion cell complex (GCC) and inner plexiform layer (IPL), key indicators of early disease. The correlation between macular structural changes and functional defects reinforces the need for central visual field testing. Integrating both 10-2 perimetry and SD-OCT into routine practice can improve early detection, refine staging, and enable more personalized treatment, ultimately enhancing quality of life for glaucoma patients.

Conflict of Interest

Not available

Financial Support

Not available

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