Micro Eye Movements in Primary Open-Angle Glaucoma Assessed with High-Resolution Retinal Eye Tracker

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Summary

Glaucoma is a chronic neurodegenerative disease traditionally assessed using structural and functional measures of the visual system. However, conventional diagnostic tools provide limited insight into oculomotor behavior, particularly small eye movements that reflect fine visuomotor control. This study explores micro eye movements – including fixation and small-amplitude saccades – as potential functional markers of glaucoma severity using high-resolution retinal eye tracker.

Keywords: primary open-angle glaucoma, eye tracking, fixation stability, microsaccades, small saccades

INTRODUCTION

Elevated intraocular pressure (IOP) is the main risk factor for primary open-angle glaucoma (POAG); however, despite effective medical and surgical treatments aimed at lowering IOP, progressive visual loss remains common. Although impairments in ocular motility in glaucoma have been reported (Montesano et al., 2018; McDonald et al., 2022), existing evidence primarily concerns eye movements of larger amplitudes. The present study aims to investigate small eye movements, including fixation and saccades with amplitudes not exceeding 2 degrees, which have not yet been sufficiently explored in glaucoma.

METHODS

A novel aspect of this study was the use of NeuroFET, a high-precision, calibration-free, non-invasive retinal eye tracker that records 2×2° retinal images at high sampling rates (620 Hz retinal imaging and 1240 Hz pupil camera), enabling the analysis of microsaccades and other subtle eye movements

not accessible with standard clinical devices (Bartuzel et al., 2020). We examined 41 eyes with mild POAG, 16 eyes with severe POAG, and 29 eyes from healthy controls. Participants completed oculomotor tasks including fixation and 1° and 2° saccades. Disease severity was determined based on clinical findings. Each participant underwent a comprehensive ophthalmologic evaluation, including visual acuity assessment, retinal nerve fiber layer (RNFL) and ganglion cell complex (GCC) thickness measurements, standard automated perimetry (SAP), and microperimetry (MP). Statistical and graphical analyses of eye movement trajectories were performed to characterize differences across disease stages.

RESULTS

Significant correlations were observed between structural and functional ophthalmologic parameters – including RNFL thickness, GCC thickness, and mean deviation (MD) – and parameters describing eye movement dynamics, such as saccadic amplitude, velocity, latency, and fixation stability. Graphical analysis revealed that in mild POAG, differentiation between patients and healthy controls based on fixation stability or 1° and 2° saccadic tasks was challenging. In contrast, patients with severe POAG exhibited markedly altered eye movement trajectories, largely attributable to visual field loss, as eye movements were not directed toward stimuli located within scotomatous regions (Fig. 1 and Fig. 2). Despite moderate GCC thinning, oculomotor function appeared to be largely preserved, with pronounced disruptions emerging predominantly in advanced stages of the disease.

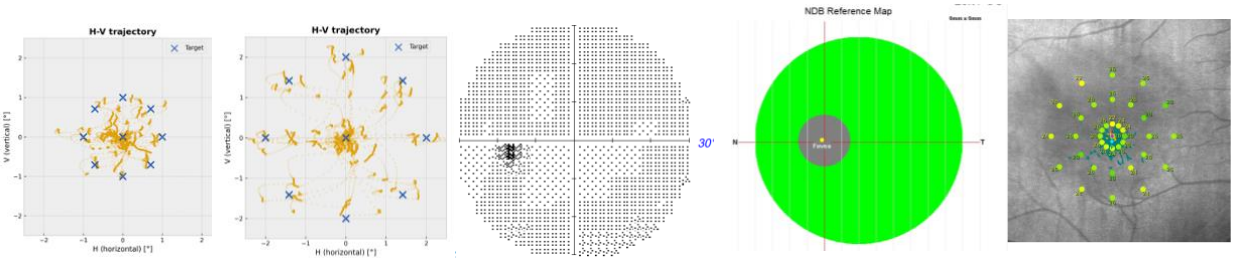

Figure. 1. Saccades 1° and 2° tasks in healthy subject (left eye) compared with HFA perimetry, GCC map and MAIA microperimetry.

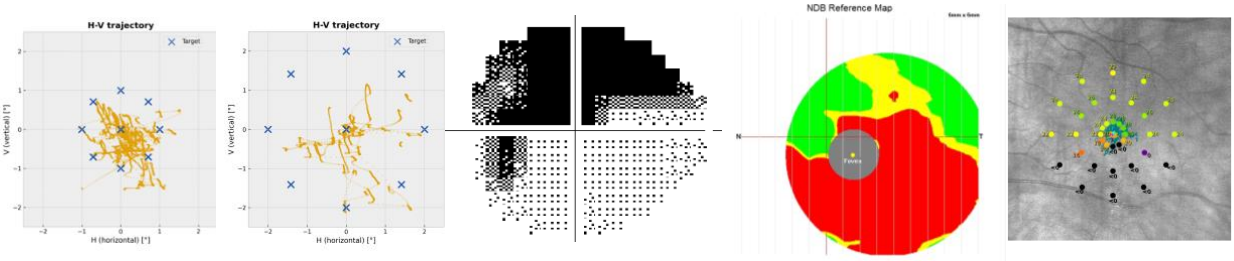

Figure. 2. Saccades 1° and 2° tasks in severe POAG patient (left eye) compared with HFA perimetry, GCC map and MAIA microperimetry.

CONCLUSIONS

High-resolution retinal eye tracking enables precise assessment of micro eye movements in glaucoma. While mild POAG remains difficult to distinguish from healthy controls using small-amplitude

saccadic tasks, advanced disease is associated with substantial alterations in eye movement trajectories driven by visual field loss. These findings suggest that oculomotor function is relatively preserved despite moderate structural damage and becomes disrupted primarily in advanced stages of glaucoma, highlighting the potential of micro eye movement analysis as a functional marker of disease progression.

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