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Spot the differences: challenges in detecting glaucoma in the myopic patient

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Clinical Case Conundrum:

A 53-year-old male was referred for glaucoma consultation regarding paracentral visual field defects in the right eye. Prior to phacoemulsification and intraocular ocular lens (IOL) implantation his refraction was -10.50 D and -11.00 D in the right and left eyes, respectively. Axial length was 28 mm in both eyes (OU). He was medically healthy. Visual acuities were 20/25 OU. Intraocular pressures (IOPs) were 16 mmHg OU. Central corneal thicknesses were 652 μ m OU. Anterior segment, gonioscopy, and fundus findings are indicated in **Figure 1**. Optical coherence tomography (OCT) analysis of the retinal nerve fibre layer (RNFL) is shown in **Figure 2**. This patient's visual fields and structure-function correlations are highlighted in **Figure 3**.

Asymptomatic myopic patients often present with normal intraocular pressures, anomalous nerves, and visual field defects that are challenging to interpret in the context of one another. This is further complicated by myopia being a known risk factor for glaucomatous progression. Decisions regarding diagnosis and management in this patient population remain challenging.

Epidemiology:

Myopia is a growing epidemic. By 2050, it is predicted that 5 billion people (50% of the global population), will have myopia. Of these, 1 billion are projected to incur vision-threatening complications of high myopia.¹ High, or pathologic, myopia is defined as a spherical equivalent > -6.00 D or an axial length > 26.5 mm.² Patients with high myopia are at higher risk for several conditions believed to arise from excessive axial stretching of the globe, including retinal atrophy and degenerations predisposing to detachments. Myopic patients can lose central vision from a host of macular conditions including choroidal neovascularization, chorioretinal atrophy, peripapillary crescents, Bruch's membrane dehiscences, and a thin macular choroid, thereby limiting visual potential.^{3,4}

Several landmark trials have identified myopia as an important risk factor for developing primary open angle glaucoma (POAG).⁵ Glaucoma represents a group of disorders culminating in optic neuropathy with stereotypic optic nerve changes, loss of retinal ganglion cells, and corresponding visual field defects.⁶ High myopia may increase the risk of POAG by as much as six-fold⁷ and make patients more susceptible to incurring POAG at an earlier age.⁸ POAG often presents despite "normal" pressures, and several studies have found plausible associations between myopia and normal-tension glaucoma.⁵ In high myopes, it has been hypothesized that axial stretching or torsional forces at the lamina cribrosa may induce glaucoma through axonal strain.^{9,10} Notwithstanding their frequent coexistence, glaucoma may be challenging to diagnose in high myopia. Due to departures from normative data for eyes with myopia and glaucoma, management of the coexisting conditions remains a common clinical conundrum.

Optic Nerve Analysis:

Glaucomatous optic nerve changes are often difficult to detect in myopic nerves for several reasons. With increasing axial length, the position of the optic disc can be displaced nasally in relation to the fovea, resulting in a rotation or 'tilt' of the disc with an associated shift in the Bruchs' Membrane opening and affording only an oblique view of the optic nerve head (ONH).^{11,12} The ONH may be more pallid, reducing contrast between the pink neuroretinal rim and the optic cup. Distinguishing zones of peripapillary atrophy (PPA), with the increase in the beta zone having been linked to glaucoma, may be difficult. The lamina cribrosa can stretch and become thin. Further, choroidal thinning and subsequent retinal pigment epithelium (RPE) atrophy can make it difficult to detect peripapillary RNFL changes.¹² However, in myopes, RNFL defects may be an early sign of glaucoma, especially if they involve the papillomacular bundles.¹³

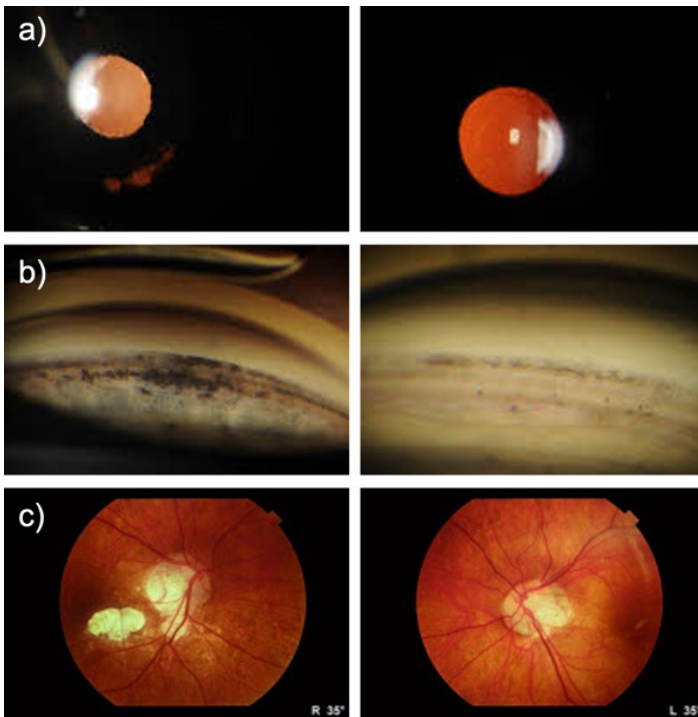


Figure 1: Clinical photograph compilation of salient exam findings including a) transillumination defects OD, b) pigment deposition OD on gonioscopy, c) fundus photographs of the optic nerve heads and peripapillary retina; courtesy of Cindy Hutnik et al.

Interpreting OCT measurements of the RNFL can also be nuanced in myopic patients. The normative database for the Cirrus® (Zeiss, Dublin, California) HD-OCT contains data from only 284 individuals, with limited representation from high myopes and hyperopes.¹⁴ The lack of a myopic reference often biases clinicians towards “red disease” in which the OCT suggests abnormal thinning when the patient in fact has a healthy RNFL (a false positive).^{15,16} Indeed, the disc-margin definition algorithm on HD-OCT can be influenced by myopic changes such as tilt, magnification or media artefact and scan circle misalignment from peripapillary atrophy. The superotemporal and inferotemporal RNFL bundles can be temporally displaced. Symmetry, correlation of other clinical parameters, and serial observations are essential, in the evaluation of a myopic patient who is considered at risk for glaucoma.^{14,17}

Visual Fields:

Visual fields may also be difficult to interpret in myopic patients. Significant PPA can cause visual field defects. Macular pathology, including choroidal neovascularization or atrophy, can cause paracentral scotomas mimicking glaucomatous field loss, especially the paracentral changes seen in normal-tension glaucoma (NTG).

Sub-foveal choroidal thickness has been shown to be the most significant predictor of visual acuity in highly myopic eyes,³ and choroidal and outer retinal thinning has been

implicated in early visual field defects in myopes.¹⁸ High myopes can have higher mean deviations¹⁹ and lower threshold sensitivities than emmetropes.²⁰ Therefore, even at a microarchitectural level, myopic macular degenerations can confound visual fields in glaucoma evaluations. It is interesting to note that choroidal thinning has also been linked to the progression of visual field damage in a cohort of NTG patients, possibly implicating choroidal thinning in NTG pathogenesis.²¹

Structural Imaging: New Frontiers and New Management Considerations:

A host of novel imaging techniques may enhance our ability to detect glaucoma in myopic patients. For instance, new sd-OCT imaging strategies may more accurately detect the neuro-retinal rim (NRR). The Bruch’s membrane opening minimal rim width (BMO-MRW) is the minimum distance from the BMO to the internal limiting membrane. Measuring the NRR using the BMO-MRW has been shown to reduce rates of false positive errors in healthy myopic eyes with tilted ONHs, yielding more accurate RNFL analyses.^{11,22}

Other imaging approaches have been introduced to better differentiate between glaucomatous optic neuropathy and myopia. Ganglion cell analysis in sd-OCT relies largely on the fact that retinal ganglion cells in the peripapillary RNFL (ppRNFL) are mainly located within the macula. Given the artefactual OCT changes that can confound analysis in myopic eyes, OCT of the ganglion cell-inner plexiform layer (GC-IPL) may aid in the differential diagnosis between glaucoma and myopia, especially in myopic eyes where the optic disc structure may introduce inaccuracies in ppRNFL measurements. Compared to RNFL analyses, macular ganglion cell complex parameters may be less susceptible to artefacts from refractive error or ONH morphology.²³

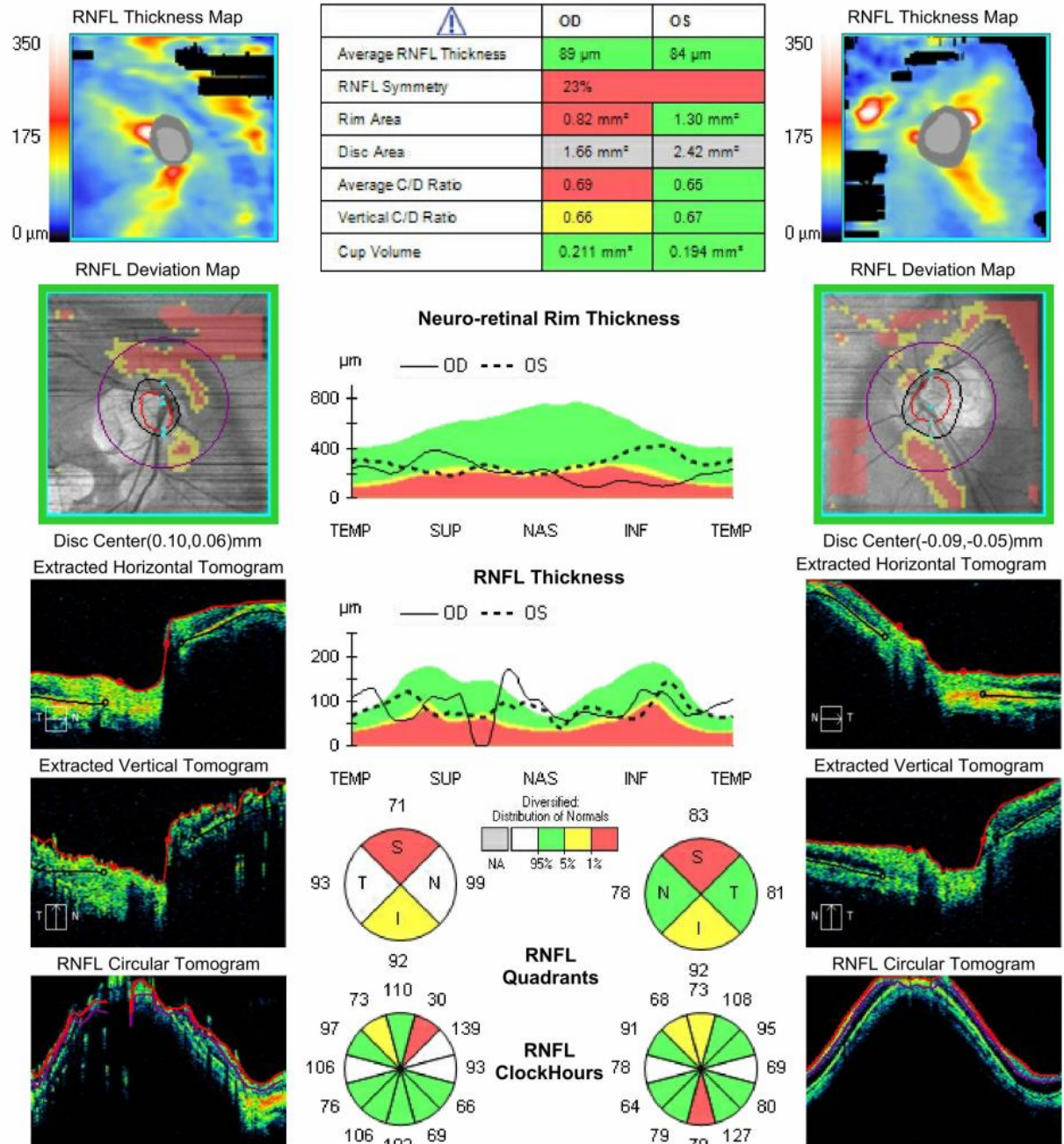
Various scoring systems for identifying glaucoma in myopic eyes have been proposed. One study involving 195 highly myopic eyes identified that the GC-IPL hemifield test has an especially high sensitivity for discriminating between myopia and glaucoma. This test measures GC-IPL thickness differences across the horizontal temporal raphe on an OCT macula. The presence of temporal hemifield asymmetry on OCT GC-IPL thickness maps (“raphe sign”) can be a particularly useful parameter for detecting glaucomatous changes in high myopes.²²

In recent years, many clinicians have advocated for the development of an OCT normative database of myopic eyes as a more meaningful reference group for clinical decision making. Several small myopic normative databases have been developed for these purposes and have shown promise in improving the specificity and sensitivity for detecting RNFL abnormalities in eyes with

ZEISS

	OD	OS	
DOB: 7/10/1968	Exam Date: 1/27/2022	1/27/2022	St. Joseph's Health Care Lond
Gender: Male	Exam Time: 9:06 AM	9:07 AM	
Technician: Operator, Cirrus	Serial Number: 6000-10923	6000-10923	
	Signal Strength: 8/10	7/10	

ONH and RNFL OU Analysis: Optic Disc Cube 200x200 OD ● ● OS



Comments Analysis Edited: 1/27/2022 9:09 AM	Doctor's Signature 	CIRRUS1 SW Ver: 11.5.2.54532 Copyright 2020 Carl Zeiss Meditec, Inc All Rights Reserved Page 1 of 1
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Figure 2: Zeiss Cirrus® HD-OCT analysis of the retinal nerve fibre layer queried superior thinning OU and inferior thinning OS; courtesy of Cindy Hutnik et al.

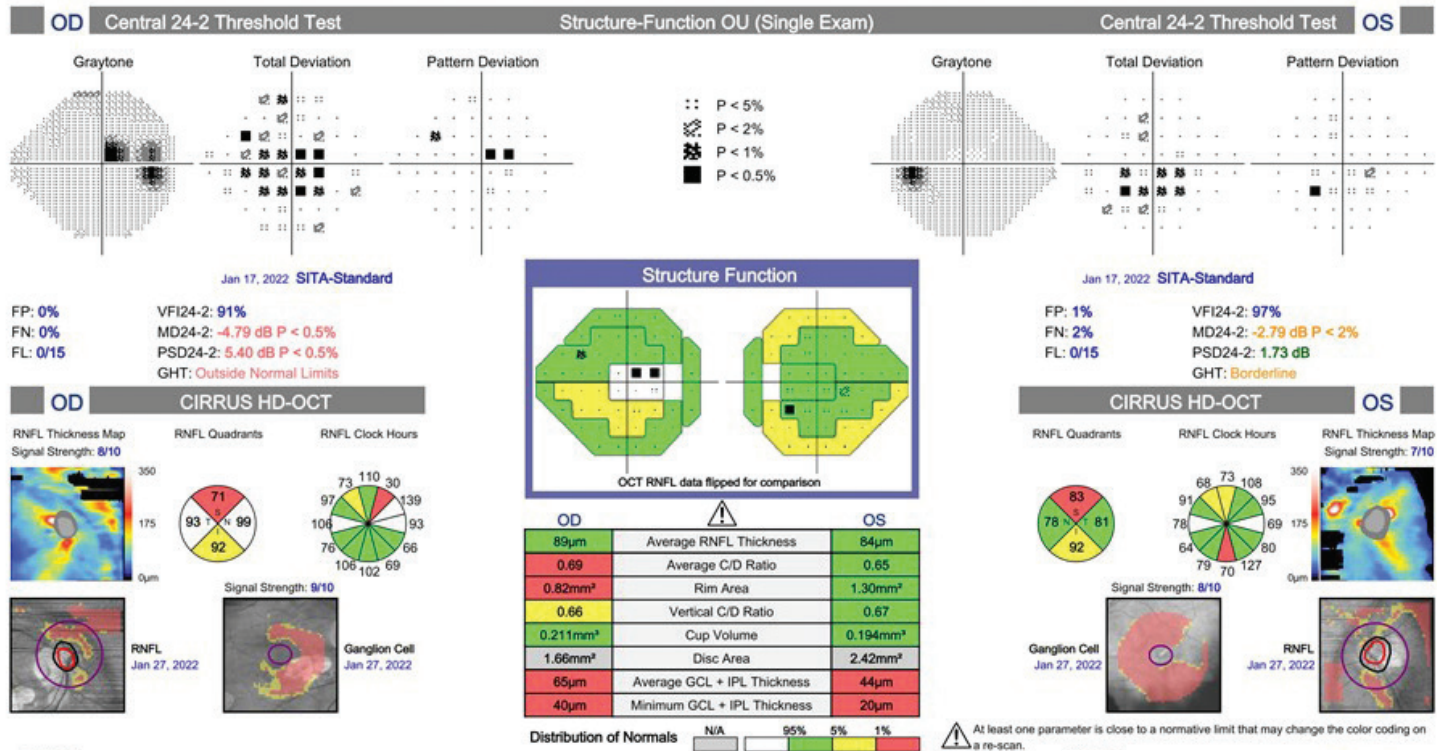


Figure 3: Structure-Function Maps (Zeiss Cirrus® HD-OCT), containing 24-2 visual field data and querying glaucoma OU; courtesy of Cindy Hutnik et al.

high myopia.^{24,25} One study found that integrating a myopic normative database for RNFL thickness analyses can lead to a substantial improvement in reduction of false positive errors in myopic eyes compared to the emmetropic normative database contained in the Zeiss Cirrus® HD-OCT.²⁵ Myopic normative databases have proven challenging to develop for recruitment and proprietary reasons. Further, the considerable diversity of ONH configurations and refractive errors seen in myopia make it challenging to identify a 'standard normal' as a reference group.

Artificial Intelligence:

The application of artificial intelligence (AI) approaches to identifying glaucoma in the setting of myopia remains an exciting prospect. Current research efforts in this area have largely focused on disease classification and prediction for both glaucoma and myopia. Machine learning models (a branch of AI) have been shown to identify both glaucoma and myopia from OCT printouts and may predict glaucomatous progression.²⁶ AI approaches have made significant inroads in detecting glaucomatous disc damage from fundus photographs and OCTs. Other algorithms may successfully predict progression of glaucoma in eyes with myopia.^{27,28} Since machine learning models in glaucoma

rely heavily on ONH morphology in making decisions, many of the developments in AI in this field are still limited by excluding highly myopic eyes from training datasets. AI remains an exciting frontier and may become an additional clinical tool in distinguishing between glaucoma and myopia. The incorporation of AI platforms into routinely used electronic medical records may be very helpful in deciphering the complexities posed by managing glaucoma in the setting of myopia.

Conclusion

The growing public health burden associated with high or pathologic myopia is of concern as these patients are at higher risk for other related conditions including POAG. Optic nerve analysis in high myope patients with glaucomatous optic nerve changes may be difficult to detect. In myopes, RNFL changes may be predictive of glaucoma but OCT measurements of the RNFL are hampered by the lack of a myopic reference group which may lead to false positives. Visual fields can also be difficult to interpret with many variables contributing to visual field defects and/or mimicking glaucomatous field loss. The emergence of new imaging techniques and the prospect of AI hold much promise in helping clinicians differentiate between glaucoma and myopia.

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