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Editorial Board Member of *World Journal of Clinical Cases*, Jaw-Yuan Wang, MD, PhD, Professor, Surgical Oncologist, Department of Surgery, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Kaohsiung 807, Taiwan. jawyuanwang@gmail.com

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ORIGINAL ARTICLE

Retrospective Study

Value of optical coherence tomography measurement of macular thickness and optic disc parameters for glaucoma screening in patients with high myopia

Hua Mu, Rui-Shu Li, Zhen Yin, Zhuo-Lei Feng

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Hua Mu, Rui-Shu Li, Zhen Yin, Zhuo-Lei Feng, Department of Ophthalmology, The First Affiliated Hospital of Harbin Medical University, Harbin 150001, Heilongjiang Province, China

Corresponding author: Hua Mu, Doctor, Department of Ophthalmology, The First Affiliated Hospital of Harbin Medical University, No. 23 Youzheng Street, Nangang District, Harbin 150001, Heilongjiang Province, China. mh13836017782@163.com

Abstract

BACKGROUND

The basic method of glaucoma diagnosis is visual field examination, however, in patients with high myopia, the diagnosis of glaucoma is difficult.

AIM

To explore the value of optical coherence tomography (OCT) for measuring optic disc parameters and macular thickness as a screening tool for glaucoma in patients with high myopia.

METHODS

Visual values (contrast sensitivity, color vision, and best-corrected visual acuity) in three groups, patients with high myopia in Group A, patients with high myopia and glaucoma in Group B, and patients with high myopia suspicious for glaucoma in Group C, were compared. Optic disc parameters, retinal nerve fiber layer (RNFL) thickness, and ganglion cell layer (GCC) thickness were measured using OCT technology and used to compare the peri-optic disc vascular density of the patients and generate receiver operator characteristic (ROC) test performance curves of the RNFL and GCC for high myopia and glaucoma.

RESULTS

Of a total of 98 patients admitted to our hospital from May 2018 to March 2022, totaling 196 eyes in the study, 30 patients with 60 eyes were included in Group A, 33 patients with 66 eyes were included in Group B, and 35 patients with 70 eyes were included in Group C. Data were processed for Groups A and B to analyze the efficacy of RNFL and GCC measures in distinguishing high myopia from high myopia with glaucoma. The area under the ROC curve was greater than 0.7, indicating an acceptable diagnostic value.

CONCLUSION
The value of OCT measurement of RNFL and GCC thickness in diagnosing glaucoma in patients with high myopia and suspected glaucoma is worthy of development for clinical use.

Key Words: High myopia suspected glaucoma; Optical coherence tomography; Retinal nerve fiber layer thickness; Ganglion cell layer thickness; Diagnostic efficacy

Core Tip: Glaucoma is an irreversible, blinding eye disease with a high clinical incidence that is characterized by loss of visual acuity, optic disc atrophy, and visual field defects. The basic method of glaucoma diagnosis is visual field examination, however, in patients with high myopia, the diagnosis of glaucoma is difficult. optical coherence tomography (OCT) is a high-resolution technique that uses low-coherence light interference to reflect light from biological tissues, allowing visualization of internal structures of the living body *via* tomographic imaging. The value of OCT measurement of retinal nerve fiber layer and ganglion cell layer thickness in diagnosing glaucoma in patients with high myopia and suspected glaucoma is worthy of development for clinical use.

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INTRODUCTION

Glaucoma is an irreversible, blinding eye disease with a high clinical incidence that is characterized by loss of visual acuity, optic disc atrophy, and visual field defects[1]. Studies have confirmed that glaucoma pathogenesis involved reduced blood supply to the optic nerve and pathologically elevated intraocular pressure[2,3].

Previously, a cup-to-disc ratio greater than 0.6 was considered to be a clinical characteristic of glaucoma and a marker for its development. However, it was found that this ratio was also seen in high myopia and was not specific to glaucoma[4]. Therefore, diagnosis of glaucoma in the setting of high myopia is more difficult.

Recent studies have confirmed a correlation between glaucoma and high myopia, which has been recognized as a risk factor for glaucoma[5]. In the early stages of glaucoma onset, abnormalities of the fundus are similar with those of highly myopic individuals. For example, enlarged cup-to-disc ratio is both a diagnostic clue for glaucoma and a clinical feature of high myopia[6,7]. Glaucoma can cause irreversible damage to visual function, and clinics are constantly searching for sensitive diagnostic indicators that can support the aim of early intervention[8].

Degenerative morphological changes in the fundus of highly myopic patients are the pathological basis for abnormal visual function. When glaucoma is comorbid with myopia, the retinal photoreceptor structure is significantly disturbed, and the patient's regulatory response during visualization is significantly worse than that of patients with pure myopia, resulting in a significant decrease in contrast sensitivity (CS). Previous studies have confirmed that color vision (CV) and best-corrected visual acuity (BCVA) are worse in patients with high myopia when it is combined with glaucoma[9]. It has been noted that in high myopia, thinning of the superior and inferior, as opposed to nasal, retinal nerve fiber layer (RNFL) thickness did not correlate well with myopic refraction; therefore, upon observation of this, RNFL damage due to glaucoma must be watched out for[10].

The basic method of glaucoma diagnosis is visual field examination; however, studies have shown that retinal ganglion cell damage may be present already before the development of visual field defects in glaucoma patients[11]. optical coherence tomography (OCT) is a high-resolution technique that uses low-coherence light interference to reflect light from biological tissues, allowing visualization of internal structures of the living body *via* tomographic imaging[12]. It is commonly used to measure parameters of the ocular RNFL and ganglion cell layer (GCC). The results of this method are in good agreement with histological testing and have been widely used in the diagnosis and follow-up of glaucoma. It has been clinically established[13] that the retinal plexiform layer, ganglion cell layer, and nerve fiber layer collectively constitute the macular ganglion cell complex, and the measurement of GCC thickness can assess ganglion cell loss. This technique accurately reflects retinal ganglion cell apoptosis and nerve fiber loss in glaucoma[14]. Many studies have confirmed the high sensitivity and validity of OCT for

glaucoma diagnosis[15,16].

This study applied OCT to the assessment of high myopia comorbid with glaucoma, evaluated its diagnostic value for glaucoma, and assessed the screening value of parameters such as optic disc parameters and macular thickness measured by OCT.

MATERIALS AND METHODS

Enrollment criteria

Patient who were enrolled into our hospital. Inclusion criteria were as follows: (1) All patients had myopia with refractive error greater than -6.00 D, and the patient's degree did not increase within 2 years, meeting the diagnostic criteria for high myopia; (2) Group B patients had elevated intraocular pressure on clinical examination, characteristic changes in the optic disc, open atrial angle, and a certain degree of visual field defect, meeting the diagnostic criteria for glaucoma in the *Expert Consensus on Glaucoma Diagnosis and Treatment* in China[17]; and (3) Group C patients had one or more of the following features in clinical examination: Open anterior chamber angle; persistent elevation of intraocular pressure; structural changes in the optic nerve suggesting glaucoma; suspicious early glaucomatous changes by visual field examination.

Exclusion criteria were as follows: (1) Optic nerve or retinal disease; (2) Family history of glaucoma; (3) Resistance of a patient to the study; (4) Ocular disease; and (5) Other diseases that may cause ocular pathology, such as intracranial pathology, hypertension, and diabetes.

All patients have given written informed consent.

Methods

OCT examination: The patient was instructed to sit with the lower jaw in the jaw frame and the pupil in its natural state without dialation. Spectralis OCT (Heidelberg, German was used for the examination. The scan was started with the central macular recess as the center, the scan diameter was set at 7 mm, and the depth was 5 μm. The thickness of the upper and lower macula and the average GCC and the general loss of volume (GLV) and focal loss of volume (FLV) were recorded. The thickness of the retinal nerve fiber layer (RNFL) of quadrant measurements (whole circumference, upper and lower quadrants, temporal side, and nasal side) in the Group A, B, and C was automatically measured and recorded by the instrument system, with the optic papilla as the center, and the scanning depth was set at 5 μm and the diameter was 3.45 mm.

Observation indicators

General ophthalmologic examination was performed on all patients, and their visual values, including CS, CV, and BCVA, were recorded. OCT was performed on all patients to record peripapillary parameters including optic cup area, optic disc area, cup/disc area ratio, and cup/disc diameter ratio.

Statistical methods

SPSS 23.0 (IBM, Amonk, New York, United States) was used to process the data. The *F*-test was performed for each patient measure (clinical examination data, RNFL thickness, optic disc parameters, mean GCC thickness, and peripapillary vascular density of patients), and the receiver operator characteristic (ROC) curve was used to determine the diagnostic value for high myopia accompanied by glaucoma at the level of $\alpha = 0.05$.

Patients in the three groups were compared for each retinal quadrant and the superior, inferior, and mean GCC thicknesses were compared to record the patients' GLV and FLV. The ROC curve for the diagnostic value of RNFL and mean GCC for high myopia comorbid with glaucoma was constructed after comparing the patients' peripapillary vascular density.

RESULTS

Ninety-eight patients (196 eyes) who were admitted to our hospital from May 2018 to March 2022 were included in the study, including 30 patients with 60 eyes with high myopia (Group A), 33 patients with 66 eyes with high myopia accompanied by glaucoma (Group B), and 35 patients with 70 eyes with high myopia suspected of glaucoma (Group C). There was no statistically significant difference in the baseline information of the three groups (Table 1), with high comparability ($P > 0.05$).

The visual value levels (of CS, CV, and BCVA) of the three groups were compared, and significant differences were observed ($P < 0.05$). Compared to Group A, the CS, CV, and BCVA levels of Groups B and C were lower, but the values in Group C were higher than those in Group B, and the differences were statistically significant ($P < 0.05$) (Table 2).

Table 1 Comparison of baseline data between the three patient groups (mean ± SD, *n*)

Group	Age (yr)	Gender (male/female)	Equivalent sphere diameter (D)	Mean refraction (D)
Group A (n = 60)	36.45 ± 3.78	22/38	-1.78 ± 2.21	-0.44 ± 1.56
Group B (n = 66)	35.48 ± 3.24	30/36	-2.16 ± 2.15	0.65 ± 2.45
Group C (n = 70)	36.15 ± 3.12	36/34	-2.57 ± 2.45	-1.05 ± 2.15
F/χ^2 value	1.384	2.858	1.949	1.430
P value	0.253	0.240	0.145	0.242

Table 2 Comparison of contrast sensitivity, color vision, and best-corrected visual acuity levels among three groups (mean ± SD, *n*)

Group	CS	CV	BCVA
Group A (n = 60)	96.45 ± 1.78	0.94 ± 0.08	0.97 ± 0.08
Group B (n = 66)	87.48 ± 1.24[a]	0.81 ± 0.05[a]	0.87 ± 0.15[a]
Group C (n = 70)	89.15 ± 1.12[a,b]	0.87 ± 0.02[a,b]	0.91 ± 0.11[a,b]
F value	32.163	90.314	11.430
P value	0.000	0.000	0.000

[a]P < 0.05 *vs* group A.
[b]P < 0.05 *vs* group B.
CS: Contrast sensitivity; CV: Color vision; BCVA: Best-corrected visual acuity.

There was no significant difference in the cup-to-disc area ratio among the three groups (P > 0.05); however, there were statistically significant differences in cup area, optic disc area, and cup/disc diameter ratio among all groups. The values of Groups B and C were significantly higher than those of Group A, and the area of the optic disc and cup/disc diameter ratio of Group C were significantly smaller than those of Group B (P < 0.05) (Table 3).

RNFL thicknesses in all quadrants (whole circumference, upper and lower quadrant, temporal side, and nasal side) were statistically different among the three groups. Compared with Group A, RNFL thickness in the whole circumference, upper and lower quadrants, and nasal side decreased in Groups B and C, and Group C was greater than that in Group B. The temporal RNFL thickness in Groups B and C was significantly higher than that in Group A, and the temporal RNFL thickness in Group C was significantly lower than that in Group B (P < 0.05) (Table 4).

The upper, lower, and mean GCC thickness and GLV and FLV values between the three groups decreased in Groups B and C, and each GCC thickness in Group C was greater than that in Group B; GLV and FLV in Groups B and C were higher than those in Group A, and Group C was lower than Group B, with statistical significance (P < 0.05). The comparison of capillary density around the optic disc among the three groups showed statistically significant differences in other regions but not in the comparison of capillary density in the optic disc (P < 0.05). The hologram, vascular density beside and within the optic disc, and capillary density beside the optic disc of Groups B and C were reduced to varying degrees, and the values of Group C were higher than those of Group B, and the difference was statistically significant (P < 0.05) (Table 5).

DISCUSSION

This study investigated the value of OCT measurement of peripapillary parameters and macular thickness as a screening test for patients with high myopia and suspected glaucoma.

There was no significant difference in the cup-to-disc area ratio between the groups when peripapillary parameters were compared. With the increase in the ocular axis of the eye that occur in high myopia, the myopic arcs gradually atrophied, some dimensions correlated with the those of disc defect, and the cup-disc area ratio also changed. Therefore, the change in cup-to-disc area ratio can only be used as an auxiliary indicator.

When combined with the measurements used in this study, the optic cup area, optic disc area, and cup/disc diameter ratio were significantly different among the three groups. Therefore, the above indicators can be applied in combination with a view to improve the effectiveness of screening for glaucoma suspected of high myopia. In this study, the CS, CV, and BCVA levels in the three groups

Table 3 Comparison of weekly parameters in the three groups (mean ± SD, *n*)

Group	Optic cup area (mm)	Optic disc area (mm)	Cup/disc area ratio	Cup/disc diameter ratio
Group A (*n* = 60)	1.02 ± 0.81	2.82 ± 0.88	0.34 ± 0.21	0.56 ± 0.05
Group B (*n* = 66)	1.31 ± 0.75[a]	3.87 ± 0.87[a]	0.37 ± 0.22	0.61 ± 0.06[a]
Group C (*n* = 70)	1.42 ± 0.65[a]	3.45 ± 0.75[a,b]	0.35 ± 0.18	0.59 ± 0.04[a,b]
F value	4.890	25.691	0.369	15.672
P value	0.009	0.000	0.692	0.000

[a]*P* < 0.05 *vs* group A.
[b]*P* < 0.05 *vs* group B.

Table 4 Retinal nerve fiber layer thickness in each of the three groups (mean ± SD, *n*)

Group	Complete cycle (μm)	Upper quadrant (μm)	Lower quadrant (μm)	Temporal side (μm)	nasal side (μm)
Group A (*n* = 60)	109.12 ± 10.54	133.23 ± 7.87	130.23 ±5.54	111.23 ± 5.36	60.45 ± 3.45
Group B (*n* = 66)	102.78 ± 9.23[a]	125.65 ± 7.54[a]	121.32 ± 5.45[a]	123.45 ± 5.21[a]	56.45 ± 2.98[a]
Group C (*n* = 70)	106.45 ± 10.21[a,b]	129.87 ± 8.56[a,b]	127.63 ± 5.78[a,b]	115.46 ± 5.14[a,b]	58.45 ± 2.12[a,b]
F value	4.212	14.177	42.888	89.611	30.552
P value	0.016	0	0	0	0

[a]*P* < 0.05 *vs* group A.
[b]*P* < 0.05 *vs* group B.

Table 5 Comparison of mean ganglion cell layer thickness and general loss of volume and focal loss of volume in the three groups (mean ± SD, *n*)

Group	Upper GCC (μm)	Bottom GCC (μm)	Mean GCC (μm)	GLV (%)	FLV (%)
Group A (*n* = 60)	94.15 ± 6.78	92.45 ± 7.45	92.56 ± 7.45	5.16 ± 4.12	1.36 ± 1.12
Group B (*n* = 66)	71.45 ± 6.56[a]	78.26 ± 11.65[a]	73.66 ± 8.12[a]	23.15 ± 8.97[a]	7.54 ± 4.85[a]
Group C (*n* = 70)	83.54 ± 5.54[a,b]	82.64 ± 8.78[a,b]	82.43 ± 8.26[a,b]	15.05 ± 8.78[a,b]	3.88 ± 2.56[a,b]
F value	205.836	36.474	88.326	85.061	57.448
P value	0	0	0	0	0

[a]*P* < 0.05 *vs* group A.
[b]*P* < 0.05 *vs* group B.
GCC: Ganglion cell layer; GLV: General loss of volume; FLV: Focal loss of volume.

were also compared, and statistically significant differences were found between the groups. We also found that these values decreased sequentially in Groups A, C, and B. These facts suggest that the above indices are more likely to be affected in patients with high myopia and glaucoma. Therefore, an effective method for the early assessment of retinal ganglion cell abnormalities is more meaningful when screening for glaucoma in the setting of high myopia. When RNFL thickness in the outer macular ring region was measured in the three groups in this study, the temporal side was found to be the thinnest and the other quadrants to be thicker, which were consistent with clinically-recognized anatomical features.

In this study, we further compared the differences between the three groups and found statistical differences in RNFL thickness in each orbital quadrant (whole circumference, upper and lower quadrants, temporal side, and nasal side), with thicker RNFL in the upper and lower quadrants next to the optic disc in each group, followed by the temporal and nasal side. The full circumferential, upper and lower quadrant, and nasal RNFL thickness in patients with high myopia accompanied by glaucoma were the smallest among the three groups, while the temporal side was the largest. Previous studies have confirmed that CV and BCVA were worse in patients with high myopia combined with glaucoma

[14], and the present study yielded consistent results.

It is suggested that the above index characteristics can be used to screen for glaucoma with suspected high myopia. The analysis was as follows: The high myopia-suspect glaucoma population may already have nerve fiber layer loss and ganglion cell damage, with the phenomenon more pronounced in patients with comorbid glaucoma. In high myopia with glaucoma, the temporal optic disc undergoes significant tilting and anticlockwise transposition, resulting in an overlap of retinal temporal fiber bundles and a significant increase in temporal RNFL thickness[18].

The efficacy of the GCC thickness parameter has been found to be better than that of the RNFL thickness parameter for the diagnosis of glaucoma[19]. In this study, GCC thickness was found to be minimal in Group B—significantly lower than those in the other two groups—and significantly lower in that in Group C than that in Group A. It has been suggested that the GCC can be used to screen people with high myopia and glaucoma. Structural changes in the macular optic ganglion cell complex can affect the function of this layer of the retina, which may account for the different sensitivities of the GCC and RNFL. Retinal ganglion cell apoptosis and axonal damage are among the pathological changes in glaucoma; therefore, GCC thickness testing is more commonly used and more effective.

Indicators, such as GLV and FLV, can assess optic nerve atrophy and changes in visual function, such as visual acuity and visual field. In the present study, the highest values of these indices were found in patients with high myopia comorbid with glaucoma, and GLV and FLV measured the average amount of loss in the whole and local GCC. The results confirmed that the GCC was significantly thinner in patients with high myopia accompanied by glaucoma. The altered GLV and FLV values are consistent with the pathological basis of glaucoma.

The results of this study showed that whole-image vascular density, intra- and near-optic disc density, and peri-optic capillary density were significantly lower in Groups A, C, and B, with statistical significance between the groups. It has been clinically established that the above indices were reduced to a greater extent in high myopia accompanied by glaucoma than in high myopia alone[20], and the AUC values for pars plana vascular density analyzed in that study were higher than those for the intra-optic disc. The results of the present study are similar to those of the previous studies.

Numerous studies have used OCT as the primary method for examining glaucoma. The present study showed that changes in RNFL thickness and each GCC parameter were more obvious in the population with high myopia comorbid with glaucoma, and the efficacy of diagnosing high myopia with glaucoma was higher. In highly myopic eyes with significant tilted degeneration of the optic disc, segmentation of the optic nerve fiber stratification measured by OCT occurs with a large error, and the combined analysis of OCT parameters was a meaningful method. The sample size of each group in this study was small and did not consider the effect of other relevant factors on the results. Further studies are required to improve the screening of high myopia with glaucoma.

CONCLUSION

In conclusion, OCT measurement of RNFL and GCC thickness is of diagnostic value for glaucoma with suspected high myopia and is worthy of clinical promotion.

ARTICLE HIGHLIGHTS

Research background

Glaucoma is an irreversible, blinding eye disease with a high clinical incidence that is characterized by loss of visual acuity, optic disc atrophy, and visual field defects. The basic method of glaucoma diagnosis is visual field examination, however, in patients with high myopia, the diagnosis of glaucoma is difficult.

Research motivation

Optical coherence tomography (OCT) is a high-resolution technique that uses low-coherence light interference to reflect light from biological tissues, allowing visualization of internal structures of the living body *via* tomographic imaging. It is commonly used to measure parameters of the ocular retinal nerve fiber layer and ganglion cell layer.

Research objectives

This study was to explore the value of OCT for measuring optic disc parameters and macular thickness as a screening tool for glaucoma in patients with high myopia. The results could promote the improvement of the diagnosis of glaucoma in patients with high myopia and suspected glaucoma.

Research methods

Visual values in patients with high myopia in, patients with high myopia and glaucoma, and patients with high myopia suspicious for glaucoma were compared. Optic disc parameters, retinal nerve fiber layer thickness (RNFL), and ganglion cell layer (GCC) thickness were measured using OCT technology and used to compare the peri-optic disc vascular density of the patients and generate receiver operator characteristic test performance curves of the RNFL and GCC for high myopia and glaucoma.

Research results

The visual value levels of the three groups were significantly different. There were statistically significant differences in cup area, optic disc area, and cup/disc diameter ratio among all groups. RNFL thicknesses in all quadrants were statistically different among the three groups. The area under the ROC curve was greater than 0.7, indicating an acceptable diagnostic value.

Research conclusions

The value of OCT measurement of RNFL and GCC thickness in diagnosing glaucoma in patients with high myopia and suspected glaucoma is worthy of development for clinical use.

Research perspectives

Further studies with large sample and other relevant factors are required to improve the screening of high myopia with glaucoma.

FOOTNOTES

Author contributions: Mu H designed the research study; Li RS performed the research; Mu H and Yin Z analyzed the data and wrote the manuscript; all authors have read and approve the final manuscript.

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ORCID number: Hua Mu 0000-0002-5224-3405; Rui-Shu Li 0000-0003-0463-672X; Zhen Yin 0000-0002-9095-518X; Zhuo-Lei Feng 0000-0001-9383-5661.

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