Original Article

Effectiveness of Glaucoma Diagnostic Parameters from Spectral Domain-Optical Coherence Tomography of Myopic Patients

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Abstract

Background: Currently, spectral-domain optical coherence tomography (SD-OCT) appears to be a new type of glaucoma diagnostic tool. Thus, this study aimed to evaluate the effectiveness of glaucoma diagnostic parameters from SD-OCT of patients with different severities of myopia.
Methods: This was a cross-sectional study. A total of 248 participants (248 eyes) were enrolled, including 51 cases in the early primary open-angle glaucoma group, 79 cases in the control group (0.50 D to −0.50 D, excluding −0.50 D), 47 cases in the low-myopic group (−0.50 to −3.00 D, excluding −3.00 D), 43 cases in the moderate-myopic group (−3.00 to −6.00 D, excluding −6.00 D), and 28 cases in the high-myopic group (≤−6.00 D). All participants were examined using the Humphrey visual field test and SD-OCT. The SD-OCT parameters of the retinal nerve fiber layer (RNFL) and ganglion cell complex were analyzed statistically using the receiver operating characteristic curve and area under the curve (AUC).
Results: The AUC showed that the best parameters for the control and low-myopic groups were the inferior and inferior temporal RNFL thicknesses (AUC >0.94), respectively; for the moderate- and high-myopic groups, the best parameter was the temporal low RNFL thickness (AUC, 0.926 and 0.896, respectively). The AUC of the inferior parameters of the moderate-myopic group (0.864) was lower, ranked 15th among all RNFL parameters. When the sensitivity was fixed at 85%, the specificity of the inferior, superior, inferior temporal, and superior temporal quadrants was higher (>80%) in the control and low-myopic groups, while they were lower (20–60%) for the moderate- and high-myopia groups. The green color based on the OCT database was also less for the high-myopic group compared with that of other groups ($P < 0.05$).
Conclusions: Glaucoma diagnostic parameters from SD-OCT were not clinically effective for the moderate- and high-myopic groups. The specificities were low. The moderate- and high-myopic groups require comprehensive analyses for the diagnoses of glaucoma. The SD-OCT database should be improved to better indicate the level of myopia based on the corresponding diopter readings.

Key words: Glaucoma; Myopia; Nerve Fibers; Open Angle; Retina

Introduction

Myopia has a very high prevalence and is an independent and significant risk factor for primary open-angle glaucoma (POAG).[1] However, an anomalous optic nerve head (ONH) caused by myopia makes glaucoma screening and early diagnosis difficult in myopic patients.[2-4] As a new type of glaucoma diagnostic tool, high-resolution spectral-domain optical coherence tomography (SD-OCT) can assist in the early diagnosis of glaucoma by quantitatively analyzing the ONH with excellent precision. However, it is not known whether the glaucoma diagnostic parameters from SD-OCT can accurately diagnose the changes in fundus related to myopia. At present, there are few studies reported in this area. We therefore determined whether SD-OCT could be used to more accurately diagnose patients with myopia and early glaucoma.

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.4103/0366-6999.237391

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Received: 08-02-2018 **Edited by:** Yi Cui
How to cite this article: Fang Y, Zhang HQ, Qiao RH, Yao XY, Pan YZ, Li M. Effectiveness of Glaucoma Diagnostic Parameters from Spectral Domain-Optical Coherence Tomography of Myopic Patients. Chin Med J 2018;131:1819-26.

Methods

Ethical approval

This study was approved by the Ethics Committee of Peking University First Hospital. Consent was obtained from all patients, and the protocol followed the principles of the *Declaration of Helsinki*.

Myopic and early glaucoma groups

This was a cross-sectional study, satisfying the inclusion and exclusion criteria, which involved consecutive outpatients at the Department of Ophthalmology in our hospital, from October 2012 to June 2016. Normal control and myopic groups were recruited from October 2012 to March 2013.

All POAG patients satisfied the following inclusion criteria: (1) A best-corrected visual acuity ≥20/30; (2) spherical refraction within −6.00 to 0 D and a cylinder correction within ±3.0 D, antimetropia ≤2 D; (3) open angles on gonioscopy and typical glaucomatous optic disc appearances such as rim thinning, notching, excavation, hemorrhage, or retinal nerve fiber layer (RNFL) defects; and (4) glaucomatous visual field (VF) loss on at least two separate occasions with mean deviations ≥−6 dB, with clusters of three or more adjacent points depressed more than 5 dB, or two or more adjacent points depressed more than 10 dB. The exclusion criteria were as follows: (1) eyes with coexisting retinal disease, optic neuropathy, uveitis, trauma and past intraocular surgery; (2) patients who had undergone eye-selective laser trabeculoplasty surgery within the past year; and (3) patients with a history of diabetes, hypertension, or other diseases that may have affected measurement results.

Myopic patients satisfied all of the following inclusion criteria: (1) a best-corrected visual acuity ≥20/20; (2) a spherical refraction ≤−0.50 D, cylinder correction within ±3.0 D, and spherical refraction >1/2 cylinder correction; (3) normal slit-lamp and fundus examinations; (4) healthy optic disc appearance, a cup-to-disc ratio <0.6, no evidence of diffuse or focal rim thinning, cupping, optic disc hemorrhage, or RNFL defects, and an interocular asymmetry of a cup-to-disc ratio <0.2, with leopard fundus changes, arc spots, and other nonpathological myopic changes accepted; (5) Goldmann applanation tonometer ≤21 mmHg and a central corneal thickness 520–580 μm; (6) normal VFs with a Glaucoma Hemifield Test within normal limits; (7) no pathological myopia; and (8) no prior history of glaucoma or a glaucomatous family history. Eyes with coexisting retinal disease, optic neuropathy, uveitis, trauma, and past intraocular surgery were excluded, as well as those with a history of diabetes, hypertension, or other diseases that may have affected the measurement results.

Controls satisfied all of the following inclusion criteria: (1) visual acuity ≥20/20; (2) a spherical refraction within ±0.50 D and a cylinder correction within ±0.75 D; and (3) all inclusion criteria of the myopic patients.

History and routine ophthalmic examinations

All patients underwent a full ophthalmic examination including visual acuity, refraction, intraocular pressure as measured using Goldmann applanation tonometry, gonioscopy, and a dilated fundus examination.

Visual field testing

All participants underwent SITA fast 24-2 perimetry (Humphrey perimetry, Humphrey Field Analyzer model 750; Carl Zeiss Meditec, Dublin, CA, USA). Minimal criteria for a glaucomatous VF defect were as follows: a Glaucoma Hemifield Test outside normal limits, a pattern standard deviation with $P < 5\%$, or a cluster of ≥3 points in the pattern deviation plot in a single Hemifield (superior or inferior) with $P < 0.05$, one of which was $P < 0.01$. Any one of the preceding criteria, if repeatable, was considered sufficient evidence of a glaucomatous VF defect. A reliable VF test was defined as one with fewer than 30% fixation losses, false-positive responses, or false-negative responses.

Fundus stereophotography

Early-glaucoma patients underwent TRC-SS (Topcon, Tokyo, Japan) fundus stereophotography examination, which was completed by an experienced technician. Photographic results were interpreted by an experienced glaucoma specialist.

Spectral domain-optical coherence tomography examinations

SD-OCT examinations using the RTVue-100, version 6.1 (Optovue, Fremont, CA, USA), were performed on all patients. The patient was seated in a mandibular jaw frame, adjusted to the appropriate position using internal fixation, choosing a nationality of Chinese. Each patient was scanned using two patterns, including an ONH scan and ganglion cell complex (GCC) scan. Quality SD-OCT scans were defined as those with a signal strength index >40. The parameters used for the analysis of the ONH were as follows: SH, IH, S, I, N, T, NU, SN, ST, TU, TL, IT, IN, NL, NU1, NU2, SN2, SN1, ST1, ST2, TU2, TU1, TL1, TL2, IT2, IT1, IN1, IN2, NL2, and NL1 [Figure 1], and the parameters used for the analysis of the GCC were GCC-a, GCC-S, and GCC-I.

Statistical analysis

One eye from each participant was selected for the analysis. If a participant satisfied the criteria of both eyes, then in accordance with a random number table, one eye was selected for statistical analysis. The data were analyzed using SPSS statistical software for Windows (version 14.0, SPSS, Chicago, IL, USA). A value of $P < 0.05$ was considered statistically significant. A logistic regression model was used to correct for age and diopter. Receiver operating characteristic (ROC) curves for a parameter with significant differences according to logistic regression results were constructed. Data with a normal distribution are expressed as the mean ± standard deviation (SD). Data with an abnormal distribution are expressed as the median (minimum and maximum). The counted data are expressed as a case number and percentage. Analysis of variance was used to compare the four groups of myopic patients and was also used to compare the myopic and early-glaucoma groups. The least

significant difference method was used to compare any two groups. The Chi-square test was used to compare the color code of the myopic groups. After drawing the ROC curve, the area under the ROC curve (AUC) was calculated to distinguish between myopic and glaucomatous eyes to find the best single parameter of interest.

Results

General condition

In this study, a total of 248 patients (248 eyes) were selected, including 51 cases of early POAG, 79 control eyes (0.50 D to -0.50 D, excluding -0.50 D), 47 cases of low myopia (−0.50 to −3.00 D, excluding −3.00 D), 43 cases of moderate myopia (−3.00 to −6.00 D, excluding −6.00 D), and 28 cases of high myopia (≤−6.00 D). The demographics of all groups are shown in Table 1. The differences in diopters among all groups were statistically significant ($P < 0.05$).

Spectral domain-optical coherence tomography parameters

The mean and standard deviation of SD-OCT parameters in early POAG patients and each myopic group are shown in Table 2. Table 2 also shows the results of comparisons between the control group and other groups. The temporal RNFL thickness was thicker for the high-myopic group than for the early POAG group ($P < 0.05$), while the other quadrant RNFL thicknesses were thinner for the high-myopic group.

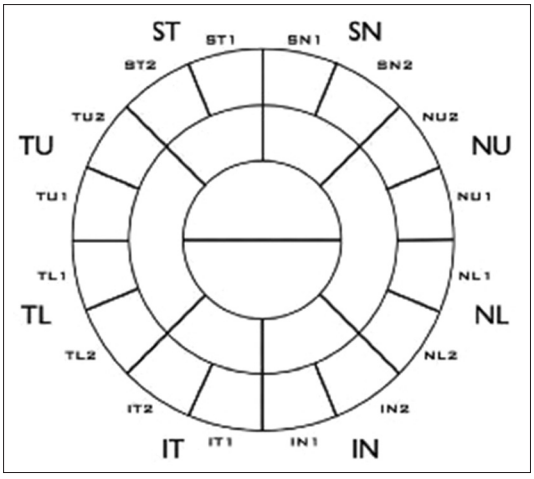

Figure 1: The ONH parameters. ONH: Optic nerve head.

Receiver operating characteristic curves

We used a logistic regression model to correct for age, given the older ages of the glaucoma group patients ($P < 0.05$). $P < 0.05$ indicated statistical difference and that the parameter was capable of distinguishing glaucoma in myopic patients. We excluded 18 parameters (IH, TL1, ST1, I, N, IT1, IN, IN1, IN2, NL, NL1, NL2, NU, NU1, NU2, SN, SN1, and SN2) in the high-myopic group and 13 parameters (IN, IN1, IN2, NL, NL1, NL2, NU, NU1, NU2, SN, SN1, SN2, and N) in the moderate-myopic group according to logistic regression results [Table 3]. ROC curves for parameters with significant differences were constructed and the AUCs were calculated [Table 4].

We further analyzed the parameters of the inferior, superior, inferior temporal, and superior temporal quadrants, which had all been well documented for their effectiveness in the diagnosis of glaucoma [Figures 2–5]. The results are shown in Table 5, when the specificity was calculated at a sensitivity of 85%.

Color code

The color code provided by SD-OCT is shown in Table 6. The number of parameters judged as normal (green) was determined from SD-OCT results. Parameters recognized for their effectiveness in the diagnosis of glaucoma were calculated. Table 7 shows the results of the Chi-square test. The differences of most parameters between the high-myopic group and other groups were significant ($P < 0.05$). Some parameters of the moderate-myopic group compared with the other groups were also statistically significant ($P < 0.05$).

Discussion

With the increase in cases of myopia,[1] the early diagnosis of POAG in myopia becomes especially important. Changes in the myopic fundus, such as disc rotation, distortion, and deformation,[1,2] affect the observations of shape and size of the optic cup and disc and interfere with the qualitative analysis

Table 1: Demographics of all groups

Characteristics	Early POAG ($n = 51$)	Low myopia ($n = 47$)	Moderate myopia ($n = 43$)	High myopia ($n = 28$)	Control ($n = 79$)
Age (years)	57.65 ± 12.27*	33.77 ± 10.64	32.81 ± 9.66	32.11 ± 7.32	39.94 ± 12.49
Equivalent spherical	−1.41 ± 1.97	2.12 ± 1.31	4.47 ± 0.82	7.54 ± 1.83	/
Sex, *n* (%)					
Male	27 (52.9)	18 (38.3)	11 (25.6)	12 (42.9)	37 (46.8)
Female	24 (47.1)	29 (61.7)	32 (74.4)	16 (57.1)	42 (53.2)
Axial length (mm)	24.27 ± 1.41	23.90 ± 0.67	25.09 ± 0.89	26.68 ± 1.06	23.03 ± 0.73
BCVA	0.95 ± 0.15	1.15 ± 0.12	1.12 ± 0.06	1.11 ± 0.09	1.18 ± 0.14
MD	−2.899 ± 1.780	−0.78 ± 1.01	−0.48 ± 1.20	−0.85 ± 1.46	−0.68 ± 1.10
PSD	3.68 ± 1.90	1.29 ± 0.71	1.32 ± 0.51	1.89 ± 1.22	1.69 ± 0.60
C/D	0.842 ± 0.120	0.252 ± 0.194	0.242 ± 0.187	0.270 ± 0.189	0.286 ± 0.189

Data are presented as mean ± SD. *The difference between glaucoma and other groups was statistically significant. POAG: Primary open-angle glaucoma; BCVA: Best-corrected visual acuity; C/D: Cup-to-disc ratio; MD: Mean deviation; PSD: Pattern standard deviation; /: Not available.

Table 2: SD-OCT parameters in early POAG, control, and each group of myopic patients (mean ± SD)

Parameters	Early POAG (n = 51)	Control (n = 79)	Low myopia (n = 47)	Moderate myopia (n = 43)	High myopia (n = 28)	F	P
RNFL average	85.172 ± 12.099	112.871 ± 10.886	112.594 ± 14.087†	104.922 ± 10.262*,†	99.750 ± 8.469*,†	53.630	<0.001
SH	87.645 ± 15.538	111.177 ± 12.542	112.633 ± 15.079†	110.326 ± 13.508†	104.333 ± 10.662†	29.654	<0.001
IH	82.695 ± 12.761	115.154 ± 12.632	111.013 ± 13.855†	99.530 ± 11.653*,†	95.442 ± 10.934*,†	59.905	<0.001
TL2	67.647 ± 13.688	88.520 ± 18.060	92.901 ± 22.619†	102.380 ± 23.150*,†	94.224 ± 17.052†	22.090	<0.001
TL1	53.588 ± 10.074	65.414 ± 9.594	69.144 ± 12.665†	73.111 ± 14.402*,†	69.385 ± 15.153†	18.948	<0.001
TU1	58.961 ± 12.159	73.881 ± 12.637	78.642 ± 20.340†	80.015 ± 14.312†	73.826 ± 13.538†	15.911	<0.001
TU2	76.961 ± 19.187	103.330 ± 20.424	109.860 ± 20.844†	113.130 ± 24.813†	104.780 ± 20.308†	22.697	<0.001
ST2	100.920 ± 29.417	141.880 ± 25.548	148.710 ± 23.327†	146.460 ± 20.819†	136.610 ± 21.307†	31.465	<0.001
ST1	113.590 ± 30.473	152.930 ± 24.355	147.400 ± 26.964†	135.300 ± 31.144*,†	126.650 ± 21.131*	19.030	<0.001
SN1	103.160 ± 23.582	132.560 ± 25.413	128.190 ± 21.261†	120.030 ± 26.724*,†	118.220 ± 20.542*,†	12.677	<0.001
SN2	102.920 ± 18.984	130.900 ± 24.290	126.210 ± 20.755†	112.180 ± 21.824*,†	110.970 ± 13.854*	17.051	<0.001
NU2	84.039 ± 19.106	102.590 ± 18.380	95.893 ± 15.926*,†	81.061 ± 18.693*,†	80.213 ± 13.822*,†	17.323	<0.001
NU1	60.490 ± 12.732	72.206 ± 11.856	65.141 ± 11.811*	57.753 ± 12.369*	57.530 ± 9.858*	15.547	<0.001
NL1	56.726 ± 9.877	66.293 ± 9.945	60.669 ± 11.996*	55.059 ± 8.709*	53.861 ± 8.590*	14.443	<0.001
NL2	73.490 ± 14.202	87.500 ± 15.510	81.241 ± 17.239*,†	72.933 ± 13.571*	71.453 ± 12.310*	11.925	<0.001
IN2	101.100 ± 18.790	126.630 ± 18.669	121.340 ± 20.956†	105.890 ± 17.005*	102.580 ± 12.948*	22.384	<0.001
IN1	104.710 ± 21.569	150.550 ± 28.555	145.740 ± 28.744†	122.410 ± 24.160*,†	117.330 ± 23.039*,†	31.165	<0.001
IT1	109.800 ± 28.702	170.900 ± 22.725	170.010 ± 28.783†	150.510 ± 26.946*,†	142.140 ± 26.628*,†	49.176	<0.001
IT2	94.314 ± 25.464	144.560 ± 27.828	148.060 ± 29.029†	150.620 ± 29.660†	138.430 ± 24.660†	36.287	<0.001
GCC-a	80.717 ± 8.727	96.801 ± 5.868	95.952 ± 13.815†	93.724 ± 6.025†	90.869 ± 5.835*,†	31.569	<0.001
GCC-S	84.471 ± 10.034	96.626 ± 5.783	96.377 ± 14.446†	93.889 ± 6.384†	91.627 ± 5.729*,†	16.446	<0.001
GCC-I	76.960 ± 11.877	96.998 ± 6.463	95.531 ± 13.429†	93.657 ± 6.149*,†	90.105 ± 6.502*,†	40.350	<0.001
I	102.480 ± 19.113	148.160 ± 17.627	146.290 ± 19.466†	132.360 ± 18.183*,†	125.120 ± 17.047*,†	56.325	<0.001
S	105.150 ± 21.280	139.570 ± 19.291	137.630 ± 18.758†	128.490 ± 20.637*,†	123.110 ± 13.582*,†	28.265	<0.001
N	68.686 ± 12.524	82.148 ± 12.379	75.736 ± 12.846*,†	66.702 ± 12.163*	65.764 ± 10.052*	18.366	<0.001
T	64.289 ± 11.375	82.787 ± 13.017	87.637 ± 16.396†	92.160 ± 17.450*,†	85.554 ± 13.616†	27.209	<0.001
IT	102.060 ± 25.213	157.730 ± 21.776	159.040 ± 23.899†	150.560 ± 24.732†	140.290 ± 22.088*,†	53.239	<0.001
IN	102.900 ± 18.854	138.590 ± 22.007	133.540 ± 22.057†	114.150 ± 19.681*,†	109.950 ± 16.565*	31.779	<0.001
NL	65.108 ± 11.506	76.897 ± 12.234	70.955 ± 14.161*,†	63.996 ± 10.756*,†	62.657 ± 10.074*,†	13.873	<0.001
NU	72.265 ± 15.246	87.399 ± 14.422	80.517 ± 13.108*,†	69.407 ± 15.073*,†	68.871 ± 11.332*,†	18.003	<0.001
SN	103.040 ± 20.005	131.730 ± 23.914	127.200 ± 19.376†	116.110 ± 22.948*,†	114.600 ± 15.424*,†	16.187	<0.001
ST	107.250 ± 27.967	147.400 ± 19.981	148.060 ± 22.210†	140.880 ± 21.866†	131.630 ± 16.734*,†	30.615	<0.001
TU	67.961 ± 14.866	88.607 ± 15.886	94.253 ± 19.957†	96.573 ± 18.723*,†	89.303 ± 16.006†	21.697	<0.001
TL	60.618 ± 11.147	76.967 ± 13.088	81.022 ± 16.403†	87.747 ± 18.003*,†	81.804 ± 15.047†	23.570	<0.001

*The difference between the control and myopic groups was statistically significant, P<0.05; †The difference between the early-glaucoma and myopic groups was statistically significant, P<0.05. RNFL: Retinal nerve fiber layer; SD-OCT: Spectral domain-optical coherence tomography; POAG: Primary open-angle glaucoma; SD: Standard deviation; GCC: Ganglion cell complex.

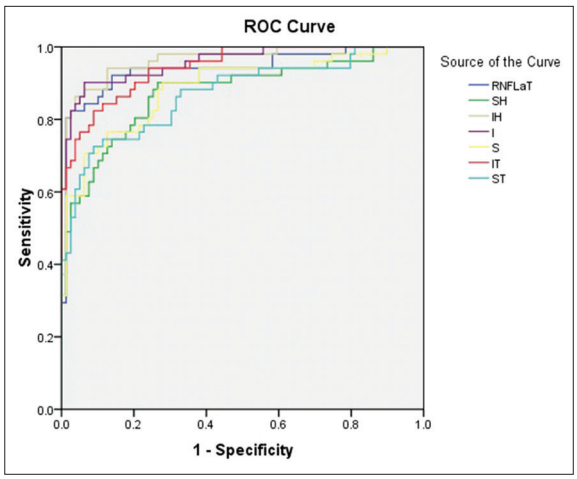

Figure 2: ROC of early POAG versus control. ROC: Receiver operating characteristic; POAG: Primary open-angle glaucoma.

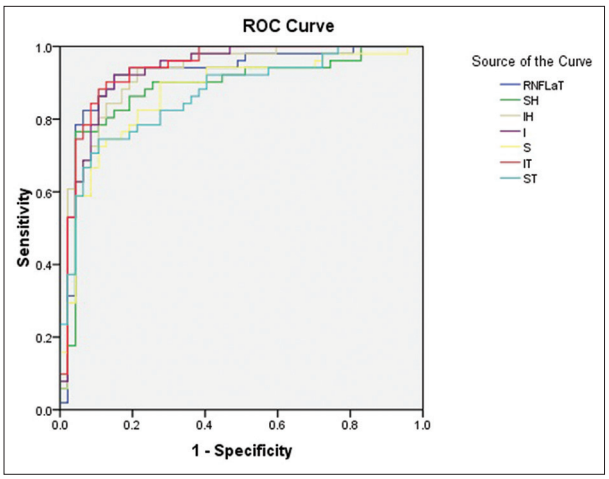

Figure 3: ROC of early POAG versus low myopia. ROC: Receiver operating characteristic; POAG: Primary open-angle glaucoma.

Table 3: *P* values of the logistic regression model

Parameters	Early POAG versus control		Early POAG versus low myopia		Early POAG versus moderate myopia		Early POAG versus high myopia	
	Wald	*P*	Wald	*P*	Wald	*P*	Wald	*P*
RNFL average	11.015	0.001	28.966	<0.001	12.040	0.001	6.744	0.009
SH	24.581	<0.001	26.254	<0.001	12.727	0.000	7.596	0.006
IH	19.277	<0.001	28.473	<0.001	6.725	0.009	3.712	0.054
TL2	14.542	<0.001	16.640	<0.001	12.463	0.000	6.673	0.010
TL1	16.892	<0.001	18.546	<0.001	9.779	0.002	2.566	0.109
TU1	19.583	<0.001	21.883	<0.001	11.943	0.001	6.970	0.08
TU2	19.653	<0.001	23.235	<0.001	12.592	0.000	8.923	0.003
ST2	21.772	<0.001	25.778	<0.001	13.059	0.000	8.257	0.004
ST1	22.310	<0.001	27.150	<0.001	6.072	0.014	3.620	0.057
SN1	20.659	<0.001	23.669	<0.001	3.168	0.075	3.478	0.062
SN2	19.407	<0.001	22.034	<0.001	1.401	0.236	1.294	0.255
NU2	16.786	<0.001	16.337	<0.001	0.002	0.962	0.414	0.520
NU1	13.997	<0.001	14.687	<0.001	0.040	0.842	0.165	0.685
NL1	16.871	<0.001	17.211	<0.001	0.075	0.784	0.486	0.486
NL2	14.996	<0.001	16.099	<0.001	0.360	0.549	0.166	0.684
IN2	21.907	<0.001	23.130	<0.001	0.039	0.843	0.008	0.927
IN1	26.911	<0.001	30.110	<0.001	1.071	0.301	0.032	0.859
IT1	23.962	<0.001	27.696	<0.001	5.570	0.018	1.685	0.194
IT2	24.812	<0.001	26.618	<0.001	12.885	0.000	6.781	0.009
GCC-a	20.383	<0.001	26.669	<0.001	11.687	0.001	7.506	0.006
GCC-S	19.987	<0.001	25.539	<0.001	11.055	0.001	7.933	0.005
GCC-I	20.455	<0.001	26.467	<0.001	11.727	0.001	6.986	0.008
I	21.473	<0.001	27.633	<0.001	7.456	0.006	2.664	0.103
S	24.721	<0.001	26.438	<0.001	9.730	0.002	6.474	0.011
N	17.907	<0.001	18.818	<0.001	0.069	0.793	0.340	0.560
T	20.790	<0.001	24.376	<0.001	12.310	0.000	7.741	0.005
IT	22.803	<0.001	27.897	<0.001	10.437	0.001	4.766	0.029
IN	26.534	<0.001	29.521	<0.001	0.522	0.470	0.024	0.878
NL	16.665	<0.001	17.556	<0.001	0.237	0.626	0.292	0.589
NU	16.149	<0.001	16.606	<0.001	0.003	0.954	0.320	0.571
SN	22.244	<0.001	23.659	<0.001	2.619	0.106	2.725	0.099
ST	24.435	<0.001	25.991	<0.001	12.063	0.001	8.007	0.005
TU	19.888	<0.001	24.318	<0.001	12.012	0.001	8.777	0.003
TL	16.928	<0.001	18.282	<0.001	11.842	0.001	5.296	0.021

POAG: Primary open-angle glaucoma; RNFL: Retinal nerve fiber layer; GCC: Ganglion cell complex.

of glaucoma in myopia and the accuracy of quantitative examinations. In the present study, myopia affected the distribution of the RNFL thicknesses around the optic disc, and the mean, inferior, and superior quadrants of the RNFL were thinner than that of the normal control eyes. In contrast, the temporal RNFL was thicker. These findings were consistent with those from previous studies.[3] These changes caused the reliability of OCT, Heidelberg retinal tomography, and polarized laser scanner parameters to be worse than that of nonmyopic eyes, especially for high-myopic patients.[3,4] In recent years, clinical applications involving quantitative analysis of glaucoma are becoming increasingly common. If the accuracy of the measured results is poor, the percentages of misdiagnoses will increase.[5,6] In the present study, we used SD-OCT, which is widely used in the early diagnosis of glaucoma.

Based on previous reports, the diagnostic ability using CIRRUS, RTVUE, or three-dimensional OCT for patients with both POAG and myopia was comparable.[7-11] The parameters of RNFL thickness and GCC have a high diagnostic performance for POAG with high-myopic patients, compared with nonglaucomatous high-myopic patients, including preperimetric POAG patients.[12] However, for most myopic patients without POAG, numerous studies have reported that the RNFL was also abnormally thin due to axial extension and atrophy of the retina.[2,5,6] In our study, a thinner RNFL was found in all myopic groups, especially for the moderate- and high-myopic groups. In the high-myopic group, the thinning included almost all the observational parameters. The main pathological change of glaucoma is selective loss of retinal ganglion cells causing thinning of the RNFL.[13,14] Both glaucoma and myopic patients have similar OCT results due to RNFL thinning.[2] This process makes myopia easily misdiagnosed as glaucoma, especially high myopia. Based on the AUC values in our study, when the AUC was >0.900, the number of parameters of the control

Table 4: AUC of all parameters

AUC	Early POAG versus control	Early POAG versus low myopia	Early POAG versus moderate myopia	Early POAG versus high myopia
>0.900	IH, I, IT, IT1, RNFL average, GCC-a, GCC-I, IN1	I, IH, IT, IT1, RNFL average, GCC-a, GCC-I, IT2	TL2, IT2, T, TL, IT	
>0.800–0.900	IT2, IN, S, SH, ST, GCC-S , T, IN2, ST2, ST1, SN, SN2, TL2, TL, TU2, TU, SN1, TU1	IN1, S, SH, IN, ST, T, ST2, TU2, TU, GCC-S, TL, TL2, SN, ST1, TU1, SN2, TL1, IN2, SN1	RNFL average, GCC-a, TU, TL1, TU2, ST2, GCC-I, TU1, SH, I, IT1, IH, ST, GCC-S, S	TL2, T, TL, IT2, IT, RNFL average, TU2, TU, ST2, GCC-I, GCC-a, SH, TU1
0.700–0.800	TL1, N, NU2, NU, NL, NL2, NU1, NL1	NU2, N, NU, NL, NL2, NU1		ST, S, GCC-S
<0.700		NL1	ST1	

AUC: Area under the curve; POAG: Primary open-angle glaucoma; RNFL: Retinal nerve fiber layer; GCC: Ganglion cell complex.

Table 5: AUC and specificity when the sensitivity was 85%

Parameters	Early POAG versus control		Early POAG versus low myopia		Early POAG versus moderate myopia		Early POAG versus high myopia	
	AUC	Specificity (%)	AUC	Specificity (%)	AUC	Specificity (%)	AUC	Specificity (%)
RNFL average	0.940	89.90	0.932	89.40	0.890	76.70	0.850	64.30
SH	0.874	75.90	0.877	80.90	0.869	79.10	0.818	67.90
IH	0.962	96.20	0.947	83.00	0.836	58.10	/	/
I	0.958	94.90	0.948	89.40	0.864	67.40	/	/
S	0.886	73.40	0.880	72.30	0.802	46.50	0.758	28.60
IT	0.944	84.80	0.942	89.40	0.906	79.10	0.861	57.10
ST	0.870	68.40	0.868	63.80	0.817	48.80	0.761	28.60
GCC-S	0.859	70.90	0.839	61.70	0.802	60.50	0.731	42.90
GCC-I	0.932	79.70	0.916	66.00	0.880	62.80	0.825	35.70
GCC-a	0.939	86.10	0.921	76.60	0.889	74.40	0.822	53.60

AUC: Area under the curve; POAG: Primary open-angle glaucoma; RNFL: Retinal nerve fiber layer; GCC: Ganglion cell complex; /: Not available.

Table 6: Numbers of green colors from SD-OCT, *n* (%)

Parameters	High myopia ($n = 28$)	Moderate myopia ($n = 43$)	Low myopia ($n = 47$)	Control ($n = 79$)
RNFL average	12 (42.9)	31 (72.1)	42 (89.4)	62 (78.5)
Superior	15 (53.6)	31 (72.1)	44 (93.6)	63 (79.7)
Inferior	13 (46.4)	31 (72.1)	42 (89.4)	70 (88.6)
ST1	17 (60.7)	34 (79.1)	45 (95.7)	74 (93.7)
ST2	20 (71.4)	39 (90.7)	45 (97.9)	63 (79.7)
IT1	12 (42.9)	29 (67.4)	45 (95.7)	72 (91.1)
IT2	20 (71.4)	39 (90.7)	39 (83.0)	68 (86.1)

SD-OCT: Spectral domain-optical coherence tomography; RNFL: Retinal nerve fiber layer.

Table 7: *P* values from the Chi-square test of the green color code between myopic groups

Parameters	HM versus MM		HM versus LM		HM versus control		MM versus LM		MM versus control		LM versus control	
	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*
RNFL average	6.069	0.013	18.823	<0.001	12.300	0.001	4.371	0.034	0.627	0.282	2.421	0.092
Superior	20550	0.090	16.767	<0.001	7.169	0.009	7.490	0.006	0.922	0.230	4.427	0.028
Inferior	4.739	0.027	16.539	<0.001	21.138	<0.001	4.371	0.034	5.329	0.021	0.017	0.572
ST1	2.824	0.080	15.027	<0.001	17.656	<0.001	5.820	0.017	5.844	0.019	0.242	0.478
ST2	4.483	0.038	11.619	0.001	0.822	0.256	2.203	0.154	2.436	0.093	8.295	0.002
IT1	4.201	0.036	26.908	<0.001	28.558	<0.001	12.306	<0.001	10.973	0.001	0.942	0.277
IT2	4.483	0.040	1.395	0.186	3.037	0.080	1.158	0.220	0.552	0.332	0.221	0.410

HM: High myopia; MM: Moderate myopia; LM: Low myopia; RNFL: Retinal nerve fiber layer.

and low-myopic groups was 8/34 and 5/34, respectively, whereas that of moderate-myopic group was 5/34 and the high-myopic group was 0. In contrast, when the AUC was <0.700, the number of parameters of the control and

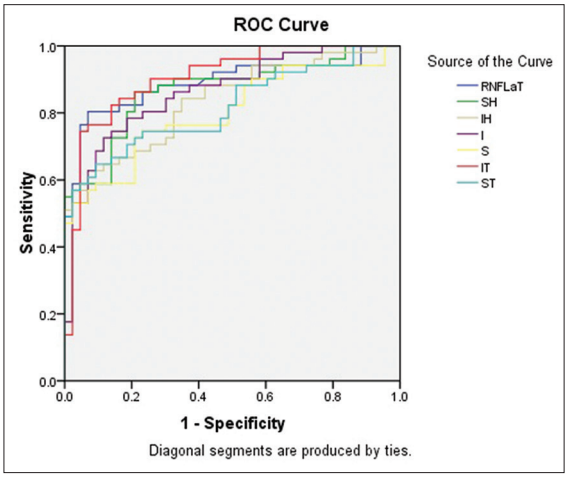

Figure 4: ROC of early POAG versus moderate myopia. ROC: Receiver operating characteristic; POAG: Primary open-angle glaucoma.

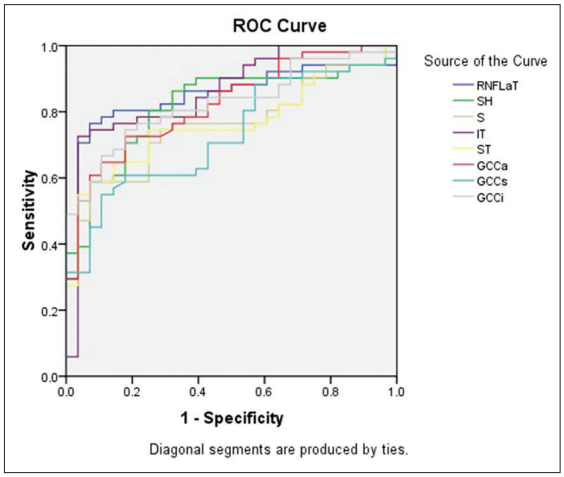

Figure 5: ROC of early POAG versus high myopia. ROC: Receiver operating characteristic; POAG: Primary open-angle glaucoma.

low-myopic groups was 0 and 1, respectively, and that of the moderate- and high-myopic groups was the same. These results indicated that the diagnostic efficacies of OCT for moderate and high myopia were reduced.

The main purpose of this study was to evaluate the ability of OCT to distinguish between myopia and early POAG. We therefore emphasized the diagnostic specificity of the SD-OCT parameters, which were well in distinguishing between normal and POAG in previous studies. When the sensitivity was 85%, specificity results indicated that most parameters of the control and low-myopic groups were better than those of the moderate- and high-myopic groups. The specificity of patients in the high-myopic group was <70%, or sometimes <50%, indicating that it was easy to be misdiagnosed with myopia when SD-OCT was used, especially for high-myopic patients.

According to the internal normative database of OCT, the printing results showed a color code for each parameter to determine the outcomes using three colors (green, normal; yellow, critical; and red, abnormal). We calculated the number of parameters that were judged as normal (green), which were significantly lower in the moderate- and high-myopic groups. Almost 40% of the high-myopic patients were judged as critical or abnormal according to the RNFL average. At present, there have been few studies in this field. Kim *et al*. reported that although OCT has a higher sensitivity in high-myopic patients with glaucoma, it also has a lower specificity.[4] Akashi *et al*.[3] studied three types of OCT diagnostic efficacies for high-myopic patients with glaucoma, reporting that the results were different, regardless of whether the normal control group had a high myopia.

Considering these previous results and the well-known observation that analyses using OCT can many times lead to misdiagnosis by ophthalmologists, we suggest that a normative database of various diopters (especially high myopia) should be established for diagnoses using OCT. Many previous investigators have suggested a similar view that this database will improve glaucoma diagnosis of myopic patients and reduce the percentage of misdiagnoses.[2-4]

Our study had several limitations. First, this study focused on the specificity index, although there was insufficient grouping (glaucoma with high-myopic group) to support the sensitivity observations. Second, the age of patients in the early-glaucoma group was significantly older than that of other groups. Since the RNFL thickness decreases with age,[15] we used a logistic regression model to correct age differences, which could affect the results. In the future, prospective studies with age-matched participants should result in more definitive conclusions.

In summary, the glaucoma diagnostic parameters of SD-OCT were not clinically relevant for moderate- and high-myopic patients. The specificities were low. As a result, misdiagnosis as glaucoma is more likely to occur in moderate- and high-myopic patients. Multifactorial analyses should be used in the diagnoses of glaucoma in moderate- and high-myopic patients. It is also suggested that the population-averaged OCT database of various diopters (especially high myopia) should be established for diagnoses using OCT.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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频域光学相干成像青光眼诊断参数在近视眼中的诊断能力分析

摘要

目的：目前频域光学相干成像（SD-OCT）可作为青光眼诊断的新工具。因此本文评价了SD-OCT所提供的青光眼诊断参数在不同屈光度近视患者中的诊断能力。

方法：横断面研究。共有248例受试者（248眼）入选。包括早期开角型青光眼组51，正常人组79例（±0.50D之内），低度近视组47例（−0.50 D to −3.00 D（不包括）），中度近视组43例（−3.00 D to −6.00 D（不包括）），高度近视组28例（≤−6.00 D）。所有受试者均行眼科常规检查及Humphrey 视野计、SD-OCT检查，将OCT检查所获得的视网膜神经纤维层(RNFL)和节细胞复合体（GCC））的相关参数进行统计学分析，分别绘制受试者操作曲线（ROC）并计算曲线下面积（AUC）。

结果：AUC结果如下：正常人、低度近视眼组的AUC最佳参数均为下方、颞下方RNFL厚度（AUC均 > 0.94），而中度近视、高度近视组的最佳参数均为颞下方参数（AUC分别为0.926，0.896），而中度近视组下方参数的AUC较小（0.864）排在所有RNFL参数的第15位。对文献中公认的诊断青光眼能力强的参数（下方、颞下方、颞上方）进行进一步分析，当灵敏度为85%时，这些参数在正视眼、低度近视眼组的特异度较高，均大于80%，而在中度近视、高度近视组特异度均较低，约在20%～60%。根据机器数据库所得绿色部分在高度近视组也较其他组少（$P < 0.05$）。

结论：SD-OCT的青光眼诊断参数在应用于中高度近视眼时的诊断能力较弱，特异度明显偏低，对中高度近视者进行青光眼的诊断时需综合分析。同时建议SD-OCT的正常人数据库应针对不同屈光度进行补充完善。