Original Article

Circumpapillary ganglion cell complex thickness to diagnose glaucoma: A pilot study

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Purpose: The purpose of this study is to evaluate the applicability of a new optical coherence tomography parameter, the circumpapillary ganglion cell complex (cpGCC) thickness for glaucoma diagnostics. **Subjects and Methods:** The RS-3000 Advance SD-OCT (NIDEK, Aichi, Japan) was used to measure global and sector macular GCC (mGCC) thickness, circumpapillary retinal nerve fiber layer (cpRNFL) thickness, cpGCC, and circumpapillary total retina (cpTR) thickness in 1 eye of 48 preperimetric/early perimetric primary open-angle glaucoma patients and 28 healthy Japanese participants. Area under the receiver-operating characteristic (AUROC) curves were used for between-method comparisons. **Results:** All global and sector parameters except for the nasal sector differed significantly between the patient groups ($P \leq 0.009$). The AUROC for global mGCC (0.917) was significantly higher ($P < 0.01$) than that for global cpRNFL (0.760), global cpGCC (0.828), and global cpTR (0.812). The AUROC values of global and temporal cpGCC were significantly higher than those of the corresponding cpRNFL parameters ($P < 0.05$). Correlation between the visual field means deviation and each of the global thickness parameters was similar (r: 0.418–0.473, $P < 0.001$). At >90% specificity, the cpGCC, cpTR, and cpRNFL were able to detect 4%, 10%, and 0% of glaucoma eyes that were not detected by the mGCC thickness. **Conclusions:** In Japanese eyes, the diagnostic accuracy of cpGCC is lower than that of mGCC but higher than that of cpRNFL. Our results suggest that the use of cpGCC may not improve glaucoma diagnostics when there is no macular disease but may be of benefit when macular diseases prevent successful mGCC measurements.

Key words: Circumpapillary ganglion cell complex, glaucoma, retinal nerve fiber layer thickness, spectral-domain optical coherence tomography, total retinal thickness

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Glaucoma is an optic neuropathy characterized by progressive loss of retinal ganglion cells, thinning of the neuroretinal rim and the retinal nerve fiber layer (RNFL), and spatially corresponding deterioration of the visual field.[1-3] Early detection of glaucoma is essential for early treatment initiation and is therefore of great clinical importance. In the last decade, spectral-domain optical coherence tomography (SD-OCT) has been widely used to detect glaucoma.[4-8] Although the diagnostic accuracy of SD-OCT is satisfactory in moderate and advanced glaucoma, its accuracy in early and preperimetric glaucoma has still not met the clinical needs.[9-11] About 30% of the retinal ganglion cells are located in the macula.[12] Therefore, compared to the circumpapillary area, the ganglion cell layer of the macula is thicker.[13] In contrast, the RNFL thickness increases with decreasing distance to the disc.[14] Circumpapillary RNFL (cpRNFL) thickness and macular ganglion cell complex (mGCC) thickness have been successfully used for diagnostic and follow-up purposes.[8,10] However, cpRNFL thickness has suboptimal accuracy in high myopia,[15,16] and mGCC is influenced both by high myopia and nonglaucomatous macular pathologies.[17-19] Thus, their clinical use is not unlimited. To further improve the diagnostic accuracy of SD-OCT technology, various novel SD-OCT parameters for their clinical usefulness in glaucoma diagnostics were investigated.[20-25] Recently, Kita *et al*. have shown that the reproducibility of the circumpapillary total retina (cpTR) thickness is higher than that of the cpRNFL thickness[24] and that the ratio of mGCC thickness to macular outer retinal thickness (G/O ratio) has significantly higher diagnostic accuracy than cpRNFL thickness in Japanese eyes.[17,20,23,25] These results show that new SD-OCT parameters may offer additional benefits in glaucoma diagnostics. In addition to cpRNFL, mGCC, and cpTR thickness, the recently introduced RS-3000 Advance OCT (NIDEK, Aichi, Japan) offers automatic determination of circumpapillary ganglion cell complex (cpGCC) thickness around the optic nerve head (ONH).[26] The cpGCC measurement area shows only modest overlap with the mGCC measurement area that is temporal to the optic disc but outside the central macular region [Fig. 1]. It is important to note that cpGCC has not yet been evaluated for glaucoma diagnostics. The goals of the current investigation were as follows (1) to evaluate

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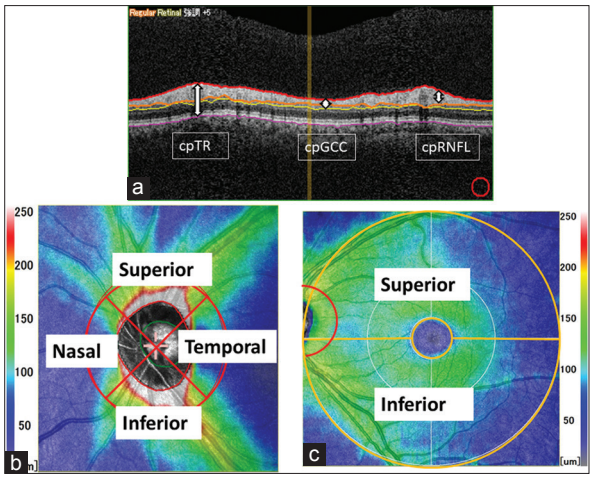

Figure 1: A typical example of circumpapillary and macular optical coherence tomography scans. (a) The retinal layer boundaries are automatically detected by the image segmentation algorithm. (b) The four quadrants of the circumpapillary area used for the analysis in the current investigation. (c) The 9.0 mm diameter macular scan area is within the orange circle. The hemispheres of the macular scan area and the central 1.5 mm diameter area (which is not used by the software for the analysis) are also encircled with orange lines. The partial overlap of the circumpapillary measurement area (red circle) and the macular scan area (orange circle) is shown on the left side of the image

the diagnostic accuracy of global and quadrant cpGCC thickness parameters in preperimetric and early perimetric glaucoma, (2) to compare their diagnostic accuracy with the corresponding accuracy figures for the mGCC, cpRNFL, and cpTR thickness, (3) to determine the classification agreement between the global cpGCC and the other global parameters at a specificity >90%, and (4) to evaluate combined diagnostic sensitivity of the cpGCC thickness and cpRNFL thickness, and the cpGCC thickness and cpTR thickness, respectively, at a specificity of >90%, in Japanese eyes.

Subjects and Methods

In total, 76 Japanese individuals (28 normal controls and 48 primary open-angle glaucoma patients) examined between October 2014 and October 2015 were retrospectively selected from a research database. One eye per subject was randomly selected as the study eye. Procedures followed the tenets of the Declaration of Helsinki, with the retrospective protocol approved by the Institutional Review Board for Human Research of Our Hospital. Patient records and information were anonymized and de-identified before analysis.

All study participants underwent a complete ophthalmologic examination that included the determination of best-corrected visual acuity (with the determination of refractive error), slit-lamp biomicroscopy, gonioscopy, Goldmann applanation tonometry, and dilated stereoscopic fundus examination. Refraction data were converted to the spherical equivalent, defined as the spherical power (in diopters) plus half the cylindrical power. Visual fields (at least two reliable and consistent tests) were analyzed with the Swedish Interactive Threshold Algorithm (SITA) 24-2 or 30-2 standard test of the Humphrey Field Analyzer (HVF, Humphrey-Zeiss Systems, Dublin, CA, USA), for the healthy control group and the glaucoma group, respectively. Visual fields were considered reliable when fixation losses were <20% and false-positive and false-negative rates were <15%. An abnormal visual field result was defined if any one of the following criteria was present: an abnormal glaucoma hemifield test, pattern standard deviation <5%, or three abnormal points (<5% probability of being normal), of which at least one labeled as <1% probability of being normal.

To be included in the normal eye group, healthy controls had to have normal intraocular pressure (IOP, <21 mmHg) and a normal ONH appearance, open anterior chamber angles, a normal and reliable visual field test result with the Humphrey visual field (HVF) SITA 24-2 standard program, a best-corrected visual acuity of 20/20 or better, a spherical refractive error between +3.00 and −6.00 diopters, and a cylindrical refractive error of <3.0 diopters. An ONH was considered normal if the stereoscopic examination revealed a vertical cup-to-disc ratio of ≤0.6, a uniform neuroretinal rim, no RNFL defects, and no other abnormalities (e.g., diffuse or localized rim thinning, disc hemorrhage, or an interocular difference in the vertical cup-to-disc ratio >0.2). The individuals were not included if they had a history of possible/definite elevated IOP (e.g., iridocyclitis, trauma), any eye disease, intraocular surgery or retinal laser procedure, or any other condition that may have influenced the visual field (e.g., pituitary lesions, demyelinating diseases, and diabetic retinopathy).

To be able to include preperimetric glaucoma eyes in the analysis, the definition of glaucoma was based on glaucomatous ONH alterations. The glaucoma group, which was comprised primary open-angle glaucoma and normal-tension glaucoma eyes, was further subdivided into preperimetric and early perimetric subgroups. The glaucoma eyes had to have a best-corrected visual acuity of 20/20 or better, spherical refractive error between +3.00 and −6.00 diopters, cylindrical refractive error <3.0 diopters, open anterior chamber angles with gonioscopy (Shaffer grade >2), and glaucomatous optic neuropathy, which was defined as neuroretinal rim narrowing at the optic disc margin with notching, excavation, or visible RNFL defect. The preperimetric glaucoma eyes had to have normal HVF results on reliable and reproducible SITA 30-2 tests. The perimetric glaucoma eyes had to have glaucomatous HVF abnormalities and a mean deviation (MD) value not worse than −6 dB on reliable and reproducible SITA 30-2 tests. Exclusion criteria for the glaucoma patients included having any retinal pathology, neurological disease, diabetes, or a history of retinal laser or intraocular surgery procedures. The glaucoma patients enrolled in the investigation were under topical IOP-lowering therapy.

Optical coherence tomography

OCT measurements were made with an RS-3000 Advance OCT (NIDEK, Aichi, Japan, software version 1.4.2.1). The RS-3000 OCT contains a confocal scanning laser ophthalmoscope. The RS-3000 OCT acquires ocular microstructural images through the use of a scanning laser diode that emits a wavelength of 880 nm. The OCT equipment has a 7 μm tissue depth resolution and a 20 μm transverse resolution. Single three-dimensional (3D) data sets are acquired in 1.6 s. Automated measurement of global and quadrant (temporal, superior, nasal, and inferior) cpRNFL, cpGCC, cpTR, and mGCC thickness is provided by the built-in software [Fig. 1]. All images were acquired after pupil dilation by the same well-trained operator. Internal fixation was successfully

achieved in all patients. All images underwent a detailed quality control. Images with segmentation errors and a signal strength index of <7 were not included in the analysis.

Circumpapillary optical coherence tomography parameters

For the cpRNFL, cpGCC, and cpTR thickness measurements, raster scanning over a 6 mm × 6 mm area centered on the optic disc center was conducted at a scan density of 512 A-scans (horizontal) ×128 B-scans (vertical). Measurements of cpRNFL thickness (the layer between the internal limiting membrane [ILM] and the outer border of the RNFL), cpGCC thickness (the layer between the ILM and the outer border of the inner plexiform layer), and cpTR thickness (the layer between the ILM and the outer border of the retinal pigment epithelium) were performed using a 3.45 mm diameter circle automatically positioned around the optic disc in each 3D data set [Fig. 1a]. The following software-provided areas were used to measure cpRNFL, cpGCC, and cpTR thickness: (1) global average for the entire 360° area around the ONH, (2) superior, (3) inferior, (4) temporal, and (5) nasal [Fig. 1b]. The circumpapillary protocol scan ring did not pass over any parapapillary atrophy in either eye.

Macular optical coherence tomography parameters

For mGCC, raster scanning over a 9 mm × 9 mm area automatically centered on the center of the fovea is conducted at a scan density of 512 A-scans (horizontal) ×128 B-scans (vertical). The central 1.5 mm diameter area is not included in the analysis. The mGCC thickness is measured between the ILM and the outer boundary of the inner plexiform layer. In the current investigation, the instrument provided the global average, and the superior and inferior mGCC thickness values that were used for the analysis [Fig. 1c].

Statistical analysis

Differences between groups were assessed using a Mann–Whitney U-test or Student's *t*-test. Spearman's rank correlation coefficients were used to assess the correlations between the visual field MD and the OCT parameters. Relationships were defined based on the *r* value. Receiver-operating characteristic (ROC) curves were used to assess the ability of each of the variables in differentiating the glaucomatous eyes from the normal eyes. To investigate the diagnostic classification agreement, Venn diagrams were calculated at a specificity of >90%. MedCalc, version 11 (MedCalc Software, Mariakerke, Belgium) was used to draw and compare the ROC curves. All other statistical analyses were performed using SPSS statistical software (Version 23.0, SPSS Inc., Chicago, IL, USA). $P < 0.05$ was considered to be statistically significant.

Results

The population analyzed was comprised 28 eyes of 28 healthy controls, 39 eyes of 39 early perimetric glaucoma patients, and 9 eyes of 9 preperimetric glaucoma patients. Table 1 summarizes the demographics of the participants. There was no significant difference between the glaucoma and normal group for gender, IOP, and optic disc area. The glaucoma group was older, more myopic, and had a worse visual field MD than the healthy normal group. Although the preperimetric glaucoma patients were younger than the perimetric glaucoma patients, there was no between-group difference seen for the gender distribution, spherical equivalent, IOP, and optic disc area [Table 1].

The comparison of the various OCT thickness parameters (e.g., cpRNFL, cpGCC, cpTR, and mGCC) between the healthy eyes and the glaucoma eyes is shown in Table 2. All global, hemisphere, and quadrant thickness parameters, with the exception of the nasal cpRNFL and nasal cpGCC thickness, could be used to separate the glaucoma eyes from the healthy control eyes (Student's *t*-test, $P \leq 0.009$) [Table 2].

For the total population, the relationship between the visual field MD and each of the global thickness parameters is shown in Table 3. All four parameters showed a similar, significant, and strong positive correlation with the MD ($P < 0.001$ for all parameters). The *r* values ranged between 0.418 (cpTR thickness) and 0.473 (cpRNFL thickness).

The comparisons of the corresponding area under the ROCs (AUROC) curve values are shown in Table 4. The overall highest AUROC value was 0.919 (superior mGCC thickness). Global mGCC thickness provided the second highest AUROC value (0.917), whereas superior cpGCC thickness provided the fourth highest AUROC value (0.841). The AUROCs for the global cpRNFL, global cpGCC, and global cpTR thicknesses were all significantly lower than of the global mGCC thickness ($P < 0.01$). The AUROC of the global cpGCC thickness was significantly greater than that of the global cpRNFL thickness ($P < 0.05$). The ROC curves for the four global thickness parameters are shown in Fig. 2. Table 5 presents the sensitivity values calculated for a specificity of >90%. The highest sensitivity at the 92.86% specificity was 72.92% for the global mGCC thickness. The second highest global sensitivity value was found for the cpTR thickness (62.50%),

Table 1: Demographics of the study participants

Variable	Healthy eyes (*n*=28)	Glaucoma eyes (*n*=48)	*P*	Early glaucoma (*n*=39)	Preperimetric glaucoma (*n*=9)	*P*
Female sex (%)	12 (42.9)	30 (62.5)	0.097*	29 (66.7)	5 (55.6)	0.530*
Age (years), median (IQR)	36.0 (10.8)	65.2 (16.8)	<0.001†	72.0 (13.0)	61.0 (16.0)	0.021§
Spherical equivalent (D; mean±SD)	−2.78±2.55	−1.44±2.00	0.025‡	−1.19±2.29	−2.31±1.35	0.070§
IOP (mmHg), median (IQR)	15.0 (2.00)	14.0 (4.75)	0.187†	15.0 (5.00)	13.7 (2.00)	0.435§
Optic disc area (mm2), mean±SD	2.19±0.44	2.19±0.52	0.966‡	2.24±0.56	2.01±0.42	0.259#
MD (dB), median (IQR)	0.35 (1.47)	−1.10 (2.77)	0.002†	−1.24 (2.32)	−0.13 (1.97)	0.003§

*Chi-square test, †Mann-Whitney *U*-test between normal group and glaucoma group, ‡Student's *t*-test between normal group and glaucoma group, §Mann-Whitney *U*-test between early glaucoma group and preperimetric glaucoma group, #Student's *t*-test between early glaucoma group and preperimetric glaucoma group. IQR: Inter quartile range, D: Diopter, IOP: Intraocular pressure, MD: Mean deviation, SD: Standard deviation

Table 2: Comparison of the retinal nerve fiber layer thickness, ganglion cell complex thickness, and total retinal thickness between the groups

	Mean±SD		P*
	Healthy eyes	Glaucoma eyes	
mGCC thickness (μm)			
Global	99.2±6.9	83.9±8.6	<0.001
Superior	98.9±7.0	82.7±9.4	<0.001
Inferior	99.5±7.2	84.9±13.1	<0.001
cpRNFL thickness (μm)			
Global	102.3±8.7	90.1±13.5	<0.001
Temporal	73.6±12.3	65.9±11.9	0.009
Superior	130.1±16.4	105.8±21.1	<0.001
Nasal	72.0±13.6	77.1±16.0	0.165
Inferior	130.3±15.4	108.9±31.4	<0.001
cpGCC thickness (μm)			
Global	141.8±11.6	124.1±15.6	<0.001
Temporal	128.7±12.2	113.9±15.1	<0.001
Superior	163.5±16.5	133.6±26.0	<0.001
Nasal	107.6±14.1	104.9±15.2	0.450
Inferior	162.9±17.9	137.4±31.5	<0.001
cpTR thickness (μm)			
Global	318.2±17.7	295.4±22.3	<0.001
Temporal	309.3±20.3	291.0±21.7	0.001
Superior	336.8±18.8	303.3±31.4	<0.001
Nasal	286.4±19.3	274.2±18.9	0.008
Inferior	330.2±21.5	300.9±33.8	<0.001

*Student's *t*-test. mGCC: Macular ganglion cell complex, cpRNFL: Circumpapillary retinal nerve fiber layer, cpGCC: Circumpapillary ganglion cell complex, cpTR: Circumpapillary total retina, SD: Standard deviation

Table 3: Correlation between each of the measured global thickness parameters and visual field mean deviation

	r	*P*
mGCC thickness	0.471	<0.001
cpRNFL thickness	0.473	<0.001
cpGCC thickness	0.420	<0.001
cpTR thickness	0.418	<0.001

mGCC: Macular ganglion cell complex, cpRNFL: Circumpapillary retinal nerve fiber layer, cpGCC: Circumpapillary ganglion cell complex, cpTR: Circumpapillary total retina, *r*: Spearman's rank correlation coefficient

followed by the cpGCC thickness (58.33%), and the cpRNFL thickness (43.75%).

The Venn diagrams calculated at a specificity of >90% showed that the cpGCC thickness detected 4% of the glaucoma eyes that were not detected by the mGCC thickness, whereas the cpTR thickness detected 10% [Fig. 3]. cpRNFL thickness did not detect any glaucoma case that could not be detected by the mGCC thickness [Fig. 3]. When glaucoma detection used the combined global cpTR and global cpGCC thicknesses, the sensitivity increased to 75% [Fig. 4], which was higher than the corresponding 72.92% sensitivity calculated for the global

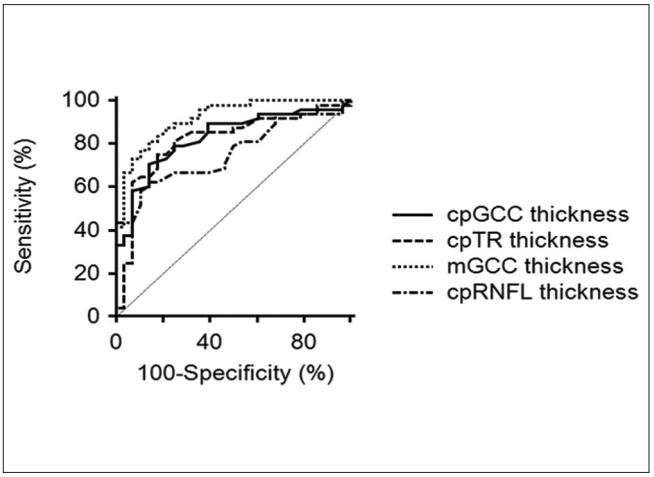

Figure 2: Receiver-operating characteristics curve of global macular ganglion cell complex thickness, circumpapillary retinal nerve fiber layer thickness, circumpapillary ganglion cell complex thickness, and circumpapillary total retinal thickness

mGCC [Table 5 and Fig. 4]. When a combination of the global mGCC, cpGCC, and cpTR thicknesses was used, 87% of the glaucoma eyes were detected [Fig. 4]. The cpRNFL thickness did not detect any of the glaucoma eyes that were not detected by the cpGCC thickness [Fig. 4].

Discussion

In this current pilot investigation, we evaluated cpGCC for diagnostic accuracy of preperimetric and early perimetric glaucoma, using the RS-3000 Advance OCT in Japanese eyes. We also compared the AUROC values calculated for the global and quadrant cpGCC thickness parameters with those calculated for the established mGCC, cpRNFL, and cpTR thickness parameters. We found that the global mGCC thickness performed significantly better than the global cpGCC thickness. This was particularly expected, as compared to other OCT instruments, the RS-3000 OCT uses a wider macular scan area for enhancing the accuracy of the glaucoma diagnostics.[27] Since it has been demonstrated that over 30% of the retinal ganglion cells are located in the macula area,[12] changes of the mGCC thickness have been shown to be early and accurate indicators of glaucomatous structural damage and progression.[4,6-8,28] However, in addition to age-related macular degeneration (AMD) becoming increasingly more common in the elderly, the coincidence of glaucoma and AMD has also been found not to be all that uncommon. AMD frequently alters image segmentation in the macular area, which results in incorrect measurement results and classification for glaucoma.[18,19]

In the current study, we found that global cpGCC thickness performed significantly better than global cpRNFL thickness, which is one of the most established SD-OCT parameters. This unexpected result may have clinical significance since it suggests that cpRNFL thickness may be less informative than has generally been thought to be when diagnosing very early glaucoma in East Asian eyes.[10,11] cpRNFL thickness, which is widely used for glaucoma diagnostics,[5-7] has also been reported to have a decreased diagnostic accuracy in myopia.[15,16] In our current investigation, we did not include eyes with high and

Table 4: Comparison of diagnostic accuracy of the corresponding thickness parameters using the area under receiver-operating characteristics curve

	Healthy versus glaucoma AUROC (SE)			
	mGCC thickness	cpRNFL thickness	cpGCC thickness	cpTR thickness
Global	0.917 (0.03)*	0.760 (0.05)	0.828 (0.05)‡	0.812 (0.05)
Temporal	N/A	0.670 (0.06)	0.783 (0.05)§	0.746 (0.06)
Superior	0.919 (0.03)†	0.816 (0.05)	0.841 (0.05)	0.834 (0.05)
Nasal	N/A	0.591 (0.07)	0.567 (0.07)	0.704 (0.06)#
Inferior	0.842 (0.05)	0.762 (0.05)	0.786 (0.05)	0.785 (0.05)

*P<0.01 for comparison with global cpRNFL, global cpGCC, and global cpTR thickness, †P<0.05 for comparison with superior cpRNFL, superior cpGCC, and superior cpTR thickness, ‡P<0.05 for comparison with global cpRNFL thickness, §P<0.05 for comparison with temporal cpRNFL thickness, #P<0.01 for comparison with nasal cpGCC thickness. AUROC: Area under receiver operating characteristic, N/A: Not applicable, SE: Standard error, mGCC: Macular ganglion cell complex, cpRNFL: Circumpapillary retinal nerve fiber layer, cpGCC: Circumpapillary ganglion cell complex, cpTR: Circumpapillary total retina

Table 5: Comparison of diagnostic accuracy of the corresponding thickness parameters using sensitivity at specificity >90%

	Healthy versus glaucoma Sn/Sp (Sp >90%)			
	mGCC thickness	cpRNFL thickness	cpGCC thickness	cpTR thickness
Global	72.92/92.86	43.75/92.86	58.33/92.86	62.50/92.86
Temporal	N/A	31.25/92.86	43.75/92.86	47.92/92.86
Superior	70.83/92.86	47.92/96.43	62.50/92.86	66.67/92.86
Nasal	N/A	31.25/92.86	10.42/92.86	35.42/92.86
Inferior	64.58/92.86	41.67/92.86	45.83/96.43	52.08/92.86

N/A: Not applicable, Sn: Sensitivity, Sp: Specificity, mGCC: Macular ganglion cell complex, cpRNFL: Circumpapillary retinal nerve fiber layer, cpGCC: Circumpapillary ganglion cell complex, cpTR: Circumpapillary total retina

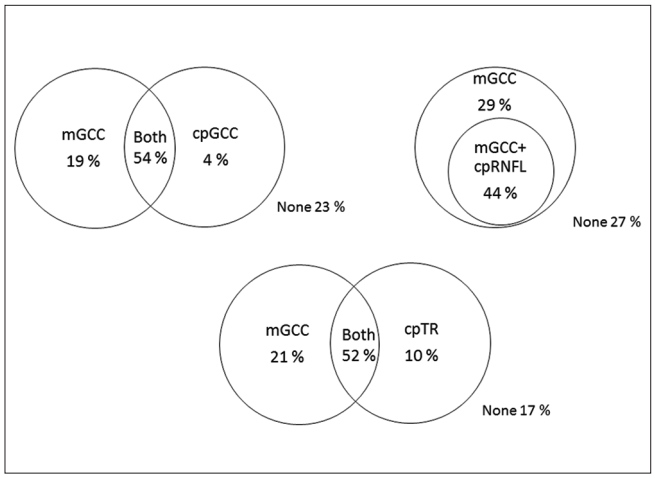

Figure 3: Venn diagrams illustrating the percentage of eyes found to be glaucomatous when using the macular ganglion cell complex thickness and circumpapillary ganglion cell complex thickness, the macular ganglion cell complex thickness and circumpapillary retinal nerve fiber layer thickness, and the macular ganglion cell complex thickness and circumpapillary total retinal thickness, respectively, at a fixed specificity of >90%

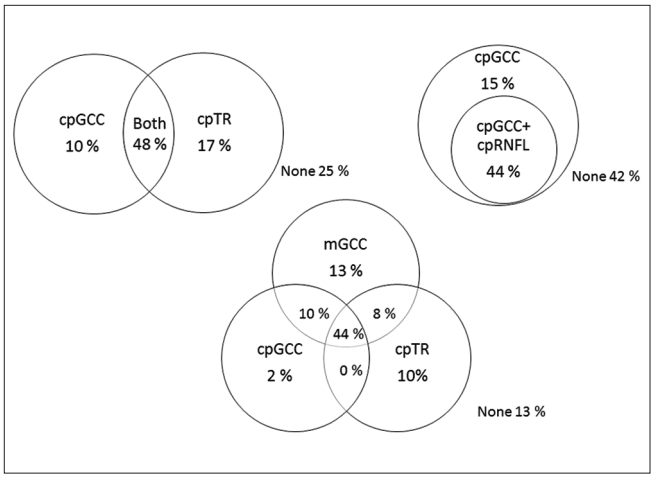

Figure 4: Venn diagrams illustrating the percentage of eyes found to be glaucomatous when using the circumpapillary ganglion cell complex thickness and circumpapillary total retinal thickness, the circumpapillary ganglion cell complex thickness and circumpapillary retinal nerve fiber layer thickness, and the macular ganglion cell complex thickness, circumpapillary ganglion cell complex thickness, and circumpapillary total retinal thickness, respectively, at a fixed specificity of >90%

pathological myopia in the analysis. However, since mild and moderate myopia was common in both patient groups, the diagnostic accuracy of the cpRNFL thickness was lower than that of the other parameters. Moreover, none of the glaucoma eyes that were undetected when using either the mGCC thickness or cpGCC thickness were detected when using the cpRNFL thickness. This has particular significance for glaucoma diagnostics in Japanese eyes, which are very commonly found to be myopic.[29]

The importance of the favorable diagnostic performance of the cpGCC thickness is further emphasized by the fact that

our glaucoma population was comprised only preperimetric and early perimetric glaucoma cases and that the cpGCC measurements avoid the central macula area and only have a minimal overlap with the nasal peripheral macular scan area of the RS-3000 OCT. Therefore, it is not likely that that parameter will be influenced by AMD. The correlation between each of the four global thickness parameters and the visual field MD was similarly strong and significant, which supports the notion that cpGCC may be applicable for use in clinical practice when either the mGCC or cpRNFL thicknesses are not informative or able to be utilized.

It is important to note that the relatively favorable diagnostic performance of the cpGCC thickness seems to be independent from that of the mGCC thickness, even though minimal overlap exists between the nasal edge of the mGCC scan area and the temporal sector cpGCC as shown in Fig. 1c. The AUROC value of the superior cpGCC thickness was also favorable and was numerically higher than that of the superior cpRNFL and superior cpTR thicknesses even though the differences did not reach the preset significance level. These results suggest that the diagnostic accuracies of the global and sector cpGCC thickness parameters are not strongly dependent on the temporal sector value.

We also found that at a specificity of >90%, the cpTR thickness detected 10% of the glaucoma eyes that were undetected by the mGCC thickness (73%). When these two parameters were combined, the glaucoma detection rate increased to 83%. In previous investigations, the cpTR thickness exhibited a high reproducibility,[24] and when using the Spectralis OCT, had an even higher diagnostic accuracy for glaucoma than the cpRNFL thickness.[30] In the current investigation, the AUROC for cpTR thickness was higher than that of the cpRNFL thickness although the difference was not statistically significant. When glaucoma detection was performed using the combined global cpTR and global cpGCC thicknesses, the ratio of detected glaucoma cases increased to 75%. This shows that combining the global cpTR and cpGCC thicknesses for the diagnosis of early glaucoma may be a viable alternative to using global mGCC thickness, which detected 73% of our glaucoma cases.

There were a few limitations for this pilot study. Since the image quality was optimal in all of the cases examined in this study, our results do not necessarily reflect the accuracy of the cpGCC thickness in routine clinical practice, where the image quality might be much poorer. In addition, none of our study eyes had high myopia, or moderate to severe visual field damage. Thus, our current results do not provide information on the diagnostic accuracy for eyes with high myopia and advanced glaucoma. In addition, since our participants were all Japanese, we cannot draw any correlations from our results with regard to patients of other ethnicities, for example, patients of African ethnicity, who, in contrast to Japanese individuals, have lower mGCC thicknesses, and white Europeans, who in contrast to Japanese, do not exhibit any correlation between the mGCC thickness and the macular outer retinal thickness.[31,32]

Conclusions

Our pilot study of moderately myopic healthy, preperimetric, and early perimetric primary open-angle glaucoma eyes suggests that cpGCC thickness may have a role in glaucoma diagnostics, at least in Japanese eyes and especially when the use of the mGCC thickness is not a viable option. However, further studies using a larger patient population will need to be undertaken to clarify if this potential new SD-OCT parameter can be successfully used in routine clinical practice for glaucoma diagnostics.

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Conflicts of interest

There are no conflicts of interest.

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