Comparison of Polarimetric Retinal Nerve Fiber Analyzer Parameters for a Single High Quality Image and the Mean Image from Three High Quality Images

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Background: To find the correlations and differences between the nerve fiber layer parameters of a GDx (polarimetric retinal nerve fiber analyzer) in single high quality images and those in the mean image from three high quality images.

Methods: The results of scanning laser polarimetry were selected from 63 eyes of 63 patients (31 male and 32 female). Complete ophthalmic examinations included slit-lamp biomicroscopy, dilated pupil for vitreous and ocular fundus examination, applanation tonometry, and subjective or objective refraction. There were no significant ophthalmic disorders other than glaucoma and mild lens opacity. Nerve fiber layer thickness of each eye was measured with GDx and at least three high quality images (passing the software's quality criteria) were obtained. The best of these three high quality images was selected as a single high quality image (Group One). The mean image (Group Two) was calculated from the same three high quality images.

Results: We found that there was a high correlation in all nerve fiber layer parameters between Group One and Group Two. There was no significant difference in the seven relative values of nerve fiber layer parameters (Number, Ellipse Modulation, Symmetry, Superior Ratio, Inferior Ratio, Superior/Nasal and Maximal Modulation) between Group One and Group Two. Group One had significantly higher values compared with Group Two in the other seven absolute values of nerve fiber layer parameters (Average Thickness, Ellipse Average, Superior Average, Inferior Average, Superior Integral, Superior Maximal and Inferior Maximal).

Conclusion: It is reasonable to take a mean image from three good quality images from a cooperative patient. If only one high quality image can be obtained in repeated acquisition of GDx, the seven relative values of nerve fiber layer parameters in this high quality image can be used as a base-line image for detecting retinal nerve fiber layer defects and for determining changes of retinal nerve fiber layer thickness in sequential images of GDx.

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Scanning laser polarimetry is a non-invasive, computerized technique for measuring the retinal nerve fiber layer (RNFL) thickness rapidly, quantitatively and objectively.[1-4] It can be used for the diagnosis and follow-up of glaucoma and various optic neuropathies with retinal nerve fiber layer loss.[5-11] The measurement principle of GDx is based on the optical retardation caused by parallel retinal nerve fiber around the optic nerve head in the illuminating laser beam; the beam is reflected from the back of the eye to the detector.[12-13] There were comparatively few data describing the correlations and differences between the nerve fiber layer parameters of GDx in a single high quality image and those in the mean image from three high quality images. Although it was suggested that some parameters reproduced better from a mean than from a single image,[14-15] it is not always possible to acquire two or more high quality images in every case during the examination. The purpose of this study is to find the correlations and differences between the nerve fiber layer parameters of GDx in a single high quality image and those in the mean image from three high quality images.

METHODS

GDx results were selected from 63 patients (42 with glaucoma and 21 with suspected glaucoma). The inclusion criteria for glaucoma were: clinical diagnosis of primary open angle glaucoma or chronic angle-closure glaucoma, glaucomatous optic nerve damage and a typical glaucomatous visual field defect by automatic visual field (VF) testing seen in at least two examinations. The inclusion criteria for suspected glaucoma were: high vertical cup/disc ratio > 0.6 or asymmetric vertical cup/disc ratio ≧ 0.3, with normal automatic VF testing. There were 31 male patients and 32 female patients with a mean age of 54 years (range 14-80 years). One eye from each of the 63 patients was examined. When both eyes were eligible, one eye was randomly selected for the study. There were 35 left eyes and 28 right eyes included in this study. The refractive status of these patients was between ± 6.0 diopter. In each case, the intraocular pressure (IOP) at the time of examination was between 10-20 mmHg (by Perkins applanation tonometer). Those cases with pupil size above 5.0 mm or less than 2.5 mm were excluded from the study. The slit-lamp biomicroscopic examinations revealed: the cornea was clear at the central area, the lens was clear or had only mild opacity at the cortex, nucleus or posterior subcapsular area, and the vitreous was clear. Patients with pseudophakia or aphakia were excluded. The ocular fundi that showed optic neuropathies were related to the glaucoma only. Any patients with chorio-retinal disorders were excluded from the study. Scanning laser polarimetry, by Nerve Fiber Analyzer, GDx version (Laser Diagnostic Technologies, San Diego, CA, USA), was performed as described previously by Weinreb R.N. et al.[1] Briefly, the pupil was not dilated before the examination. The retinal nerve fiber of each eye was measured with GDx using a 15°×15° field of view. At least three high quality images were obtained in each case. Each high quality image had to pass the GDx software's quality criteria (software version 1.0.14). The best quality (highest Q value) of these three high quality images was selected as the single high quality image (Group One). The mean image was calculated from the same three high quality images (Group Two) using the software. A single examiner (Dr. Lai) delineated the disc margin of each image and a ten-pixel-wide measurement ellipse was automatically generated (1.75 times greater than the disc diameter). A computer algorithm automatically generated retardation measurements throughout the peripapillary region and along the measurement ellipse. Fourteen nerve fiber layer parameters (Number, Ellipse Modulation, Average Thickness, Ellipse Average, Superior Average, Inferior Average, Superior Integral, Symmetry, Superior Ratio, Inferior Ratio, Superior/Nasal, Maximal Modulation, Superior Maximum and Inferior Maximum) were collected for comparison between these two groups. The meaning of each retinal nerve fiber layer parameter has been reported elsewhere.[5] All the data were analyzed by paired samples correlations and paired samples test. A p value less than 0.05 was considered statistically significant.

RESULTS

The mean and standard deviation of nerve fiber parameters (Number, Ellipse Modulation, Average Thickness, Ellipse Average, Superior Average, Inferior Average, Superior Integral, Symmetry, Superior Ratio, Inferior Ratio, Superior/Nasal,

Inferior/Nasal, Maximal Modulation, Superior Maximum and Inferior Maximum) in the single high quality images (Group One) and those in the mean images (Group Two) are shown in Table 1. In this study, a high correlation was found in all 14 nerve fiber layer parameters between Group One and

Table 1. Correlations and Differences Between Nerve Fiber Parameters (GDx) in Single High Quality Images and Mean Images from three High Quality Images

GDx parameters	N	Mean (S.D.)	Correlation†	Difference‡	95% Confidence interval of the difference
Number					
Single	62	45.7 (21.9)	r = 0.979	p = 0.067	(-2.24, 0.08)
Mean	62	46.7 (22.5)			
Ellipse modulation					
Single	63	1.7 (0.6)	r = 0.923	p = 0.628	(-0.08, -0.05)
Mean	63	1.7 (0.6)			
Average thickness (μm)					
Single	63	67.6 (11.2)	r = 0.975	p = 0.000*	(1.26, 2.61)
Mean	63	65.7 (9.9)			
Ellipse average (μm)					
Single	63	69.6 (11.6)	r = 0.969	p = 0.000*	(1.29, 2.80)
Mean	63	67.6 (10.4)			
Superior average (μm)					
Single	63	71.9 (13.2)	r = 0.975	p = 0.000*	(1.27, 2.86)
Mean	63	70.0 (11.4)			
Inferior average (μm)					
Single	63	81.8 (15.1)	r = 0.968	p = 0.000*	(1.14, 3.09)
Mean	63	79.7 (13.8)			
Superior integral (mm^2)					
Single	63	0.2110 (0.044)	r = 0.960	p = 0.000	(0.002, 0.009)
Mean	63	0.2050 (0.045)			
Symmetry					
Single	63	0.91 (0.11)	r = 0.927	p = 0.663	(-0.09, 0.01)
Mean	63	0.91 (0.11)			
Superior ratio					
Single	63	1.68 (0.38)	r = 0.958	p = 0.381	(-0.04, 0.16)
Mean	63	1.70 (0.36)			
Inferior ratio					
Single	63	1.86 (0.40)	r = 0.947	p = 0.453	(-0.04, 0.02)
Mean	63	1.87 (0.39)			
Superior/Nasal					
Single	63	1.54 (0.29)`	r = 0.958	p = 0.412	(-0.12, 0.03)
Mean	63	1.53 (0.29)			
Maximal modulation					
Single	63	0.93 (0.39)	r = 0.953	p = 0.874	(-0.03, 0.03)
Mean	63	0.93 (0.39)			
Superior maximum (μm)					
Single	63	80.8 (15.3)	r = 0.976	p = 0.000*	(0.99, 2.66)
Mean	63	79.0 (14.7)			
Inferior maximum (μm)					
Single	63	89.7 (17.2)	r = 0.955	p = 0.002*	(0.81, 3.42)
Mean	63	87.6 (15.6)			

*Statistically significant differences between groups ($p < 0.05$);
†Pair correlation;
‡Pair-t test.

Group Two (Table 1). There was no significant difference in the seven relative values of nerve fiber layer parameters (Number, Ellipse Modulation, Symmetry, Superior ratio, Inferior Ratio, Superior/Nasal and Maximal Modulation) between Group One and Group Two. Group One had significantly higher values than Group Two in the other seven absolute values of nerve fiber layer parameters (Average Thickness, Ellipse Average, Superior Average, Inferior Average, Superior Integral, Superior Maximal and Inferior Maximal).

DISCUSSION

In this study, 63 eyes of 63 patients were examined with scanning laser polarimetry (GDx) to find the correlations and differences between the nerve fiber layer parameters in a single high quality image and those in mean images from three high quality images. Our results showed that there was a high correlation between the nerve fiber layer parameters in the single high quality images and those in the mean images. The seven absolute values of nerve fiber layer parameters were found significantly higher for Group One. Our results are different to those of the previous study by Colen and associates,[14] in which they found some parameters reproduced better in a mean than in a single image. These differences, however, were small and generally not statistically significant. Though the acquisition time for one GDx image is only 0.7 sec, it can be a difficult task to obtain two or more high quality images due to poor fixation, poor cooperation, intolerance to repeated image acquisition etc. Poor quality images or motion artifacts in scanning laser polarimetry might make the retardation of laser beams highly variable, and impair the sensitivity and specificity of GDx to detect retinal nerve fiber layer defects.[16-17] If the mean image is calculated from a combination of high and poor quality images, the data would be less reliable and the mean image would be more unreliable as a base-line for detecting nerve fiber layer change. In our opinion, if only a single high quality image can be obtained in a repeated acquisition of GDx, we believe that scanning images with identified motion artifacts or poor image quality should be disregarded. Further, this single high quality image can be a base-line image for diagnostic analysis and comparison with an image acquired later.

In this study, the scanning laser polarimetry (GDx) uses a fixed anterior segment compensator with a magnitude of 60 nm (single pass retardance) and a slow polarization axis at 15° nasally downward. The setting will always yield artifactually higher retardation values throughout the entire field.[18] The range of retinal nerve fiber layer thickness appeared to be narrower with the variable anterior segment birefringence compensator than with the fixed corneal compensator, and the retinal nerve fiber layer pattern appeared to be a better match of the expected anatomy of the eye.[19-20] If scanning laser polarimetry with variable anterior segment birefringence compensation could be used, we propose that a single high quality image would be more reliable as a base-line image for detecting retinal nerve fiber layer damage and for determining the change of retinal nerve fiber layer thickness in sequential images of GDx. Examination speed and predictive power are always two important considerations when choosing glaucoma screening tests. The results of this study also revealed that using a single high quality image in a glaucoma screening test could take less time and have nearly the same predictive power as using the mean image from three high quality images. In conclusion, it is reasonable to take a mean image from three good quality images from a cooperative patient. If only one high quality image can be obtained in repeated acquisition of GDx, the seven relative values of nerve fiber layer parameters in this high quality image can be used as a base-line image for detecting retinal nerve fiber layer defects and determining the changes of retinal nerve fiber layer thickness in sequential images of GDx. We recommend the above conclusion to be a GDx practice guideline for future routine examination.

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單一高品質 GDx 影像與 3 張高品質 GDx 合成影像關係與差異之研究

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背 景： 爲了比較分析 GDx (掃瞄式雷射偏光儀；視網膜神經纖維層分析器) 用於青光眼及疑似青光眼病患之檢查時，使用單張高品質影像參數的效果與使用三張高品質影像之合成影像有無差異。

方 法： 共有 63 位病患 (31 位男性，32 位女性；共 63 隻眼睛) 爲青光眼或疑似青光眼病患接受 GDx 的檢查；將三張高品質影像中最好的影像挑出來作爲第一群，並將此三張影像之合成影像作爲第二群。GDx 檢查所得到的 14 個參數以統計方法檢定其相關性及差異性。

結 果： 比較分析此二群影像，14 個參數之中有 7 個相對參數無統計上之差異，另外七個絕對參數達則有統計上的差異，但此二群影像之參數均有相當大的相關性。

結 論： 如果對於使用 GDx 檢查影像取得困難的病患，例如老人家或其他不易維持固定姿勢的患者，或者是用在需要盡可能節省時間的青光眼或其它視神經病變的篩選上，擷取一張高品質影像應可作爲偵測視視網膜神經纖維層缺陷的基礎影像資料及日後追蹤時比較神經纖維層厚度有無變化之依據。

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關鍵字：GDx，掃瞄式雷射偏光儀，視網膜神經纖維層分析器。

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