CLINICAL STUDY

The correlation of the visual field with scanning laser ophthalmoscope measurements in glaucoma

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Abstract

Purpose **To assess the relationship between Humphrey visual field data and optic disc topographical data collected by the Heidelberg Retina Tomograph (HRT) scanning laser ophthalmoscope in chronic glaucoma patients.**
Methods **The mean deviation (MD) and corrected pattern standard deviation (CPSD) from Humphrey visual fields of 106 eyes of 106 patients with glaucoma were analysed for correlation with the multiple topographical measures calculated by the HRT.**
Results **Significant correlations were found between MD of the visual field and several optic disc measurements. These included neuroretinal rim volume, mean nerve fibre layer thickness and cross-sectional area, and the cup shape measure. CPSD correlated significantly only with mean nerve fibre layer cross-sectional area. This pattern was common to the whole circumference of the disc with the exception of the directly temporal segment.**
Conclusion **Optic disc topography performed by HRT reflects the optic disc pathology in correlation with perimetry.**

Key words Comparative study, Cup shape measure, Glaucoma, Optic disc, Scanning laser ophthalmoscope, Visual field

The clinical assessment of the optic disc both structurally and functionally are prerequisites for the diagnosis and follow-up of glaucoma. Static threshold automated perimetry has become the gold standard for functional assessment. However, the interpretation of automated visual fields is complicated by the subjectivity and variability of the patient performing the test. A number of methods for describing the morphological appearance of the optic disc and retinal nerve fibre layer in glaucoma have been evaluated.[1] This approach may be relatively more important in detecting early axonal dropout from glaucoma before the advent of visual field defects.

Recently confocal scanning laser ophthalmoscopy and polarimetry have been used quantitatively and qualitatively to assess the optic disc and retinal nerve fibre layer.[2-4] The purpose of the present study was to further define the relationship between the wealth of global and segmental data available from topographic scanning of the optic disc and the corresponding visual field in glaucoma patients.

Patients and methods

From an original database of HRT (Heidelberg Retina Tomograph) measurements of 270 well-controlled glaucoma patients we selected 106 patients with stable, reliable fields demonstrating established glaucomatous defects. The mean age of the patients was 70.3 ± 11.8 years. Mean spherical correction was 0.2 ± 2.9 dioptres (range −11.25 D to 10 D). This group comprised 80 patients with primary open angle glaucoma, 20 patients with normal tension glaucoma and 6 patients with chronic angle closure glaucoma. One eye of each patient was randomly selected. An established glaucomatous defect was regarded as a superior or inferior arcuate scotoma, nasal step or a combination of these. Two subgroups were defined with well-defined superior arcuate ($n = 37$) and inferior arcuate field defects ($n = 19$). All fields were checked by two experienced clinical observers (D.M.T. and M.J.M.). Automated static threshold perimetry was performed on the Humphrey 24-2 programme. The average Humphrey mean deviation ± standard deviation was −9.6 ± 5.5 dB.

All topographic imaging was performed by an experienced observer using the HRT (Heidelberg Engineering, Heidelberg, Germany) within 6 months of the visual field test. The technician had been using the HRT since 1993 and at the time of writing has recorded over 10 500 database entries.

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Table 1. *Summary of correlation statistics between visual field data and global topographic measurements*

	MD		CPSD	
	r	*p*	*r*	*p*
Disc area	0.11	0.263	−0.11	0.260
Cup area	−0.18	0.069	0.12	0.232
Cup volume	−0.16	0.109	0.07	0.478
Neuroretinal rim volume	0.27	**0.005**	−0.16	0.108
Cup shape measure	−0.26	**0.005**	0.17	0.084
Peak elevation of contour line	0.24	**0.014**	−0.13	0.188
Mean NFL thickness	0.29	**0.003**	−0.16	0.103
Mean NFL cross-section	0.32	**0.001**	−0.20	**0.041**

MD, mean deviation; CPSD, corrected pattern standard deviation; NFL, nerve fibre layer.
All correlation statistics Pearson *r*.

The HRT records a series of 32 confocal images at consecutive focal planes, each 256 × 256 pixels in size, that the computer then converts to a single topographic image. A series of three scans per eye were performed at an image angle of 10°. From these an overall mean topographical image was produced. A contour line was drawn at the disc edge by a combination of circle and draw. The stereo viewing and interactive measurement menus were used as an aid to define the disc margin and topographical measurements of the optic disc and the retinal nerve fibre layer were made. All measurements were made from the standard reference plane using HRT software version 1-11. The data were then exported to a spreadsheet format (HRTcalc utility version 1.05).

The following parameters were analysed: optic disc area, cup area, cup volume, rim area, rim volume, cup shape measure, height variation contour, mean retinal nerve fibre layer thickness and cross-sectional area. Each parameter was calculated for the whole disc and in six pre-defined 60° segments (temporal, temporal superior, temporal inferior, nasal, nasal superior and nasal inferior).

Statistical analysis was carried out using STATISTICA version 5.1 (Statsoft). Field and topographical data were all normally distributed. Pearson correlation statistics were used to assess the relationship between the visual field indices, namely the mean deviation (MD) and the corrected pattern standard deviation (CPSD), and the global and segmental topographic measurements for the optic disc and retinal nerve fibre layer. Paired *t*-tests were used to evaluate differences between areas of the disc margin.

Results

The correlation results for MD and CPSD and global topographical measures are summarised in Table 1. As can be seen from the table Humphrey MD correlates well with the neuroretinal rim volume and nerve fibre layer thickness and cross-sectional area. There is a high correlation with cup shape measure. This is a mathematical expression of the cup shape based on the third central moment of the distribution of the depth values for the optic disc structures. The CPSD reached a mild level of significance only with the nerve fibre layer cross-section. Apart from the peak elevation of the contour line no other global topographical measures reached significant correlation with either MD or CPSD.

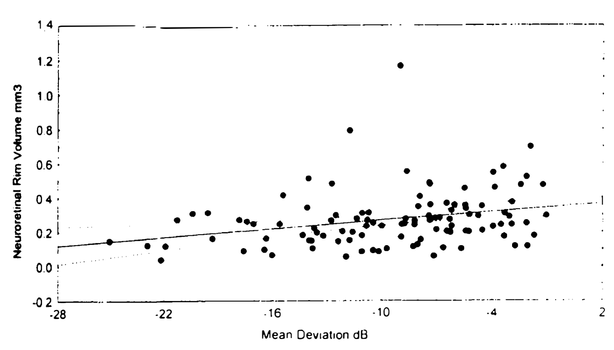

Fig. 1. *Correlation of mean deviation with neuroretinal rim volume. Pearson* r = *0.27,* p = *0.005 (95% confidence bands).*

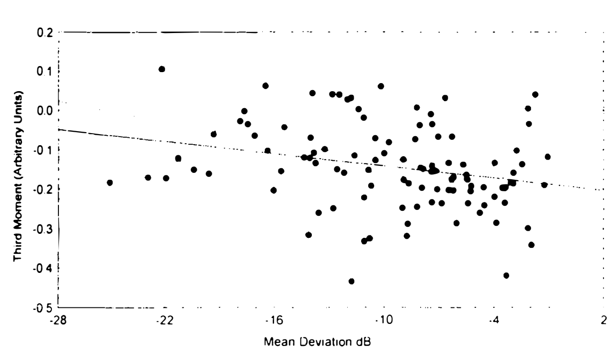

Fig. 2. *Correlation of mean deviation with third moment. Pearson* r = *−0.26,* p = *0.005 (95% confidence bands).*

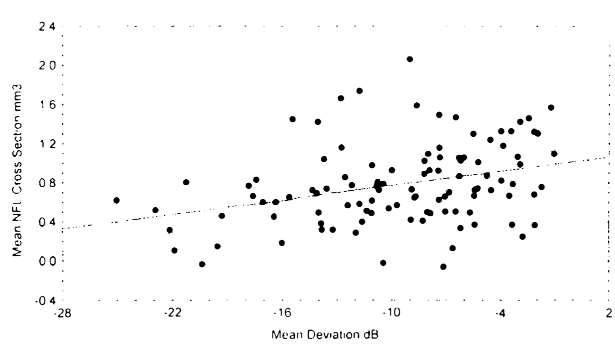

Fig. 3. *Correlation of mean deviation with nerve fibre layer cross-section. Pearson* r = *0.32,* p = *0.001 (95% confidence bands).*

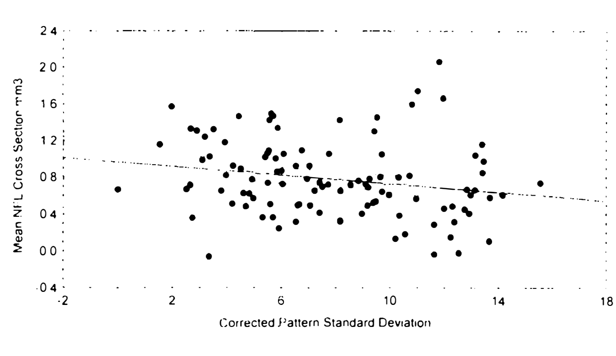

Fig. 4. *Correlation of corrected pattern standard deviation with nerve fibre layer cross-section. Pearson* r = *−0.20,* p = *0.041 (95% confidence bands).*

Table 2. *Summary of correlation statistics between mean deviation and segmental topographic measurements*

	T		TS		TI		N		NS		NI	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Disc area	0.12	0.232	0.08	0.407	0.11	0.269	0.10	0.296	0.13	0.174	0.09	0.347
Cup area	−0.05	0.637	−0.13	0.199	−0.17	0.084	−0.23	**0.018**	−0.13	0.199	−0.29	**0.002**
Cup volume	−0.04	0.681	−0.13	0.195	−0.17	0.074	−0.22	**0.027**	−0.15	0.122	−0.22	**0.027**
Neuroretinal rim volume	0.03	0.750	0.23	**0.017**	0.2	**0.039**	0.26	**0.008**	0.24	**0.014**	0.37	**0.000**
Cup shape measure	−0.14	0.158	−0.21	**0.029**	−0.22	**0.022**	−0.25	**0.009**	−0.21	**0.033**	−0.23	**0.019**
Peak elevation of contour line	0.15	0.117	0.24	**0.013**	0.25	**0.009**	0.26	**0.007**	0.23	**0.018**	0.26	**0.006**
Mean NFL thickness	0.10	0.311	0.29	**0.002**	0.28	**0.004**	−0.23	**0.019**	0.28	**0.004**	0.29	**0.003**
Mean NFL cross-section	0.13	0.180	0.31	**0.001**	0.3	**0.002**	0.26	**0.006**	0.30	**0.002**	0.32	**0.001**

T, temporal; TS, temporal superior; TI, temporal inferior; N, nasal; NS, nasal superior; NI, nasal inferior; NFL, nerve fibre layer.
All correlation statistics are Pearson *r*.

Figs. 1–4 are example scatterplots of some of the highly correlated global topographic and field measurements.

Similar correlations were carried out for the six segmental topographical measurements. Significant correlations were found in a very similar pattern for the segments except the directly temporal 60°, which showed no correlations whatsoever. CPSD correlated only with the nerve fibre layer cross-sectional area, as in the global data. Correlations between the MD and measures of disc topography are summarised in Table 2.

Because of the possibility that the disc topography would be a more accurate reflection of early glaucomatous damage than advanced changes a further analysis was carried out using only those fields with less than a 10 dB reduction in MD. Results for these 61 cases are summarised in Table 3. Surprisingly it can be seen that all significance disappears. Similarly, when only the 84 cases with well-established field loss are considered (greater than 5 dB MD) significance is also considerably reduced (Table 3).

The pattern of field loss was also carefully examined. Thirty-seven cases of definite isolated superior arcuate defect and 19 cases of definite isolated inferior arcuate defect were identified. Topographical disc measurements for the two groups were analysed.

Superior arcuate field group (mean MD −9.5 ± 5.7). The superior disc segments were compard directly with the inferior segments using a paired *t*-test. In contrast to the normal disc anatomy, as one would expect in this group the superior disc neuroretinal rim and nerve fibre layer were larger than the inferior and this reached a high level of statistical significance for a number of parameters. The results are summarised in Table 4.

Inferior arcuate field group (mean MD −9.8 ± 4.2) The results for this group were similarly reversed, with the inferior disc margin being generally the better preserved, and this reached significance for a large number of parameters (Table 5).

Discussion

Previous studies have reported on the correlation between retinal nerve fibre layer loss estimated by monochromatic photography or digital analysis of the optic nerve head and nerve fibre layer height with static automated perimetry.[5–7] Confocal scanning laser ophthalmoscopy is a new method for measuring the morphology of the optic disc and the retinal nerve fibre layer. It provides both quantitative and qualitative information that is rapidly acquired through an undilated pupil even in the presence of media opacities.

We found that the global measure of visual field loss in glaucoma, namely MD, was significantly correlated with loss of the neuroretinal rim volume, the maximal height of the nerve fibre layer at the contour line and a reduction in the nerve fibre layer thickness and cross-sectional area. All these parameters are indicative of

Table 3. *Summary of correlation statistics between visual field data and topographic measurements for selected severity of field loss*

	< 10 dB MD (*n* = 61)				> 5 dB MD (*n* = 84)			
	MD		CPSD		MD		CPSD	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Disc area	0.16	0.224	−0.03	0.821	0.03	0.778	−0.09	0.392
Cup area	−0.01	0.951	−0.02	0.892	−0.17	0.114	0.05	0.622
Cup volume	−0.02	0.907	−0.07	0.601	−0.19	0.080	0.08	0.497
Neuroretinal rim volume	0.08	0.526	0.08	0.558	0.21	0.055	−0.05	0.673
Cup shape measure	−0.10	0.448	0.00	0.997	−0.22	**0.041**	0.10	0.358
Peak elevation of contour line	0.18	0.177	0.06	0.650	0.15	0.162	−0.03	0.758
Mean NFL thickness	0.11	0.380	−0.01	0.928	0.22	**0.043**	−0.04	0.702
Mean NFL cross-section	0.15	0.247	−0.03	0.848	−0.24	**0.027**	−0.08	0.496

MD, mean deviation, CPSD, corrected pattern standard deviation; NFL, nerve fibre layer.
All correlation statistics are Pearson *r*.

Table 4. *Comparison of disc topography between superior and inferior segments in patients with well-defined superior arcuate defects* (n = 37)

	TS Mean	TI Mean	p	NS Mean	NI Mean	p
Disc area	0.32	0.33	0.462	0.31	0.31	0.283
Cup area	0.14	0.18	**0.000**	0.10	0.11	0.578
Cup volume	0.05	0.05	0.579	0.03	0.03	0.212
Neuroretinal rim volume	0.04	0.02	**0.001**	0.05	0.05	0.344
Cup shape measure	−0.10	−0.02	**0.004**	−0.17	−0.10	**0.002**
Peak elevation of contour line	0.24	0.20	**0.015**	0.26	0.25	0.447
Mean NFL thickness	0.18	0.13	**0.002**	0.22	0.20	0.340
Mean NFL cross-section	0.12	0.09	**0.001**	0.15	0.14	0.347

T, temporal; TS, temporal superior; TI, temporal inferior; N, nasal; NS, nasal superior; NI, nasal inferior; NFL, nerve fibre layer. Dependent t-test.

retinal ganglion cell loss and are strong indicators of glaucomatous optic nerve damage.[8,9] Previously measurement of the peripapillary nerve fibre layer height by analysis of stereoscopic videographic images[10] and scanning laser topography[11] has been found to be a useful structural parameter for distinguishing between glaucomatous and healthy eyes. Caprioli and Miller[10] found it to have a higher sensitivity and specificity than conventional measurements of cup/disc ratio, cup volume and disc area.

Our study also showed a statistically significant correlation between the cup shape measure and the visual field mean deviation. Brigatti and Caprioli[2] were the first to describe this correlation and concluded that this measurement is strongly related to the overall shape of the cup and is a strong indicator of the degree of glaucomatous optic nerve damage. In our study the cup shape measure was correlated with the disc area (Pearson $r = 0.26$, $p = 0.008$) and obviously the overall disc size has some influence on this parameter. Despite this there was still a strong correlation with glaucomatous field abnormality.

We also found a significant correlation with the neuroretinal rim volume, which has been shown to show concordance with field loss in previous studies.[12–16] However, a more recent study that estimated the neuroretinal rim by planimetry of stereophotographs of the optic disc failed to show a significant correlation.[17]

Analysis of the segmental topographical data showed very similar correlations with field abnormalities to the global measures. Clinical experience would lead one to expect the directly temporal segment of the disc to be a poor guide to glaucomatous damage. More surprising are the consistently high correlations around the nasal half of the disc that one might expect to be rather less affected by glaucomatous damage than the rest of the disc.

Optic nerve changes often precede visual field loss in glaucoma. By selecting those patients with a less than 10 dB reduction in MD and excluding advanced field loss we hoped to show the value of the HRT in early glaucomatous disc damage. Disappointingly the correlations all lose statistical significance when we analysed this group. This may reflect the statistical effect of reducing the numbers (from 106 to 61 eyes) and further evaluation would be needed with a much larger group of patients. Conversely, excluding the small group of patients with very mild field loss (< 5 db MD) also merely reduced the significance of the correlations.

By selecting out the relatively small groups of eyes with well-defined patterns of field loss we were able to demonstrate that the HRT is reliably measuring the expected disc damage both superiorly and inferiorly – despite the fact that such comparisons are obviously hampered by the relative thickness of the inferior neuroretinal rim compared with the superior in a normal disc.

Detailed knowledge about the correlation between optic disc structure, especially the neuroretinal rim and cup shape measure, and the visual field is vital in the diagnosis and follow-up of glaucoma patients. This information can now be collated quickly and accurately using the scanning laser ophthalmoscope. Further advances will be made by assessing the role of these measurements in longitudinal studies.

We are grateful for the expertise of Mr Mike Geall, departmental senior medical photographer, in collecting the HRT data.

Table 5. *Comparison of disc topography between superior and inferior segments in patients with well-defined inferior arcuate defects* (n = 19)

	TS Mean	TI Mean	p	NS Mean	NI Mean	p
Disc area	0.33	0.35	**0.011**	0.34	0.32	**0.006**
Cup area	0.22	0.20	0.079	0.15	0.11	**0.013**
Cup volume	0.08	0.05	**0.000**	0.06	0.03	**0.003**
Neuroretinal rim volume	0.02	0.02	0.303	0.04	0.05	**0.026**
Cup shape measure	0.09	0.00	**0.017**	−0.09	−0.10	0.952
Peak elevation of contour line	0.18	0.19	0.649	0.21	0.24	**0.048**
Mean NFL thickness	0.12	0.13	0.547	0.16	0.20	**0.019**
Mean NFL cross-section	0.08	0.09	0.500	0.11	0.14	**0.012**

T, temporal; TS, temporal superior; TI, temporal inferior; N, nasal; NS, nasal superior; NI, nasal inferior, NFL, nerve fibre layer. Dependent t-test.

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