European Journal of Ophthalmology / Vol. 11 / Suppl. 2, 2001 / pp. S57-S62

Evaluation of glaucomatous visual field loss with locally condensed grids using fundus-oriented perimetry (FOP)

U. SCHIEFER[1], A. MALSAM[1], M. FLAD[1], F. STUMPP[1], T. J. DIETRICH[1], J. PAETZOLD[1], R. VONTHEIN[2], M. KNORR[3], P.O. DENK[3]

[1] University Eye Hospital Tübingen, Dept. II;
[2] Department of Medical Biometry, University of Tübingen;
[3] University Eye Hospital Tübingen, Dept. I, Tübingen - Germany

PURPOSE. *We compared detection rates of glaucomatous visual field defects (VFDs) between a conventional rectangular stimulus grid and locally condensed test point arrangements in morphologically suspicious regions.*

METHODS. *Humphrey Field Analyzer model 630 (HFA I, program 30-2 with a rectangular 6° x 6° grid) was used as the conventional perimetric method. Individual local test-point condensation was realized by fundus-oriented perimetry (FOP) on the Tuebingen Computer Campimeter (TCC).*

RESULTS. *Of a total of 66 glaucoma patients, or suspected sufferers, 23 showed normal findings and 27 showed pathological findings with both methods. In 15 cases we found normal visual fields in HFA 30-2, whereas FOP revealed early glaucomatous functional damage. Only one case showed pathological HFA results, while FOP was normal. Detection rates of VFDs significantly differed between the two methods (*$p < 0.001$*; sign test).*

CONCLUSIONS. *FOP, using individually condensed test grids, significantly increases detection rates of glaucomatous VFDs in morphologically suspicuous areas compared with a conventional HFA 30-2 technique using equidistant rectangular (6° x 6°) test point arrangements.* Eur J Ophthalmol 2001; 11 (Suppl 2): S57-S62

KEY WORDS. *Glaucoma, Perimetry, Fundus-oriented perimetry, Visual field defect, Scotoma, Follow-up*

INTRODUCTION

In reality, perimetric characterization of functional *change* is more important than the detection of functional *loss*. Nevertheless, reliable *detection* of a glaucomatous field defect is an essential prerequisite and baseline for evaluation of functional changes that manifest themselves in a variety of scotoma depths and/or sizes. Whereas defect *depth* should be assessed by a sophisticated thresholding algorithm, quantification of scotoma *size* demands an adequate target density. Due to limitations in test duration, condensation of test points needs to be restricted to those visual field areas that correspond to morphologically suspicious regions (optic disc notching, splinter hemorrhages, retinal nerve fibre layer defects). This is realized in fundus oriented perimetry (FOP) using Tuebingen Computer Campimeter (TCC), with the optic disc and foveola serving as morphological landmarks for adjustment of their psychophysiological counterparts (i.e. blind spot and visual field centre).

The purpose of this study was to compare detection rates of glaucomatous visual field defects (VFDs) between a local "evidence-based" condensation of perimetric test locations in morphologically suspicious

 1120-6721/S57-06$03.00/0

areas, using FOP, and those of conventional perimetry. Humphrey Field Analyzer (HFA I, 30-2 grid) served as the conventional perimetric control.

METHODS

FOP has been described elsewhere in detail (1–4). This new concept uses a digitized fundus image of the tested subject as a basis for "constructing" an individual grid of perimetric stimuli. The fundus image is downloaded from a data carrier (disc, photo CD), or digitized by a slide scanner, and is depicted on a control monitor and mirrored, if necessary, with the help of software. Assuming central fixation, the foveola of the fundus image is aligned to the centre of the perimetric field using a cross hair. In a second step, the blind spot, which has been previously determined by means of kinetic perimetry, is interactively superimposed onto the optic disc of the fundus image by automatic activation of rotatory and zoom routines. Thus, the method allows a direct adaptation of the perimetric procedure to the individual fundus morphology. It is capable of detecting even minute VFDs, such as angioscotomata or shallow nerve fibre bundle defects (4–7).

In the set-up, a calibrated high-resolution visual display unit (8–10) is used instead of a cupola. The 20" monitor covers a visual field of approximately 35° horizontally and approximately 24° vertically ("radius") in an examination distance of 30 cm. This set-up renders a continuous recording of pupil size and position during the examination.

A modified 4-/2-/1-dB strategy with 3 reversals is applied with FOP. Each perimetric grid is adapted according to the individual fundus findings. Additional test points are inserted between the "original 30-2" stimulus locations. "Mesh density" of the stimulus grid within the scotoma area is at least 3° x 3°. The test-point grid exceeds the scotoma border by at least 5° in each direction. The maximum number of stimulus locations is 152. The FOP grid is split into two complementary, randomized sub-sets of an approximately equal number of test points, which are presented in two subsequent sessions. Thus, no more than 76 locations are examined in each perimetric subset. There are nine identical stimulus locations (one at the visual field centre, the others on the oblique meridians located at eccentricities of 15° and 25°, respectively) in both sets of FOP sub-grids in order to check for intra-individual retest reliability.

Conventional perimetry with HFA 30-2 (HFA I, program 30-2; 4-2-dB strategy; two reversals; 30´ stimulus) served as a control.

Ophthalmological examinations

The following examinations were performed:

- Subjective and objective refraction (retinoscopy).
- Visual acuity (distant, near).
- Orthoptic examination.
- Examination of efferent and afferent pupil reaction
- Slit lamp examination.
- Intraocular pressure (IOP) measurement (non-contact tonometer – additional IOP dates from reliable records).
- Gonioscopy.
- Fundus examination (dilated pupils: direct and indirect binocular ophthalmoscopy, 78 dpt lens).

Photodocumentation

(Stereo-)photography of the optic disc, posterior pole and nerve fibre layer were performed, no more than 2 months before the first, and after the last, perimetric session. The sequence of perimetric methods (HFA I 30-2 and TCC-FOP, respectively) was changed at random.

Inclusion criteria

Glaucoma patients who had localized glaucomatous morphological lesions (retinal nerve fibre layer [RFNL] defect, cupping of optic disc, ...) were included in the study, with or without corresponding localized glaucomatous VFDs (AULHORN stage I–III). Patients also had:

- No history or signs of other (neuro)-ophthalmological diseases (beside ametropia, see below).
- Spherical ametropia < 8 dpt.
- Cylindrical ametropia < 3 dpt.
- Central visual acuity > 0.5 (10/20).
- No relevant opacities of central refractive media (cornea, lens, vitreous body).
- No miotic drugs.

Patients suspected of having glaucoma were defined as patients with ocular hypertension and/or morphological

changes *without* VFDs in conventional perimetry.

Only one eye of each patient or suspected patient was enrolled in the study. If both eyes suffered from a localized RNFL defect, one was selected at random.

Evaluation of perimetric results

Perimetric results *within the morphologically suspicuous areas* were evaluated according to the following criteria:

- ≥ 3 contiguous non-edge points with $p < 0.05$, with
- ≥ 1 non-edge point with $p < 0.01$ (11, 12). The evaluation was based on the analysis of total deviation plots.

RESULTS

A total of 66 eyes of 66 glaucoma patients or suspects (34 females, 32 males), aged 14–85 years were enrolled in the study.

Table I shows the comparison of detection rates of HFA 30-2 and TCC-FOP, according to the above mentioned evaluation criteria. In 23 patients, both methods showed normal findings. A total of 27 individuals revealed pathological findings with both methods. In 15 cases we found normal visual fields in HFA 302, whereas FOP revealed early glaucomatous functional damage. Only one case showed pathological HFA-results, while FOP was normal. Detection rates of VFDs significantly differed between the two methods ($p < 0.001$; sign test).

Figure 1 shows a typical result. Neither HFA I 30-2 grey-scale plot nor total deviation plot reveals a typical glaucomatous VFD (right), which clearly shows up in FOP with locally enhanced grid density.

Due to its three reversals, examination duration of a *single* session in TCC technique (21.3 ± 2.8 min; MEAN ± SD) is longer than in HFA I (15.2 ± 2.1 min). In all, TCC-FOP, which is based on two sessions, takes more than twice the time of the (single session) HFA 30-2 examination.

DISCUSSION

Reductions in examination duration is now a major issue in glaucoma perimetry. This is achieved by modifying the perimetric strategy and/or the thresholding algorithm, as in the “TOP” or “SITA” procedures (13–18). By this means, the “number of questions asked”, as well as patient fatigue, can be reduced – possibly at the expense of an impaired local threshold estimation. Furthermore, the widely used rectangular 6° x

TABLE I - COMPARISON (CONTINGENCY TABLE) OF NORMAL (n) AND PATHOLOGICAL (p) RESULTS BETWEEN CONVENTIONAL PERIMETRY USING HFA I (RECTANGULAR 6° X 6° TEST POINT ARRANGEMENT; 30-2 GRID) AND FUNDUS ORIENTED PERIMETRY (FOP) WITH INDIVIDUALLY CONDENSED TEST POINT ARRANGEMENTS PERFORMED WITH TCC. EVALUATION CRITERIA ACCORDING TO (11,12) ARE ADDITIONALLY LISTED

$p<0.001$ (sign test)

		HFA 30-2		
		n	**p**	**sum**
FOP	n	23	1	24
	p	15	27	42
	sum	38	28	66

Criteria:
Abnormal VF: ≥ 3 contiguous non-edge points ($p \leq 0.05$), with
≥ 1 non-edge point ($p \leq 0.01$)
within morphological suspicuous areas

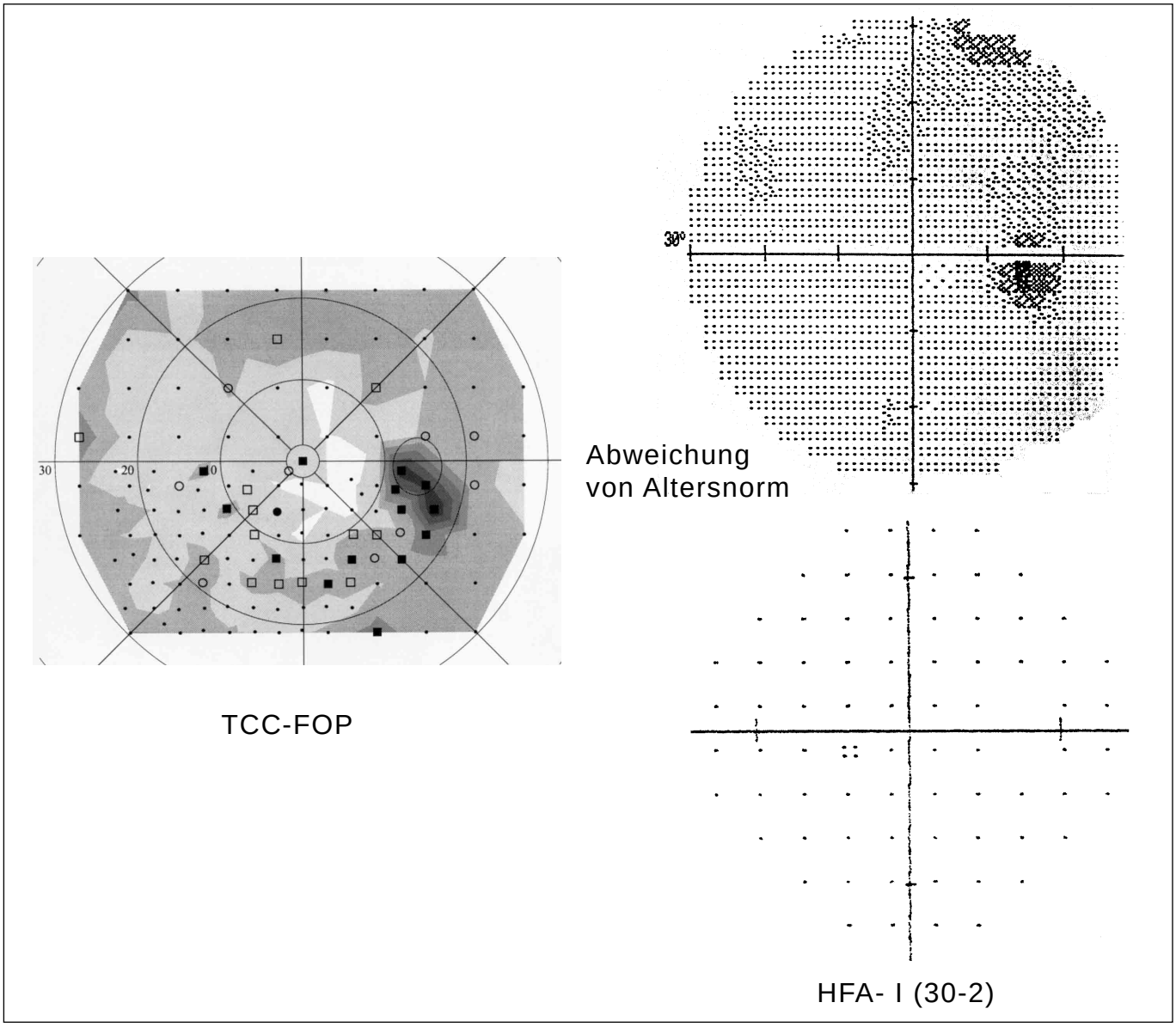

Fig. 1 - *Representative visual field results: the grey-scale plot with superimposed total deviation plot of FOP (left) clearly shows a typical glaucomatous VFD within the locally condensed test-point arrangement, which does not show up in the conventional rectangular 6° x 6° HFA 30-2 grid (right)(grey-scale plot and total deviation plot).*

6° grid may be too coarse to unequivocally and reproducibly detect subtle defects. This reduced resolution with respect to space and depth does not only impair scotoma detection, but also counteracts to demonstrate subtle *changes* in case of follow-up examinations, partially due to an unstable baseline. These phenomena have been recently shown in the ocular hypertension treatment study (19).

Recent results indicate that glaucomatous progression occurs in the vicinity of already affected visual neurons (20–22), thereby inducing a *local* progression of scotoma depth and/or size. As a logical consequence, perimetric techniques should enhance resolution with respect to both above-mentioned parameters, additionally, referring to a reliable (as well as comparable) perimetric baseline result.

Langerhorst et al (23) demonstrated that higher test-point density within the central 10° visual field en-

hanced scotoma detection. Westcott et al (12, 24) showed a similar effect by adding test locations within the region of the nasal step. In contrast to FOP, both methods did not adapt stimulus arrangements according to the individual morphological findings, but used default grids, thereby eventually "wasting" additional test points in obviously normal regions.

With the help of fundus-controlled perimetry, targets can be presented via scanning laser opthalmoscope (SLO) or fundus camera directly onto the retina under observation of the examiner (25–27). However, the examination area is comparatively small (< 20° "radius"), especially with an SLO, and it is therefore not possible to detect changes within the nasal step region. In contrast to exclusively circumscribed retinal lesions, (e.g. glaucomatous) alteration of the RNFL does not exclusively affect just the morphologically visible area, but predominantly affects more peripheral regions corresponding to the course of nerve fibres. This further reduces the value of direct fundus controlled perimetric methods.

The individual arrangement of test points, as realized in FOP, requires an age-related smooth model of the entire 30° hill of vision (Schwabe et al, in preparation), since a considerable number of stimuli cannot be directly referred to as a "rigid" set of normative test points.

The results presented in this paper clearly demonstrate that individual condensation of test points by FOP using the TCC significantly increases detection of glaucomatous VFDs compared with a conventional HFA 30–2 technique. Of course, this positive effect is purchased at the expense of examination duration. Since FOP can be divided up into several sessions, this procedure is reasonable, especially in the case of in-patient situations or in combination with other time-consuming examinations, such as diurnal IOP recordings, etc. Intra-individual quality ("medium-term fluctuation") can be assessed by analyzing inter-session variability of the nine reference points, which are presented in fixed locations at all sessions (Stumpp et al, in preparation).

Since not only test-point arrangement but also instruments and therefore examination technique were changed in these experiments, suspicion might arise that the latter circumstance may have been of decisive influence on this result. As already mentioned in the methods section, test-point arrangement in the FOP-TCC *technique* is interwoven with an original 30-2 grid. [Comparison between TCC-FOP grid and TCC 30-2 grid again showed a significant difference of detection rates between these two grids for one and the same instrument – again favouring the FOP grid (Schiefer et al, in preparation).

ACKNOWLEDGEMENTS

Supported by MSD Sharp & Dohme GmbH, Haar, Germany; Allergan, Irvine, CA, USA.

Reprint requests to:
Prof. Ulrich Schiefer
University Eye Hospital Tübingen
Department II
Schleichstr. 12–16
D-72076 Tübingen
Germany
ulrich.schiefer@uni-tuebingen.de

REFERENCES

1. Schiefer U, Stercken-Sorrenti G, Dietrich TJ, Friedrich M, Benda N. Fundus-oriented perimetry. Evaluation of a new visual field examination method for detecting angioscotoma. Klin Monatsbl Augenheilkd 1996; 209: 62-71.
2. Schiefer U, Witte A. Patent: Perimetrisches Untersuchungsverfahren - Fundusgestützte Perimetrie II. Deutsches Patentamt München, Az 196 21 961 2 1996; 1-15.
3. Schiefer U, Stercken-Sorrenti G, Dietrich TJ, Friedrich M, Benda N. Fundus oriented perimetry - a new concept for increasing the efficiency of visual field examination. In: Wall M, Heijl A, eds. Perimetry update 1996/1997. Amsterdam, New York: Kugler Publications, 1997; 107–9.
4. Schiefer U, Selig B, Dietrich TJ. Automated static campimetry with locally enhanced spatial resolution. In: Wall M, Wild JM, eds. Perimetry update 1998/1999. Hague, Netherlands: Kugler Publications, 1999: 261–72.
5. Benda N, Dietrich TJ, Schiefer U. Fitting angioscotomas.

In: Wall M, Heijl A, eds. Perimetry update 1996/1997. Amsterdam, New York: Kugler Publications, 1997; 207–10.
6. Schiefer U, Benda N, Dietrich TJ, Selig B, Hofmann C, Schiller J. Angioscotoma detection with fundus-oriented perimetry. A study with dark and bright stimuli of different sizes. Vision Res 1999; 39: 1897–1909.
7. Benda N, Dietrich TJ, Schiefer U. Models for the description of angioscotomas. Vision Res 1999; 39: 1889–96.
8. Wabbels B, Schiefer U, Treutwein B, Benda N, Sterck-en-Sorrenti G. Automated perimetry with bright and dark stimuli. German J Ophthalmol 1995; 4: 217–21.
9. Dietrich TJ, Friedrich M, Selig B, Benda N, Schiefer U. Application of video display units for campimetric purposes - luminance characteristics and calibration procedures. In: Wall M, Heijl A, eds. Perimetry update 1996/1997. Amsterdam, New York: Kugler Publications, 1997; 471.
10. Dietrich TJ, Selig B, Friedrich M, Benda N, Schiefer U. Calibration routines for video display units for perimetric examinations. German J Ophthalmol 1996; 5 (Suppl): S125.
11. Katz J, Sommer A, Gaasterland DE, Anderson DR. Comparison of analytic algorithms for detecting glaucomatous visual field loss. Arch Ophthalmol 1991; 109: 1684–89.
12. Westcott MC, McNaught AI, Crabb DP, Fitzke FW, Hitchings RA. High spatial resolution automated perimetry in glaucoma. Br J Ophthalmol 1997; 81: 452–9.
13. Morales J, Weitzman ML, Gonzalez de la Rosa M. Comparison between Tendency-Oriented Perimetry (TOP) and octopus threshold perimetry. Ophthalmology 2000; 107: 134–42.
14. Morales J. New perimetry algorithm test sensitivity points relative to each other; results in 3 minutes. Ocul Surg News 1997: 8.
15. Bengtsson B, Heijl A. SITA fast, a new rapid perimetric threshold test. Description of methods and evaluation in patients with manifest and suspect glaucoma. Acta Ophthalmol Scand 1998; 76: 431–7.
16. Bengtsson B, Olsson J, Heijl A, Rootzen H. A new generation of algorithms for computerized threshold perimetry, SITA. Acta Ophthalmol Scand 1998; 75: 368–75.
17. Langerhorst CT, Carenini LL, Bakker D, van den Berg TJTP, De Bie-Raakman MAC. Comparison of SITA and dynamic strategies with the same examination grid. In: Wall M, Wild JM, eds. Perimetry update 1998/1999. Hague, Netherlands: Kugler Publications, 1999; 17-24.
18. Heijl A, Bengtsson B, Patella VM. Glaucoma follow-up when converting from long to short perimetric threshold tests. Arch Ophthalmol 2000; 118: 489–93.
19. Keltner JL, Johnson CA, Cello KE, Quigg JM, Kass MA, Gordton MO. Severity of the types of visual field abnormalities in the ocular hypertension treatment study (OHTS). Invest Ophthalmol Vis Sci 2000; 41 (Suppl): S84.
20. Schwartz M, Lazarov-Spiegler O, Moalem G, Yoles E. Dialog between traumatized optic nerve axons and immune cells: Implications for survival and regrowth. Invest Ophthalmol Vis Sci 1998; 39 (Suppl): S876.
21. Yoles E, Schwartz M. Degeneration of spared axons following partial white matter lesion: implications for optic nerve neuropathies. Exp Neurol 1998; 153: 1–7.
22. Schwartz M, Yoles E. Self-destructive and self-protective processes in the damaged optic nerve: implications for glaucoma. Invest Ophthalmol Vis Sci 2000; 41: 349–51.
23. Langerhorst CT, Carenini LL, Bakker D, De Bie-Raakman MAC. Measurements for description of very early glaucomatous field defects. In: Wall M, Heijl A, eds. Perimetry update 1996/1997. Amsterdam, New York: Kugler Publications, 1997; 67–73.
24. Westcott MC, Garway-Heath DF, Fitzke FW, Hitchings RH. Is conventional perimetry sufficient for the evaluation of the nasal step in glaucoma? High spatial resolution perimetry can identify scotomas not apparent on conventional Humphrey testing. Invest Ophthalmol Vis Sci 1999; 40 (Suppl): S581.
25. Rohrschneider K, Becker M, Kruse FE, Fendrich T, Völcker HE. Stability of fixation: results of fundus-controlled examination using the scanning laser ophthalmoscope. German J Ophthalmol 1995; 4: 197-202.
26. Kani K, Ogita Y. Fundus controlled perimetry. Docum Ophthal Proc Series 1978; 19: 341-50.
27. Ohta Y, Amoto TM, Harasawa K. Experimental fundus photo perimeter and its application. Docum Ophthal Proc Series 1978; 1: 351-8.