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Multicenter evaluation of tendency-oriented perimetry (TOP) using the G1 grid

M.GONZÁLES DE LA ROSA[1], J. MORALES[2], F. DANNHEIM[3], E. PAPST[4], N. PAPST[4], T. SEILER[5], C. MATSUMOTO[6], Y. LACHKAR[7], A. MERMOUD[8], C. PRÜNTE[9]

[1] University of La Laguna - Spain
[2] Texas Tech University at Lubbock - USA
[3] General Hospital Harburg, Hamburg
[4] Praxis, Hamburg
[5] University of Dresden - Germany
[6] Kinki University School of Medicine, Osaka - Japan
[7] St. Joseph Hospital, Paris - France
[8] University of Lausanne
[9] University of Basel - Switzerland

PURPOSE. *The G1-TOP program is a short automated perimetric strategy which sub-divides the G1 grid of 59 points into four sub-grids. Each point is tested only once, but each patient's response is used to modify that particular point and the surrounding ones from the remaining sub-grids. This study compared the results of the G1-TOP program with the Standard Bracketing strategy.*
METHODS. *Eleven participating institutions provided data from 213 patients (406 eyes). The main group consisted of 284 glaucomas and 55 glaucoma suspects. Other groups included 31 eyes with neurological disorders, 20 with chorioretinal lesions and 16 normal eyes. Mean age was 62.7 ± 15.4 (range 14-88) years. All subjects had previous perimetric experience and visual acuity better than 0.5. Examination included G1-Standard Bracketing and G1-TOP testing, in interchangeable order, with the Octopus 1-2-3 perimeter.*
RESULTS. *The correlation coefficient for mean defect (MD) was 0.95. Standard error (YX) for MD, square root of loss variance (LV) and individual thresholds were 1.86 dB, 1.29 dB, and 4.72 dB, respectively. Mean sensitivity values were similar (difference 0.04 ± 1.87 dB) (p>0.05). Mean duration for G1-TOP was 2.19 ± 0.26 min, while G1-Standard Bracketing took 11.51 ± 1.52 min (ratio 1/5.1, or a net reduction of 80.4%). The sensitivity of G1-TOP versus G1-Standard Bracketing was: glaucoma 77.1/78.5, glaucoma suspects 38.2/47.3, neurological disorders 87.1/87.1 and chorioretinal lesions 80.0/85.0.*
CONCLUSIONS. *The G1-TOP program gave very similar results to G1-Standard Bracketing in only 20% of the time required by the standard strategy. (Eur J Ophthalmol 2003; 13: 32-41)*

KEY WORDS. *Perimetry, Visual field, Glaucoma, Threshold*

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INTRODUCTION

A well-known problem of standard automated perimetry is that it takes too long, causing patients fatigue and making them reluctant to take the test, and giving less worthwhile results (1). Attempts to shorten testing strategies have been made but no significant decrease in time was achieved until recently. New ultra-short perimetric strategies such as tendency-oriented perimetry (TOP) (2) and the Swedish inter-

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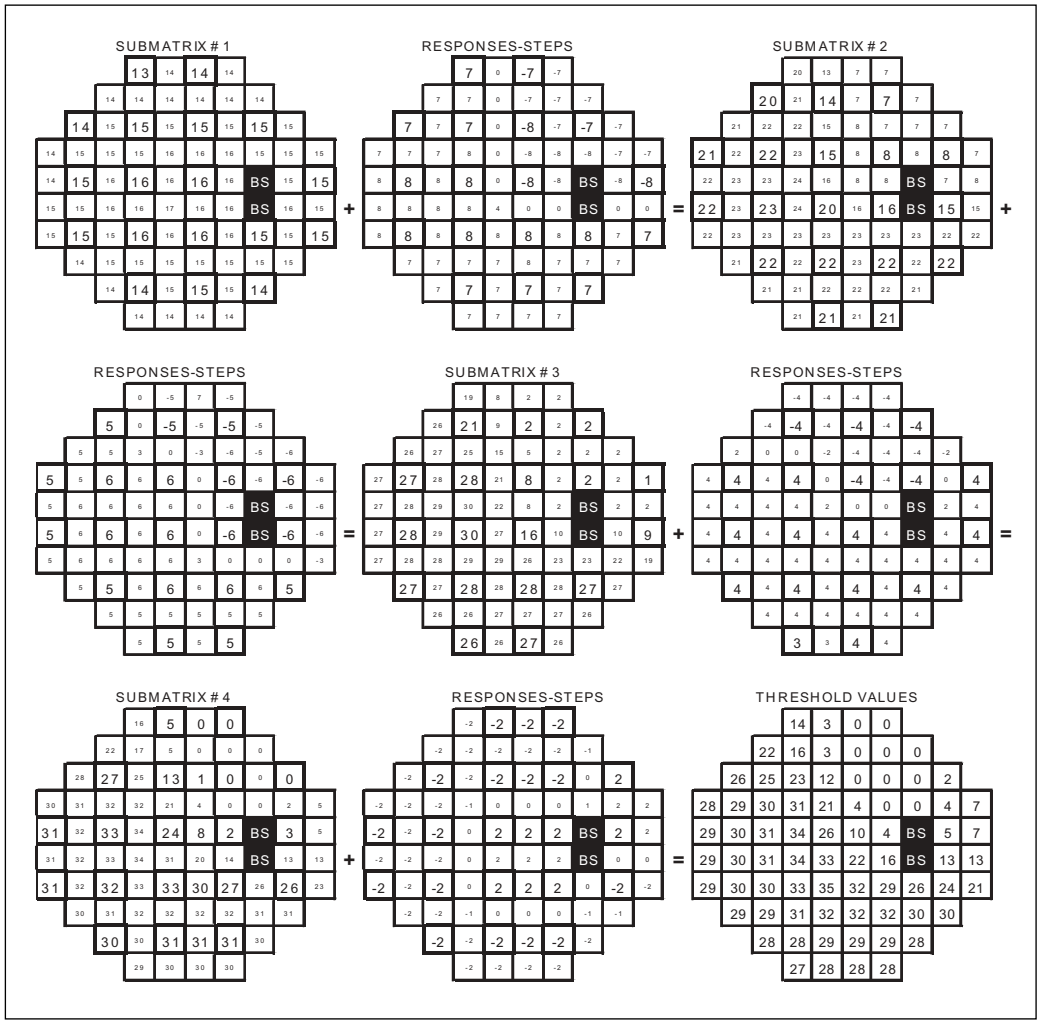

Fig. 1 - *Example of the progression of the sequential examination of the four submatrixes using the TOP-32 algorithm.*

active threshold algorithm (SITA) (3) have attained significant time saving taking, in the same group of patients, 2.5 min for TOP, 8.7 min for SITA Standard and 5.7 min for SITA Fast (4).

In clinical studies TOP has been shown (2, 5-7) to give an estimate of the thresholds at the central 30 degrees of the visual field (Octopus grid 32 with 76 points) with satisfactory sensitivity, specificity, reproducibility and correlation with Standard Bracketing (SB) strategy results. An assessment on a small group of patients indicated that the strategy could also be applied to irregular grids of test points (8). Its usefulness has also been proved in the determination of other peripheral visual functions such as the critical fusion frequency (9, 10), spatial resolution, contrast and motion perception (11).

The purpose of this study was to compare the results of TOP and Standard Bracketing perimetry (SB) in a large group of patients utilizing an optimized grid for glaucoma (G1).

METHODS

The main characteristics of the TOP algorithm have been described (2, 7). In short, the procedure involves the successive examination of four sub-matrixes of points that are intercalated with each other. After each of the four steps, the patient's answer to one point is used to estimate the thresholds at that point and at surrounding points by a linear interpolation procedure (Fig. 1). Since the G1 matrix is irregular, some adjustments were necessary to adapt the TOP strategy, as follows: 1) Addition of ten extra points to the G1

grid to ensure homogeneous distribution of points in the four sub-matrixes (Fig. 2). These points were mainly used for intermediate interpolation during the test, and were excluded at the end of the examination. Thus, just the results of those points normally used in the G1 grid are shown. 2) Utilization of non-linear interpolation by identifying the three points closest to the one being tested (Fig. 3).

Eleven participating institutions provided data from 213 patients (406 eyes). The majority of eyes had a diagnosis of glaucoma (284 eyes) or were glaucoma suspects (55 eyes). Since clinicians performing automated perimetry are not only looking for glaucomatous changes, but are also interested in detecting concomitant pathologies, three other groups of eyes with neurological disorders (31 eyes), chorioretinal lesions (20 eyes) and normal individuals (16 eyes) were examined. There were 95 males and 118 females with an age range of 14-88 years (mean 62.7 ± 15.4).

Inclusion criteria were visual acuity better than 0.5 and previous perimetric experience. Diagnosis of glaucoma required characteristic optic nerve excavation and previous visual field abnormalities (with SB) consisting of reproducible visual field defects, significant asymmetries from the contra-lateral eye or confirmed evolution; glaucoma suspects were diagnosed on the basis of elevated intraocular pressure (IOP) in the presence of previously normal visual fields (with SB). Exclusion criteria included previous intraocular surgery, other ocular pathology, reliability indices outside normal limits (i.e. more than 30% false-negative and false-positive responses), etc. This study was conducted in accordance with the Declaration of Helsinki* and informed consent was obtained from each participant.

All subjects were examined consecutively with the G1-SB and the G1-TOP programs, using the Octopus 1-2-3 perimeter (Interzeag AG, Schlieren-Zürich, Switzerland). All patients used their distance refractive correction which is mandatory for this instrument. A minimum resting period of 30 minutes was required between experimental and standard tests. The order of testing was interchangeable, starting with either G1-TOP or G1-SB (forming two groups of half the patients). Both eyes were included when possible since the patient sample was big enough to avoid individual statistical influences.

Statistical analysis included correlation coefficient for global indices (r), estimation error of each regression equation (YX standard errors), distribution histo-

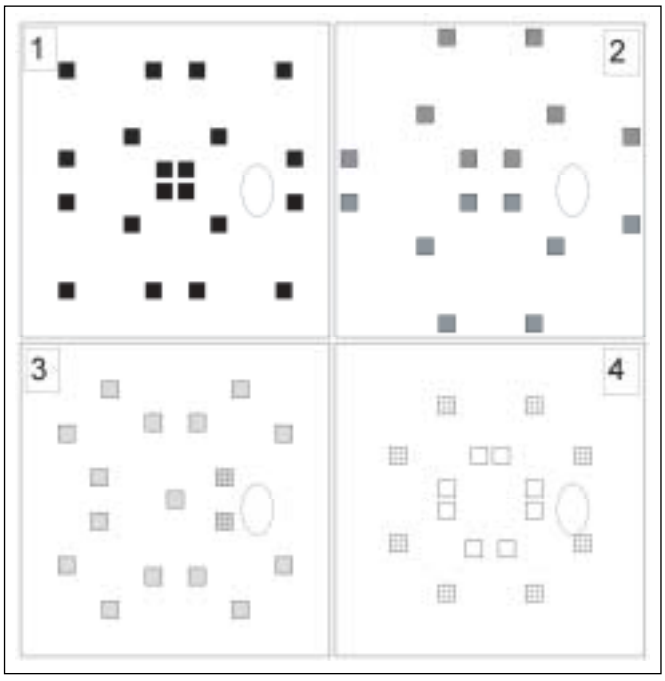

Fig. 2 - *Points included in the four phases of program G1-TOP. Two extra points are added to phase III and eight to phase IV.*

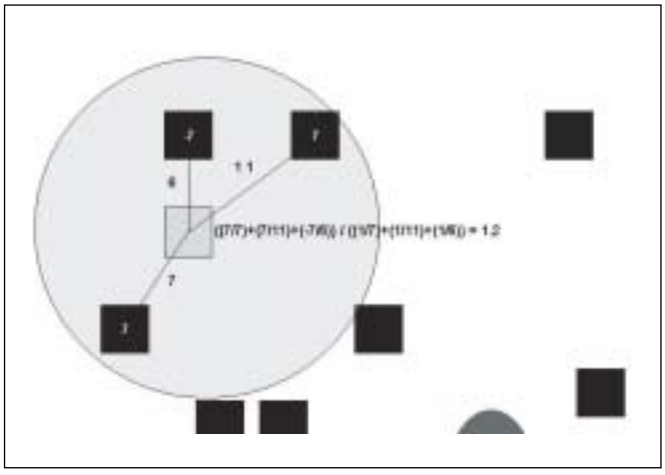

Fig. 3 - *Calculation of vector magnitude for a non-examined point based on the magnitude values and distances from the closest points examined.*

**All procedures in this study were performed in accordance with the ethical standards leid down in the 1964 Declaration of Helsinki.*

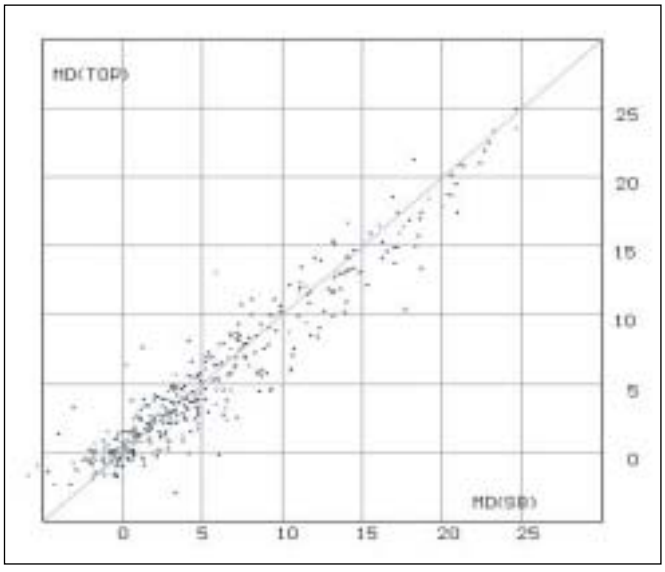

Fig. 4 - *Scattergrams for the MD values.*

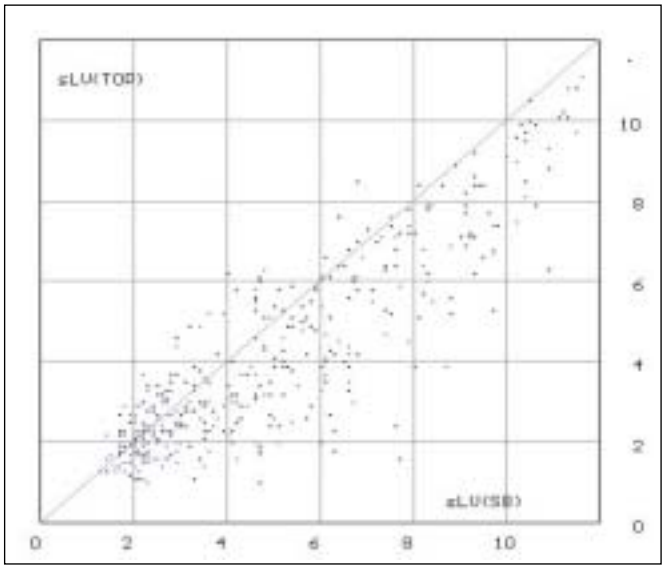

Fig. 5 - *Scattergrams for the sLV values.*

grams for point-by-point comparison, two-tailed paired t test and sensitivity/specificity analysis. For sensitivity/specificity cut-off points of normality, a visual field was classified as abnormal if there were four or more points with a deviation more than 5 dB higher than the age-expected value, with at least two of them contiguous. This criterion was based on a modification of the one described in a article dealing with perimetric screening in glaucoma (12), adapted in our study to deal with any type of visual field pathology, and a smaller group of points.

RESULTS

A high correlation was found between the global indices of both strategies and with regard to point- by-point analysis (Figs. 4, 5 and Tab. I). The correlation coefficient for the MD was 0.95. Standard errors (YX) for MD, square root of LV (sLV) and individual thresholds were 1.86, 1.29, and 4.72 dB respectively. sLV was 18.3% lower with TOP than with the SB procedure. The subjective appearance of the gray scales was similar in most cases (Fig. 6).

Both programs showed an increase in sLV directly proportional to the increase in MD up to the 15-18

TABLE I - CORRELATION COEFFICIENT (r) AND STANDARD ERROR (S.E.YX) FOR TOTAL MEAN SENSITIVITY, MEAN SENSITIVITY PER QUADRANT AND TOTAL THRESHOLD FOR THE WHOLE SAMPLE IN EACH STRATEGY AND SUBGROUP

	All cases		**Glaucoma**		**Glau. suspect**		**Neurological**		**Chorioretinal**		**Normal**	
	r	**S.E. (YX)**	**r**	**S.E. (YX)**	**r**	**S.E. (YX)**	**r**	**S.E. (YX)**	**r**	**S.E. (YX)**	**r**	**S.E. (YX)**
MD	0.95	1.86	0.96	1.74	0.66	1.79	0.96	1.74	0.87	3.13	0.61	1.29
MD (NS)	0.94	2.64	0.95	2.66	0.51	2.05	0.96	5.52	0.86	3.48	0.48	1.87
MD (NI)	0.94	2.42	0.95	2.26	0.66	2.17	0.94	2.46	0.84	4.14	0.61	1.80
MD (TS)	0.94	2.20	0.94	2.24	0.68	1.83	0.96	2.26	0.91	2.73	0.70	0.91
MD (TI)	0.93	2.29	0.93	2.25	0.64	2.19	0.96	2.21	0.84	3.06	0.54	1.65
sLV	0.89	1.29	0.89	1.29	0.54	1.31	0.93	1.13	0.73	1.47	0.56	1.33
Thresholds	0.82	4.72	0.82	4.41	0.55	3.63	0.86	4.57	0.74	5.33	0.47	3.13

MD level at which point a decrease in sLV was observed (Figs. 7, 8). The correlation coefficient between MD and sLV for MD values less than 10 dB was 0.75 for G1-TOP and 0.55 for G1-SB ($p<0.001$). For MD values less than 18 dB, correlation coefficients between MD and sLV were 0.83 for G1-TOP and 0.72 for G1-SB ($p<0.001$).

Mean sensitivity was slightly higher with G1-TOP (difference 0.04 ± 1.87 dB) ($p>0.05$) (Fig. 9), but the difference varied depending on the location of the point. An inverse relationship was noted with G1-TOP, showing sensitivity 0.35 dB higher in points 15 degrees away from fixation and with G1-SB levels 0.32 dB higher within the central 15-degrees field.

The global distribution of local defects, calculated for the whole sample, showed minimal differences (Fig. 10) which, however, were not equal for various levels of pathology. The Octopus terminology uses negative signs for deviations corresponding to thresholds higher than the normal mean. For points with negative deviations, the SB strategy produced more tests with "hyper-normal" results than TOP (Fig. 11). Deviations corresponding to thresholds lower than the normal mean are expressed with a positive sign in Octopus. This way, between 0 and 9 dB both programs produced an equivalent defect level in general. For points with a deviation higher than 9 dB, TOP resulted in smaller defects, with a maximal difference of 3-4 dB for points with deviations between 15 and 20 dB. For points with big deviations (deep scotomas) both programs gave similar results (Fig. 11). These differences, although not distributed equally among the four sub-grids, did not get larger. They were minimal for the first sub-grid, increased for the second one, decreased again for the third one and increased for the fourth one.

Case-by-case comparison of local deviations and the standard error of regression analysis gave a predictable difference between both systems. This difference increases gradually, peaking for cases with MD between 10 and 20 dB and decreasing after that (Fig. 12).

Sensitivity comparison of G1-TOP and G1-SB for the different sub-groups gave the following values: glaucoma 77.1/78.5, glaucoma suspects 38.2/47.3, neurological disorders 87.1/87.1 and chorioretinal lesions 80.0/85.0. Specificity comparison for the whole sample was 87.5/62.5.

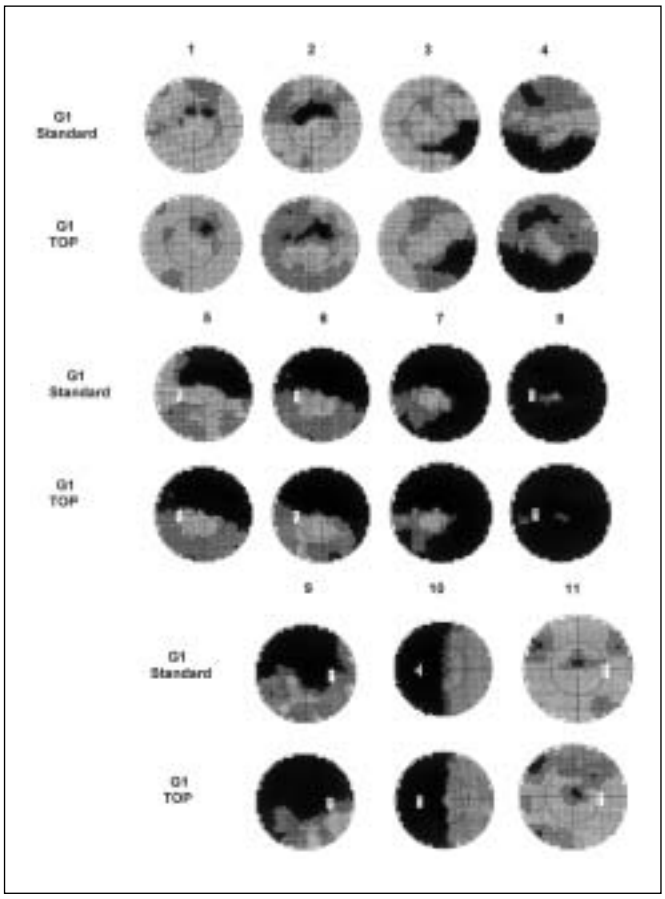

Fig. 6 - *Visual field examples: Field pairs showing the grayscale results of both strategies in the same patient. Numbers 1-8: Examples from early to advanced glaucomatous visual field damage. Number 9: A patient with optic nerve pathology showing central scotoma. Number 10: A patient with retrochiasmatic disease, showing a hemianopic defect. Number 11: A patient with retinal pathology, showing a small central scotoma.*

The mean duration of the test for G1-TOP was 2.19 ± 0.26 min, while G1-SB took 11.51 ± 1.52 min ($p<0.001$). The time ratio of G1-TOP to G1-SB was 1/5.1, amounting to a net reduction of 80.4% when using G1-TOP. An average of 312 ± 42 stimuli presentations was necessary for the SB strategy, while 70.7 ± 3.0 were enough for the TOP program ($p<0.001$).

DISCUSSION

Similar to other perimetric strategies to shorten testing time, TOP obtains threshold sensitivity values which are slightly higher and MD values lower than those

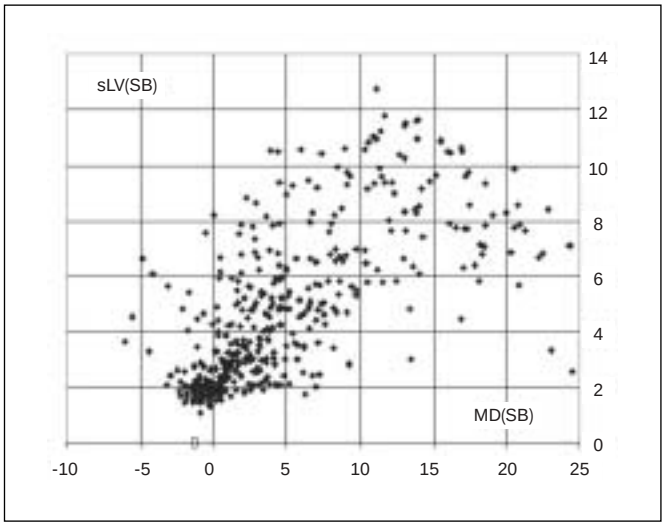

Fig. 7 - *Scattergrams for MD in relation to sLV in Standard Bracketing examinations.*

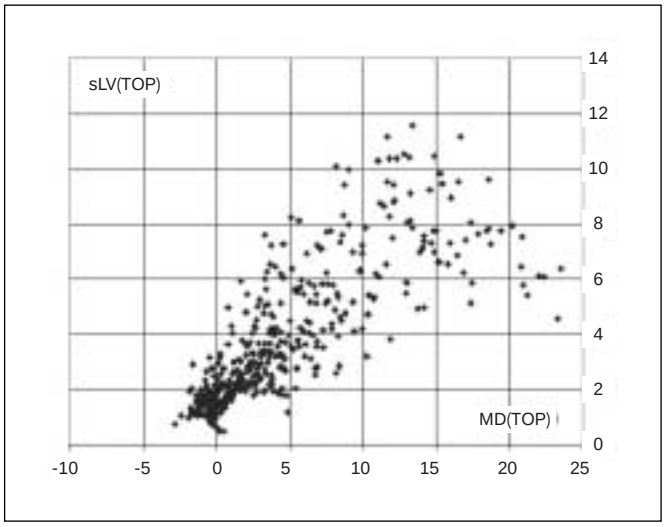

Fig. 8 - *Scattergrams for MD in relation to sLV in TOP examinations.*

obtained with the conventional strategy (7, 13-17). These differences were first attributed to an error of measurement of the shorter strategy. However, nowadays the origin of the difference is thought to lie in a reduction of the "fatigue effect" which falsely lowers the threshold sensitivity in a long perimetric test (1, 18, 19).

The differences between both strategies with regards to MS, however, were smaller than in a previous comparison of TOP-32 and Standard-32 strategy (2, 7). The difference did not reach statistical significance, perhaps because the higher TOP values in the periphery were counteracted by the smaller values in the center of the field. The fatigue effect tends to become more noticeable in the most peripheral points (1, 18) and the 32 grid examines more eccentric points on average than the G1 grid.

Another difference was that SB had more hyper-normal thresholds ("white scotomas") than TOP. This could be explained by the intrinsic differences between algorithms. As a result of its method for threshold calculation, TOP has a maximal threshold value equal to 18/16 of the normal mean. In other words, with TOP the maximal threshold cannot surpass 12.5% of the expected normal value and the maximal hyper-normal deviation is 3.5 dB. However, numerous cases of "white scotomas" with the SB technique were located above the 5% level of the Bebie defect curve. This usually results from a high level of false positive responses.

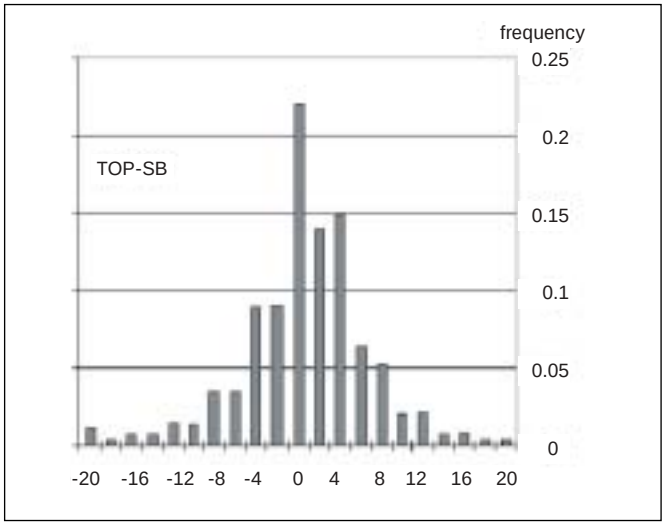

Fig. 9 - *Point-by-point analysis: Histogram of frequency with the threshold differences between G1-TOP and G1-Standard Bracketing thresholds.*

The characteristics of the present sample permitted a careful estimate of sensitivity, showing equivalent levels for TOP and SB. Although the number of normal cases was small in this sample, the specificity levels are similar to those obtained in larger studies (7, 20).

When using TOP on a simulation program with no fluctuation or fatigue effect, there was no reduction

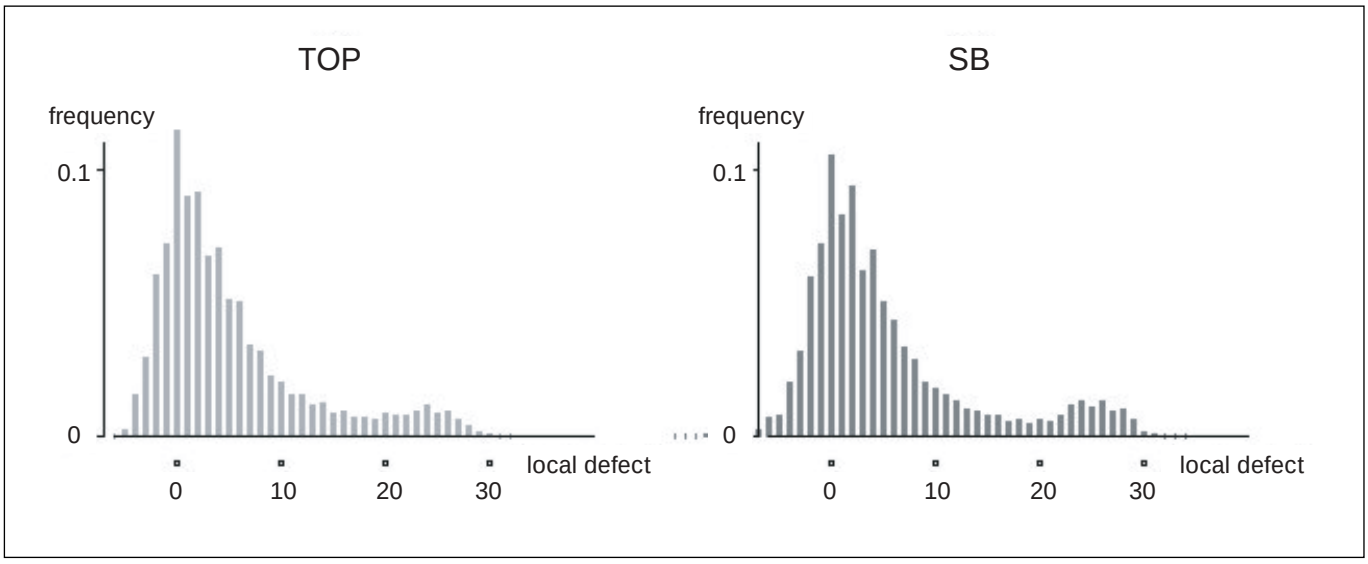

Fig. 10 - *Histogram of frequencies of local defects in the whole sample, both strategies.*

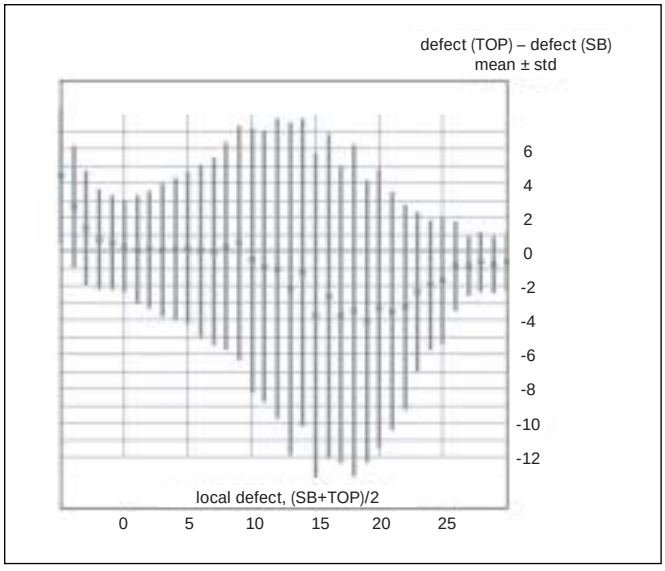

Fig. 11 - *Mean differences ± standard deviation (TOP minus Standard Bracketing defect) for the different levels of local defect [(TOP+SB)/2].*

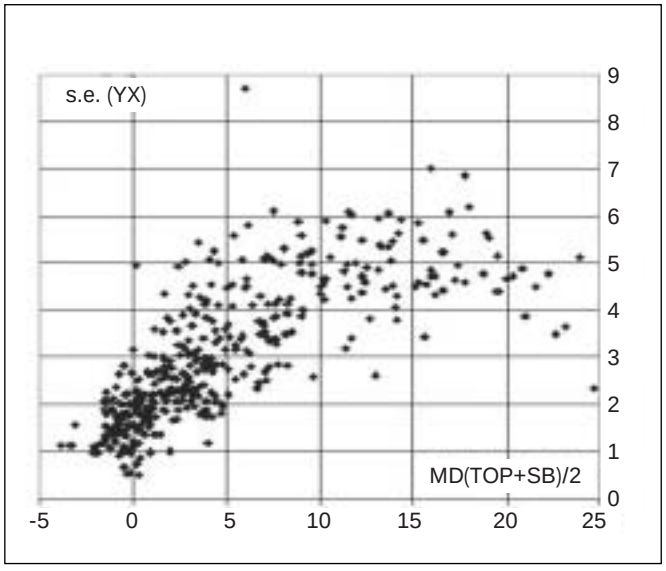

Fig. 12 - *Relation between the MD mean value [(TOP+SB)/2] and the standard error of the regression equations obtained by comparison of the local deviations for each type of examination.*

of defect for TOP as compared with SB, in the range of deviations between 10 and 20 dB. This may be linked to these two factors or to the better correlation between MD and sLV with the TOP strategy than with SB. The relation between both indices has been described (21), indicating that the increase of fluctuation and the irregularity of the visual field are directly linked to the progression of most of the abnormalities.

In view of the lateral influences used by TOP for calculating the threshold, it is obvious that this approach smoothes scotoma edges. This leads to a slight reduction of the LV, not affecting the MD. The same has been described for other short strategies, such as Dy-

namic (23). The fact that TOP gives LV values lower than the SB might suggest that TOP underestimates local visual field defects (24). However, the LV reduction should not nfluence the diagnosis if it is known and interpreted correctly, since it corresponds to a proportional displacement of values, as shown in Figure 5. In contrast with an earlier opinion, TOP has been described as having 94.4% sensitivity in the diagnosis of early glaucoma when an abnormality criteria of LV higher than 6dB^2 is used (5). A diffuse loss of threshold sensitivity, which would reduce the MD value without any increase in the LV index, is uncommon or temporary, and is generally attributed to a "pre-retinal origin" or media abnormalities such as extreme miosis, cataract, etc. (25).

In cases with normal MD, TOP gives fewer cases with high LV than the SB strategy (Figs. 7, 8). This could be due to TOP having low sensitivity when detecting cases with normal MD and high LV or to a marked tendency of SB to give high LV values in normal cases. Sensitivity and specificity values previously obtained (7) and the sensitivity levels found in this study make us consider the second option more probable. The fatigue effect and the "white scotomas" could contribute to the high levels of LV found with SB in elderly subjects. Age is certainly related with a fatigue effect, especially in long perimetric examinations (18). Defects increase with age as do threshold fluctuation (26), physiological reflexes and other biological functions. The fatigue effect increases with age in normal subjects as well as in individuals with pathological fields (19).

Possible causes of the differences in individual threshold values with the two strategies remain speculative. It could be argued that the last sub-matrixes are responsible, and this would be borne out by our observation that the first sub-matrix, which corresponds to the largest steps, seems to give very similar results in both procedures. These differences also seem more noticeable in the later sub-matrixes. However, when analyzing the results for each submatrix, the differences do not seem to present as a single factor, since their amplitude is not directly proportional to the order of the sub-matrix. Other factors may explain the differences, such as the proximity of the specific points tested to the horizontal and vertical meridians, the direction of the ganglion cell axons, and other issues related to the specific location of the point in question.

However, the data does suggest that TOP gives information that represents reality as accurately as SB. Its sensitivity, specificity or reproducibility levels are similar to SB (7, 27). Point-by-point comparison shows a (YX) standard error of 4.72 dB for both strategies, which is very similar to the one obtained when testing the same patient twice with the SB strategy (4.47dB) (19). There were no significant differences between the numbers of deviated points, at different levels of probability, with the two procedures (7).

It has been recommended (28) that perimetric variability should be reduced as much as possible to avoid the fatigue effect having an unpredictable and irregular influence on the results. TOP is currently the fastest program available to estimate the threshold sensitivity of the visual field (29); it can be used to examine children (30), and it is the most constant as regards the time needed. Previous procedures, based on reducing the number of examination points, have managed to make ultra-short, useful estimates of the main perimetric indexes (31-33). However, they have not been clinically accepted because of limitations in identifying the position of the defects (34), although many of the points raised against them are debatable (35). However, TOP manages, in a similar time, to give correct topographic information, based on the topographic relations in glaucomatous damage (36).

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Reprint requests to:
Manuel González de la Rosa, MD
25 de Julio, 34. 38004
Santa Cruz de Tenerife, Spain
mgdelarosa@jet.es

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