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Comparison of Swedish interactive threshold algorithm and full threshold algorithm for glaucomatous visual field loss

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PURPOSE. *To compare the prevalence of visual field loss, the sensitivity distribution, and the size and depth of glaucomatous visual field defects using the standard full threshold (FT) and the Swedish interactive threshold algorithm (SITA) standard (SS) procedures in patients with early or suspected glaucoma.*

METHODS. *Automated perimetry findings were retrospectively evaluated in 53 patients (105 eyes) with early or suspected glaucoma.*

RESULTS. *The number of eyes judged to have glaucomatous visual field loss by SS (48 eyes) was significantly larger than what was found with FT (35 eyes), and 70 eyes were classified as pre-perimetric glaucoma. In these 70 eyes, there were many locations where the sensitivity was significantly higher with SS than with FT (intrasubject difference), and SS had less intersubject variability than FT at most locations. The cumulative decibel scores at the region of glaucomatous defects were larger with SS (206.2±103.3 dB) than with FT (162.1±87.5 dB) ($p=0.02$), which indicated that the depth of defects measured by SS was shallower than that by FT. The sizes of defects were significantly larger with SS (11.2±5.6) than with FT (9.7±5.1) ($p<0.05$).*

CONCLUSIONS. *Glaucomatous defects were measured as being significantly shallower and larger with SS than with FT. In addition, the prevalence of visual field defect was higher with SS according to some of the criteria for glaucomatous visual field defects. These results might be related to the fact that SS strategy has a lower variability and to the Bayesian statistical properties of the SITA algorithm. (Eur J Ophthalmol 2007; 17: 196-202)*

KEY WORDS. *Full threshold, Glaucomatous visual field defects, Swedish interactive threshold algorithm, Variability*

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INTRODUCTION

Fatigue is a possible cause of decreased accuracy on perimetry testing (1-3). The fatigue effect might be reduced by shortening the testing time with FASTPAC strategy using a Humphrey Field Analyzer (HFA, Humphrey/Zeiss Systems, Dublin, CA), but FASTPAC reportedly has a higher measurement error and is less accurate or reliable than the full threshold (FT) strategy (4).

Recently, the Swedish interactive threshold algorithm (SITA), a new method for determining thresholds using an HFA, has been developed (5, 6), and it does not decrease accuracy even with its shortened testing time (7, 8). Using SITA, threshold and its measurement errors are continu-

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ously estimated during the test. As soon as measurement errors decrease to a certain level, the threshold value is considered to be of sufficient accuracy and testing is terminated. Therefore, testing time with SITA is generally shorter than with the FT method. The length of the test is also shortened by the Bayesian logic (9, 10) and by the elimination of catch trials that determine the frequency of false positive answers (6). Bayesian logic is a kind of statistical analysis that is applied to quantify a situation with an uncertain outcome by determining its probability using the knowledge of prior events to predict future events. This logic is applied to some of the modern proprietary fast threshold strategies (e.g., SITA). Especially, the improved accuracy of SITA for detecting a glaucomatous defect by applying models of normal and glaucomatous visual fields and the other responses obtained during testing is important (5).

Generally, visual field analysis and estimation of the optic disc's appearance are critical indicators for diagnosing and managing glaucoma, and FT has been the gold standard for automated perimetry testing. SITA standard (SS) should be as accurate as the FT when used for the diagnosis of glaucoma. In studies comparing threshold, mean sensitivity, and test-retest variability between SS and FT (8, 11-20), mean sensitivity and mean deviation (MD) are higher in SS than in FT. However, especially in cases of mild visual field defects, differences have been reported between the two methods regarding the characteristics of glaucomatous visual field defect even if the available data are not in agreement: in fact the defects were found to be deeper (20), narrower or wider, and shallower with SS than with FT (14, 17). Recently, the accuracy of SS for detecting visual field defects has been investigated by comparing SS and FT with regards to sensitivity and specificity (8), the size, depth, and severity of visual field defect (14), and the ability to detect depressed points at the initial test (21). Furthermore, there are reports that SS has narrower normal limits of sensitivity than FT, which means that SS should have lower variability (11, 13, 15, 19). Consequently, the results from SS estimation may differ from FT method results (13), and it is not yet known whether the two measurement results can be evaluated using the same criteria.

In the present study, the prevalence, sensitivity distribution, and size and depth of glaucomatous visual field defects were compared using FT and SS in patients with early or suspected glaucoma.

METHODS

The subjects were 53 patients (105 eyes) with a mean age of 56.1±9.6 years (mean ± standard deviation) who visited the Glaucoma Service of Jikei University Hospital due to early or suspected glaucoma whose MD value was not worse than –10 dB under FT testing. In the present study, patients with suspected glaucoma included those with past history of ocular hypertension, those with glaucomatous optic nerve disorder (e.g., shape change and thinning of the neuroretinal rim, localized and diffuse deepening and widening of the optic cup, and retinal nerve fiber layer defects), and those who had open angle glaucoma in the fellow eye. These subjects were required to be experienced visual field takers, having been tested on two or more prior occasions using the HFA. The study was conducted in accordance with the Declaration of Helsinki, with written informed consent obtained from all subjects before the start of this study. Eyes were examined within a 3-month period in random order by both SS and FT using program 30-2 of the HFA II 750. Visual fields were excluded if any abnormal reliability factor was present (fixation loss >20%, false-positive rate >33%, or false-negative rate >33%).

Patients were ineligible if they had a history of diabetes or other systemic disease, ocular disease other than glaucoma, ocular surgery, or were receiving any medication known to affect the visual field. In an initial group of 106 eyes, one patient had advanced open angle glaucoma in one eye, and the eye was excluded from further analysis.

The purpose of this study was to compare the prevalence of visual field loss, sensitivity distribution, and size and depth of glaucomatous visual field defects between FT and SS.

Prevalence of visual field loss

In this study, a glaucomatous visual field defect had to meet one of the following three minimal criteria (22): the results of the glaucoma hemifield test (GHT) outside normal limits, pattern standard deviation (PSD) with p values less than 5%, or a cluster of three or more non-edge points except the two points at the far nasal positions having a nerve fiber bundle pattern in the pattern deviation (PD) plot in a single hemifield (superior or inferior) with p values less than 5% and at least one at less than 1%. The prevalence of PSD abnormal, clusters of depressed points, and GHT outside normal limits were compared among the two algorithms.

Sensitivity distribution

Of all subjects having an early or suspected glaucoma, pre-perimetric glaucoma was classified as those eyes that did not met any of the minimal criteria using FT strategy. Using the visual field test results of FT and SS in pre-perimetric glaucoma, intrasubject differences (the difference in mean sensitivities between patients) and inter-subject variability (the ratio [SS/FT] of standard deviations at each measuring location) were evaluated as discussed by Wild et al (19). The standard deviation of the mean sensitivity at each test location (i.e., the between-subject variability) for SS expressed as a ratio of that of FT at the corresponding location.

Size and depth of glaucomatous visual field defects

In the present study, a region of glaucomatous defects referred to a region of clusters in the PD plot that met one of the minimal criteria for glaucomatous visual field defects during FT testing: cluster of three or more non-edge points except the two points at the far nasal positions having a nerve fiber bundle pattern in the PD plot in a single hemifield (superior or inferior) with p values less than 5% and at least one at less than 1%. Depth was determined by adding the threshold values of the points identifying the cluster in the PD plot. Size was determined by counting the number of points identifying the cluster in the PD plot. In addition, the depth of abnormal points in clusters detected with FT was compared with the depth of the same points determined with SS.

Data obtained at all the test locations including the edge locations were used for analyzing the sensitivity distribution, and those obtained at the edge locations except the two points at the far nasal positions were excluded for other analyses. The results were analyzed through paired *t* tests and correlation analyses using Intercooled Stata 5.0 (Stata Co., College Station, TX). p Values of less than 0.05 were considered to be statistically significant.

RESULTS

Prevalence of visual field loss

The prevalence of visual field defect according to the minimal criteria for abnormality was significantly higher by SS (45.3%, 48 eyes) than by FT (33.0%, 35 eyes) (Tab. I) ($p<0.05$). Furthermore, the prevalence of criteria 2 and 3 were significantly higher under SS testing than with FT ($p<0.05$). There was no significant difference between the two techniques using the GHT criterion. The mean MD value was –3.20±2.41 dB (± standard deviation, range: –9.78 to +0.48 dB) with FT and –2.80±2.40 dB (range: –9.21 to +2.04 dB) with SS.

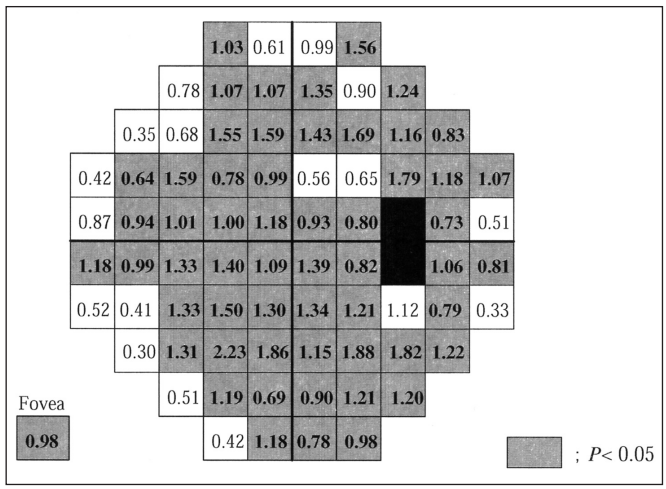

Fig. 1 - *The differences in mean sensitivity (i.e., intrasubject differences) at each measuring location between Swedish interactive threshold algorithm standard and full threshold for a normal visual field. Data are given as decibels.*

Sensitivity distribution

Seventy eyes were classified as pre-perimetric glaucoma because their visual field test results by FT met none of the minimal criteria. Figure 1 shows the difference between the sensitivities estimated by SS and those estimated by FT as a function of stimulus location (i.e., the intrasubject difference) in these 70 eyes. We observed many locations where the sensitivity was significantly higher with SS than with FT ($p<0.05$). Table II shows the mean sensitivity of the whole visual field and at each eccentricity in pre-perimetric glaucoma. Mean sensitivity with SS was higher than with FT by approximately 1 dB at any eccentricity.

Figure 2 shows the ratio (SS/FT) of standard deviations (intersubject variability) at each test location in the pre-perimetric glaucoma. The intersubject variability was smaller with SS than with FT at many test locations other than the edge locations and those adjacent to the blind spot.

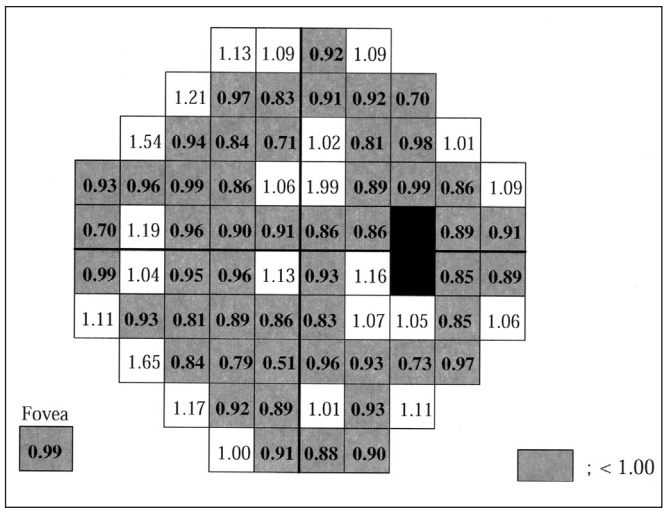

Fig. 2 - *The standard deviation of mean sensitivity at each measuring location (i.e., intersubject variability) for Swedish interactive threshold algorithm standard expressed as a ratio of full threshold's standard deviation at the corresponding location. Data are given as ratio.*

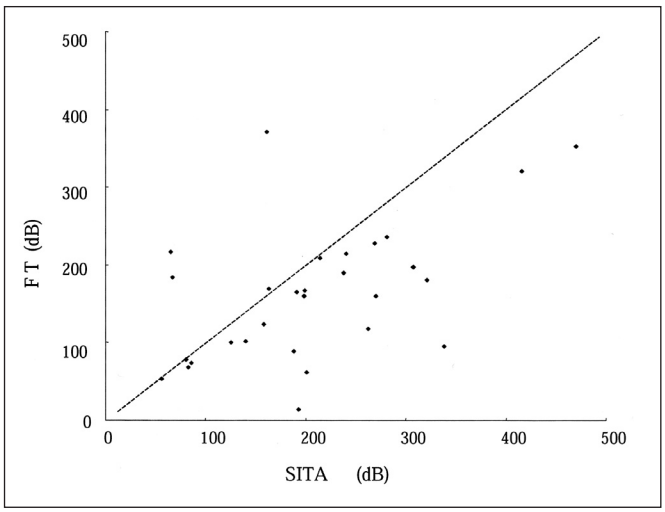

Fig. 3 - *Total sensitivity in the regions of visual field defects where clusters were formed with full threshold and Swedish interactive threshold algorithm standard (dB) (y = 0.45x + 69.6, r2 = 0.28, p<0.001, n=29).*

Size and depth of glaucomatous visual field defects

Among 105 eyes, the number of eyes detected to have clusters in the PD plot with both FT and SS was 29 (Tab. III). Figure 3 shows a scattergram comparing the depth of glaucomatous defects between FT and SS in these 29 eyes. The number of eyes detected to have cluster with FT was 32 (Tab. III). Figure 4 shows a scattergram comparing between the depth of abnormal points in clusters detected with FT and the depth of the same points determined with SS in these 32 eyes.

There was a statistically significant correlation between the cluster depths with FT and those with SS (Fig. 3), the depth of the same points determined with SS (Fig. 4). There was significant difference between the depth of abnormal points in clusters detected with FT (157.7±85.1 dB) and that of the same points determined with SS (183.5±86.6 dB) ($p<0.01$) (Fig. 4). The cumulative decibel scores at the regions of glaucomatous defects are larger, which indicates that the depth of defects measured is shallower. Therefore, the depth of the same points determined with SS was significantly shallower than the depth of abnormal points in clusters detected with FT.

As shown in Table IV, the cumulative decibel scores at the region of glaucomatous defects were significantly larger (i.e., the glaucomatous defects [depth] were measured shallower) with SS (206.2±103.3 dB) than with FT

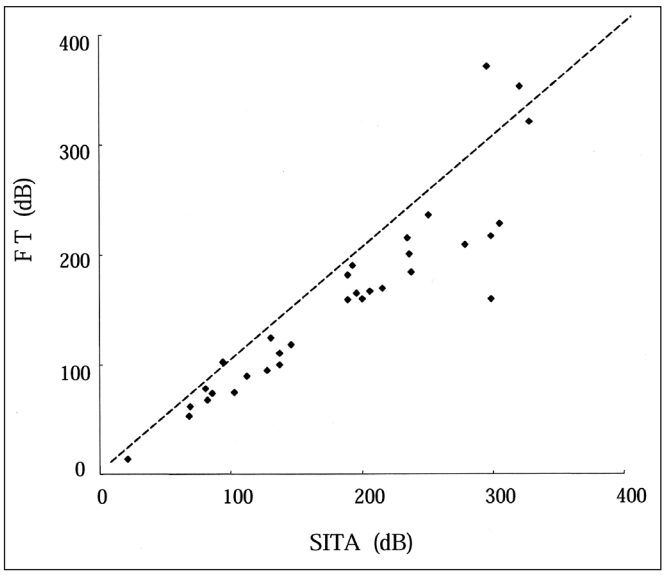

Fig. 4 - *Total sensitivity in clusters detected with full threshold was compared with the depth of the same points determined with Swedish interactive threshold algorithm standard (dB) (y = 0.90x – 4.8, r2 = 0.82, p<0.001, n=32).*

(162.1±87.5 dB) in 29 eyes ($p=0.02$).

The number of abnormal points identified in the cluster in the PD plot was significantly more with SS than with FT: this means that the sizes of defects were significantly larger with SS than with FT ($p<0.05$).

In addition, the depth of abnormal points in clusters de-

TABLE I - THE PREVALENCE OF VISUAL FIELD DEFECT

Basis of abnormality	FT, 35 (33.3)	SITA, 48 (45.7)	p<0.05*
PSD	25 (23.8)	34 (32.4)	<0.05*
PD cluster	32 (30.5)	45 (42.9)	<0.05*
GHT	32 (30.5)	33 (31.4)	0.82

Data are n (%). N=105.
*The prevalence of SITA higher than of FT.
FT = Full threshold; SITA = Swedish interactive threshold algorithm; PSD = Pattern standard deviation; PD = Pattern deviation; GHT = Glaucoma hemifield test

TABLE II - MEAN SENSITIVITY IN PRE-PERIMETRY GLAUCOMA

Eccentricity	SITA	FT	SITA-FT
3°	32.6 (1.6)	31.5 (1.7)	1.1
9°	31.3 (2.2)	30.3 (2.0)	1.0
15°	29.7 (2.5)	28.2 (2.7)	1.5
21°, 27°	27.5 (3.1)	26.6 (3.1)	0.9

SITA: 28.6±2.4 dB; FT: 27.6±2.5 dB; p<0.05.
dB = Average (standard deviation).
SITA = Swedish interactive threshold algorithm; FT = Full threshold

TABLE III - THE INCIDENCE OF THE CLUSTERS

Cluster	SITA (+)	SITA (–)	Total
FT (+)	29 (27.6)	3 (2.9)	32 (30.5)
FT (–)	16 (15.2)	57 (54.3)	73 (69.5)
	45 (42.9)	60 (57.1)	

TABLE IV - SIZE AND DEPTH OF GLAUCOMATOUS VISUAL FIELD DEFECTS (CLUSTERS)

Cluster	FT	SS	p
Size (no. of points)	9.7±5.1	11.2±5.6	<0.05*
Depth (dB)	162.1±87.5	206.2±103.3	0.02*

Data are mean ± SD. N=29.
*SS defects significantly larger and shallower than FT.
FT = Full threshold; SS = Swedish interactive threshold algorithm standard

tected with FT was compared with the depth of the same points determined with SS in 32 eyes. The depth of the same points determined with SS (183.5±86.6 dB) was significantly shallower than the depth of abnormal points in clusters detected with FT (157.7±85.1 dB) (p<0.01).

DISCUSSION

In this study, the prevalence of visual field defect according to the criteria for minimal abnormality was significantly higher when testing with SS than with FT (Tab. I).

The depth of the glaucomatous defects on the PD plots was significantly shallower with SS than with FT, and the sizes of the defects were significantly larger with SS than FT (Tab. IV).

Regarding the difference in sensitivity when testing the normal visual field, reports indicate that SS has higher mean sensitivity and MD values (approximately 0.7–1.9 dB) than FT (12, 13, 18, 19), and higher sensitivity of the whole visual field in cases of glaucoma (8, 11, 14, 16-18, 20). In the present study, intrasubject difference in 70 eyes which were classified as pre-perimetric glaucoma was significantly greater for SS at many locations (Fig. 1). This means that sensitivities of a visual field test by SS are higher than by FT at many locations.

The mean sensitivity of the pre-perimetric glaucoma, both over the whole field and at each eccentricity, was higher with SS than with FT by approximately 1 dB (Tab. II). These results are similar to many previous reports (12, 13, 15, 18). However, other studies have also reported more varied results regarding regions of glaucomatous defect; e.g., the region is deeper (20), narrower or wider, and shallower with SS than with FT (14, 17).

A study shows that both SS and FT have excellent sensitivity and specificity for the minimal criteria for glaucomatous visual field defect (8). On the other hand, when using different criteria to classify an abnormality, our results, which are in agreement with other authors (14), showed that the prevalence of visual field defect was significantly higher when testing with SS than with FT. Therefore, the detection of a glaucomatous visual field defect by SS and FT might differ depending on the criteria used to classify the glaucomatous defect.

In this study, many patients were judged to have pre-perimetric glaucoma by FT, but glaucomatous visual field by SS according to the minimal criteria for abnormality. Heijl et al (15) describe that shallow defects, which may be within the range of normal variability with FT, would be clinically significant with SS since SITA normal limits are significantly narrower than FT limits. This might be one of the reasons why many patients were judged to have glaucomatous visual field by SS in this study. SS had less intersubject variability than FT in 70 eyes which were classified as pre-perimetric glaucoma. This was consistent with the results of other studies (11, 13, 15, 19). As shown in Figure 2, it was not clear why intersubject variability was larger at the edge locations and regions adjacent to the blind spot, but Wild et al (19) indicate that it may be due to the reduced efficacy of SITA at these locations.

Furthermore, we found that with SS a significantly large number of patients were judged to have a glaucomatous visual field defect based on cluster criterion (Tabs. I and III).

The depth of the glaucomatous defects was measured significantly shallower with SS than with FT, and the sizes of defects were significantly larger with SS than with FT (Tab. IV). In addition, when the depth of abnormal points in clusters detected with FT was compared with the depth of the same points determined with SS, the sensitivity was significantly shallower with SS than with FT (Fig. 4). These indicate that a cluster might be formed more easily with SS than with FT. There is a characteristic of the SITA that makes correlations between threshold values higher at adjacent test points than at points located further apart (23, 24).

Therefore, with SS, points with slight sensitivity depression adjacent to an abnormal point would more likely be judged abnormal and form a cluster, leading to more patients being diagnosed with a glaucomatous visual field based on the finding of the cluster formation. It is possible, however, that the different normative databases used for SITA and FT can partially explain the differences observed.

In the present study, glaucomatous defects were measured as being shallower and larger using SS versus FT. The prevalence of visual field defect was higher with SS than with FT according to the minimal criteria for glaucomatous visual field defects. These results might be related to the fact that SS strategy has a lower variability and to the Bayesian statistical properties of the SITA algorithm.

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REFERENCES

1. Johnson CA, Adams CW, Lewis RA. Fatigue effects in automated perimetry. Appl Opt 1988; 27: 1030-7.
2. Johnson CA, Chauhan BC, Shapiro LR. Properties of staircase procedures for estimating thresholds in automated perimetry. Invest Ophthalmol Vis Sci 1992; 33: 2966-74.
3. Hudson C, Wild JM, O'Neill EC. Fatigue effects during a single session of automated static threshold perimetry. Invest Ophthalmol Vis Sci 1994; 35: 268-80.
4. Glass E, Schaumberger M, Lachenmayr BJ. Simulations for FASTPAC and the standard 4-2 dB full-threshold strategy of the Humphrey Field Analyzer. Invest Ophthalmol Vis Sci 1995; 9: 1847-54.
5. Bengtsson B, Olsson J, Heijl A, Rootzen H. A new generation of algorithms for computerized threshold perimetry, SITA. Acta Ophthalmol Scand 1997; 75: 368-75.
6. Olsson J, Bengtsson B, Heijl A, Rootzen H. An improved method to estimate frequency of false positive answers in computerized perimetry. Acta Ophthalmol Scand 1997; 75: 181-3.
7. Bengtsson B, Heijl A. Evaluation of a new perimetric threshold strategy, SITA, in patients with manifest and suspect glaucoma. Acta Ophthalmol Scand 1998; 76: 268-72.
8. Budenz DL, Rhee P, Feuer WJ, Mcsoley J, Johnson CA, Anderson DR. Sensitivity and specificity of the Swedish interactive threshold algorithm for glaucomatous visual field defects. Ophthalmology 2002; 109: 1052-8.
9. Turpin A, McKendrick AM, Johnson CA, Vingrys AJ. Properties of perimetric threshold estimates from Full Threshold, ZEST and SITA-like strategies as determined by computer simulation. Invest Ophthalmol Vis Sci 2003; 44: 4787-95.
10. Vingrys AJ, Pianta MJ. A new look at threshold estimation algorithms for automated static perimetry. Optom Vis Sci 1999; 76: 588-95.
11. Artes PH, Iwase A, Ohno Y, Kitazawa Y, Chauhan BC. Properties of perimetric threshold estimates from Full Threshold, SITA Standard, and SITA Fast strategies. Invest Ophthalmol Vis Sci 2002; 43: 2654-9.
12. Bengtsson B, Heijl A, Olsson J. Evaluation of a new threshold visual field strategy, SITA, in normal subjects. Acta Ophthalmol Scand 1998; 76:165-9.
13. Bengtsson B, Heijl A. Inter-subject variability and normal limits of the SITA Standard, SITA Fast, and the Humphrey Full Threshold computerized perimetry strategies, SITA STATPAC. Acta Ophthalmol Scand 1999; 77: 125-9.
14. Budenz DL, Rhee P, Feuer WJ, Mcsoley J, Johnson CA, Anderson DR. Comparison of glaucomatous visual field defects using standard full threshold and Swedish interactive threshold algorithms. Arch Ophthalmol 2002; 120: 1136-41.
15. Heijl A, Bengtsson B, Patella VM. Glaucoma follow-up when converting from long to short perimetric threshold tests. Arch Ophthalmol 2000; 118: 489-93.
16. Inazumi K, Tsuji A, Yamamoto T, Kitazawa Y. Evaluation of the Swedish interactive thresholding algorithm, a new thresholding algorithm, of the Humphrey Field Analyzer in glaucoma patients. J Jpn Ophthalmol Soc 1998; 102: 667-72.
17. Sharma AK, Goldberg I, Graham SL, Mohsin M. Comparison of the Humphrey Swedish Interactive Thresholding Algorithm (SITA) and full threshold strategies. J Glaucoma 2000; 9: 20-7.
18. Shirato S, Inoue R, Fukushima K, Suzuki Y. Clinical evaluation of SITA. A new family of perimetric testing strategies. Graefes Arch Clin Exp Ophthalmol 1999; 237: 29-34.
19. Wild JM, Pacey IE, Hancock SA, Cunliffe IA. Between-algorithm, between-individual differences in normal perimetric sensitivity: Full Threshold, FASTPAC, and SITA. Invest Ophthalmol Vis Sci 1999; 40: 1152-61.
20. Wild JM, Pacey IE, O'Neill EC, Cunliffe IA. The SITA perimetric threshold algorithms in glaucoma. Invest Ophthalmol Vis Sci 1999; 40: 1998-2009.
21. Schimiti RB, Avelino RR, Kara-José N, Costa VP. Full-threshold versus Swedish Interactive Threshold Algorithm (SITA) in normal individual undergoing automated perimetry for the fist time. Ophthalmology 2002; 109: 2084-92.
22. Anderson DR, Patella VM. Automated Static Perimetry. St. Louis: Mosby, 1999; 152-3.
23. Heijl A. Improved test algorithms for automated perimetry. In: Krieglstein GK, ed. Glaucoma Update, vol. 5. Heidelberg: Kaden Verlag, 1995; 168-73.
24. Heijl A, Lindgren A, Lindgren G. Inter-point correlations of deviations of threshold values in normal and glaucomatous visual fields. In: Heijl A, ed. Perimetry Update. Proceedings of the 8th International Perimetric Society Meeting 1988. Amsterdam: Kugler & Ghedini, 1989; 177-83.