A New SITA Perimetric Threshold Testing Algorithm: Construction and a Multicenter Clinical Study

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• PURPOSE: To describe a new time-saving threshold visual field–testing strategy—Swedish Interactive Thresholding Algorithm (SITA) Faster, which is intended to replace SITA Fast—and to report on a clinical evaluation of this new strategy.

• DESIGN: Description and validity analysis for modifications applied to SITA Fast.

• METHODS: Five centers tested 1 eye of each of 126 glaucoma and glaucoma suspect patients with SITA Faster, SITA Fast, and SITA Standard at each of 2 visits. Outcomes included test time, mean deviation, and the visual field index (VFI), significant test points in probability maps, and intertest threshold variability.

• RESULTS: Mean (standard deviation) test times were 171.9 (45.3) seconds for SITA Faster, 247.0 (56.7) for SITA Fast, and 369.5 (64.5) for SITA Standard ($P < .001$). SITA Faster test times averaged 30.4 % shorter than SITA Fast and 53.5 % shorter than SITA Standard. Mean deviation was similar among all 3 tests.VFI did not differ between SITA Fast and SITA Faster tests, mean difference 0%, but VFI values were 1.2% lower with SITA Standard compared to both SITA Fast ($P = .007$) and SITA Faster ($P = .002$). A similar trend was seen with a slightly higher number of significant test points with SITA Standard than with SITA Fast and SITA Faster. All 3 tests had similar test–retest variability over the entire range of threshold values.

• CONCLUSIONS: SITA Faster saved considerable test time. SITA Faster and SITA Fast gave almost identical results. There were small differences between SITA Faster and SITA Standard, of the same character as previously shown for SITA Fast vs SITA Standard. (Am J Ophthalmol 2019;198:154–165.

COMPUTERIZED PERIMETRY STARTED IN THE EARLY 1970s. Careful theoretical calculations and pilot studies on patients were performed initially.[1–3] Early clinical use and clinical studies of computerized perimetry usually involved supraliminal screening tests.[4–6] At that time, manual kinetic and manual static perimetry were perimetric criterion standards, but automation of threshold perimetry certainly was a goal. Clinical studies of computerized threshold tests would soon follow.[7–10]

Clinical use of computerized threshold perimetry became more common in the early 1980s. Test times for threshold tests available at that time were long—usually 12 to 20 minutes per eye.[11–14] This was tiring for patients and limited the number of tests that could be performed, and there was a strong desire for more rapid testing. Threshold tests could be shortened by simply testing fewer points, by using larger step sizes, and by performing fewer repetitions.[7,10] However such changes generally decreased test quality; there was a trade-off between accuracy and efficiency.[15]

We began developing the Swedish Interactive Thresholding Algorithm (SITA) strategies in the latter half of the 1980s. Our goal was to reduce test time without loss of test quality. We used a Bayesian prior model and iterative maximum posterior probability estimation of threshold values in real time, which made it possible to interrupt testing at each tested location at predetermined levels of test certainty. We also used a new method to calculate false positive (FP) answers and an improved timing algorithm to shorten test time.[16,17] Two SITA tests were developed: SITA Standard,[12] which was intended to replace the original Full Threshold test, and SITA Fast,[18] which was intended to replace Fastpac.

The new SITA tests were compared with the original strategies and performed well. Test times were reduced drastically, by about 50% for SITA Standard as compared with Full Threshold and also about 50% for SITA Fast compared with Fastpac, without worsening intertest variability.[12,14,18–21] Threshold sensitivity values were

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somewhat higher with the newer shorter tests.[12,22] This was expected because visual fatigue tends to decrease threshold values with increasing test time.[23–25] Despite these test time reductions, SITA test programs identified at least as much glaucomatous field loss[22,26–28] as the algorithms that they replaced, and the SITA testing strategies enjoyed broad acceptance.[29–33]

Over the last 15 years, results from large randomized glaucoma trials have changed our sense of what constitutes optimal glaucoma management. It has become clear that many or perhaps even most glaucomatous eyes progress, even in patients where measured intraocular pressures always are within statistically normal limits, and that rates of progression vary tremendously among eyes.[34–36] Observed progression is an indication for more frequent visual field testing, and rate of progression now plays a central role when setting target pressures.[37–40] Assessing rate of progression requires a series of field tests, and therefore recommendations have been put forward that visual field testing should be performed frequently during the first few years after a patient is diagnosed with manifest glaucoma (eg, 3 fields per year for the first 2 years after diagnosis[38,40,41]). This is much more frequent than has been common in clinical practice,[42,43] but statistical modeling has shown that there is a strong rationale for following these suggestions.[44] However, even if the frequency of field testing has increased in some clinics, the newer recommendations certainly are not being generally followed.[45] In a survey of ophthalmologists in the United Kingdom, this increased testing frequency was regarded as ideal by many but is often impossible because of limited resources.[46]

We believe that access to shorter perimetric threshold testing could make it easier for health care providers to follow current glaucoma management recommendations. With the benefit of >2 decades of experience with the original SITA tests, we realized that certain modifications could be made to create an even faster version of SITA. The aim of this paper is to describe the development of a new threshold testing strategy called SITA Faster that is intended to replace SITA Fast, and to report the results of a multicenter clinical evaluation thereof.

METHODS

THIS PAPER DESCRIBES THE DEVELOPMENT AND CONSTRUCTION of SITA Faster and a multicenter clinical evaluation of this strategy.

• **DEVELOPMENT OF SITA FASTER:** We performed both simulations and clinical testing in developing SITA Faster. Six of the 7 modifications of SITA Fast listed below, all except the timing issue (item 7), were first tested in simulations, each one separately and then combined. Our simulations suggested that a 21% reduction in the number of stimulus presentations as compared with SITA Fast might be achieved with no important effect on accuracy when applying all modifications except the timing change described below, which could not be simulated.

Seven modifications were made to SITA Fast to produce SITA Faster:

1. Starting stimulus intensities: Like the original Full Threshold strategy, SITA Standard and SITA Fast programs begin each examination by presenting 25 dB stimuli at each of 4 primary test points. A primary point is the first tested point in each quadrant. Twenty-five dB is considerably brighter than the threshold in normal eyes, and most of the time several stimuli must be presented before the visual threshold is reached. In SITA Faster, the test sequence begins at the age-corrected normal threshold level, therefore reducing the number of stimulus presentations for most eyes.
2. Reversals at primary test points: In older test programs, 2 staircase test sequences were performed at each primary point. In SITA Faster, only 1 staircase test reversal is required. Step sizes are unchanged.
3. Prior models: The legacy SITA tests and SITA Faster all use iterative maximum posterior probability calculations of threshold levels in real time to determine when testing can stop at each point location.[16] Visual field models of thresholds at each test location are important for the efficiency of this process. SITA Fast and SITA Standard visual field models were based on distributions of normal threshold levels obtained using the original Full Threshold program because normal values for SITA were not yet available when those SITA tests were under development. SITA Faster's visual field model uses the distribution of SITA Fast normal values, leading to more time-efficient testing.
4. Retesting at perimetrically blind points: In older strategies, test points where the test subject has not responded to the maximum stimulus intensity of the perimeter (0 dB/10,000 apostilb) have been confirmed by presenting a second maximum intensity stimulus. In SITA Faster, this second check is not performed.
5. False negative catch trials: Ever since the early days of computerized perimetry, we have tried to assess test reliability using several "reliability parameters"—blind spot catch trials, false negative (FN) responses and FP responses. FP catch trials were replaced with "listen time" already in the original SITA strategies.[20] In SITA Faster, FN catch trials are no longer performed.
6. Blind spot catch trials: In SITA Faster, the earlier method of checking fixation by projecting stimuli

into the blind spot has been replaced by use of the Humphrey gaze tracker.

7. Stimulus timing: SITA tests have a rather advanced timing algorithm that is sensitive to each patient's individual reaction time and to how that reaction time may change as testing proceeds. In earlier SITA programs, an extra 300-ms delay was added after nonseen stimuli at the end of the response time window before a new stimulus was presented. This extra delay was eliminated in SITA Faster.

SITA Faster has been developed for the 24-2 test point pattern.

The timing change (item 7) was tested in 34 eyes of 34 patients having manifest or suspect glaucoma. Patients' subjective experience did not differ between the 2 versions. Therefore, patients did not feel that either of the tests was more stressful or simpler. The timing change resulted in a mean test time reduction of 28 seconds (unpublished results).

Early versions of the new strategy were tested clinically in Malmö, first comparing the results of SITA Fast and SITA Faster in 44 eyes of 44 patients having manifest or suspect glaucoma. Another series performed both in Malmö and at Carl Zeiss Meditec in Dublin, California, included 57 patients, where again SITA Faster was compared with SITA Fast. This time SITA Fast testing was performed twice. The differences between SITA Faster and SITA Fast were similar to differences seen between the repeated SITA Fast tests. The final SITA Faster strategy, specified above, then went through a pilot study in Malmö, Tajimi, and Dublin, including a total of 70 eyes, after which the protocol for the multicenter study described below was finalized.

• **MULTICENTER CLINICAL EVALUATION:** The final version of SITA Faster was tested in a separate investigator-initiated clinical study performed at 5 centers: Department of Ophthalmology, Skåne University Hospital Malmö, Lund University, Malmö, Sweden; Tajimi Iwase Eye Clinic, Tajimi, Japan; Tays Eye Centre, University of Tampere, Tampere, Finland; Department of Ophthalmology and Visual Sciences, Chinese University of Hong Kong, Hong Kong, China, and School of Optometry and Vision Science, University of California, Berkeley, California, USA.

The study was conducted in accordance with the Helsinki declaration and was approved by the Ethics Committee of the Gifu Prefecture Medical Association, the Ethics Committee of Tampere University Hospital, the Committee for Protection of Human Subjects of the University of California Berkeley, and the Kowloon Central Research Ethics Committee. The study also was submitted to the Regional Ethics Review Board in Lund, Sweden. The Lund Board concluded that the study did not need their approval but that they saw no ethical issues with it. The study and data collection were in conformance with all laws and with Health Insurance Portability and Accountability Act regulations. All patients at all centers were given detailed study information, written and oral, and gave informed consent.

• **SUBJECTS:** Eligible patients were women and men between 20 and 82 years of age either having a diagnosis of glaucoma or being followed as glaucoma suspects. A glaucoma diagnosis was based on the presence of repeatable visual field defects with corresponding structural defects in the optic disc or retinal nerve fiber layer. Patients with clear abnormalities at the disc or the retinal nerve fiber layer but with normal fields, and patients with clear glaucomatous field defects but without corresponding structural abnormalities, were also eligible. Glaucoma suspects were patients being followed because of elevated intraocular pressure, suspect optic disc or retinal nerve fiber layer changes, or a positive family history of glaucoma, but without manifest glaucoma. Only patients having open angle glaucoma or suspect glaucoma with open angles were accepted, including primary open angle glaucoma, exfoliation glaucoma, and pigmentary glaucoma. Recruitment was not consecutive; instead, we strived for a broad range of glaucoma stages from each participating center, and the study protocol specified that each center should test eyes with a broad spectrum of disease from no detectable or early field loss (mean deviation [MD] values better than −6 dB) to moderate field loss (with MD values between −6 dB and −12 dB) to serious field loss (MD values worse than −12 dB). We only enrolled patients having previous experience with threshold perimetry on a Humphrey perimeter and having refractive errors between −8 and +8 D spherical equivalent and cylinder ≤3 D. Most patients had been followed for >1 year and therefore had been tested several times with SITA perimetry in both eyes.

We did not enroll eyes from patients with diabetic retinopathy or eyes from patients who might have had field loss related to causes other than glaucoma (eg, neurologic disease, age-related macular degeneration, or retinal detachment).

• **VISITS AND TESTS:** Each patient underwent automated perimetric testing at 2 separate clinic visits. The acceptable time interval between clinic visits was between 1 day and 2 weeks. At each visit, patients were tested in the single study eye with SITA Fast 24-2, SITA Faster 24-2, and SITA Standard 24-2 threshold tests, all performed on a single Humphrey 800 series perimeter (Carl Zeiss Meditec, Inc, Dublin, CA, USA). Tests were performed in random order; each test center received a randomization list of test orders. At the second visit, the test order used at the first visit was reversed. Perimetrists were not masked as to the type of test that they were administering.

TABLE 1. Differences in Visual Field Parameters Mean Deviation, Visual Field Index, and Numbers of Significant Test Points in Probability Maps Between the 3 SITA Strategies

Parameters	SF vs SFR, Mean (SD)	SS vs SF, Mean (SD)	SS vs SFR, Mean (SD)	Repeated Measures ANOVA *P* Value
Test duration, sec	75.1 (30.7)	122.5 (42.2)	197.6 (41.7)	<.001[a]
MD, dB	0.06 (1.84)	−0.06 (1.68)	0.00 (1.58)	.91
VFI, %	0.0 (5.1)	−1.2 (4.7)	−1.2 (4.5)	.003[b]
No. TD points <5%	−0.3 (6.1)	−0.7 (6.6)	−1.0 (5.5)	.12
No. TD points <1%	−0.1 (5.7)	0.9 (5.1)	0.8 (4.7)	.051
No. PD points <5%	0.1 (5.5)	0.8 (4.5)	0.9 (5.3)	.07
No. PD points <1%	0.2 (3.9)	0.8 (4.0)	1.1 (3.8)	.007[c]

MD = mean deviation; PD points = significant points in pattern deviation probability maps; SF = SITA Fast; SFR = SITA Faster; SITA = Swedish Interactive Thresholding Algorithm; SS = SITA Standard; TD points = significant points in total deviation probability maps; VFI = visual field index.

[a]All pairwise differences significant ($P < .001$).

[b]Pairwise significant differences between SS and SF $P = .007$ and between SS and SFR $P = .002$.

[c]Pairwise significant differences between SS and SF $P = .023$ and between SS and SFR $P = .002$.

At each visit, the 2 first tests were run without any extra rest between tests, as in ordinary clinical practice. After those 2 tests, patients received a break of at least 15 minutes before the third test was started. The patient's second eye was not included in the study, but if the second eye needed testing for clinical reasons, such tests were performed after the 3 study tests.

Each patient was refracted before the first test, and appropriate near refractive correction was used for all tests. Study eyes were not dilated and did not undergo tonometry before field testing. Tests were run in the default mode for each test strategy. Therefore, SITA Standard 24-2 and SITA Fast 24-2 tests used gaze tracking, plus blind spot and FN catch trials, while SITA Faster 24-2 tests were run with gaze tracking engaged but without blind spot and FN catch trials.

If results were deemed faulty because of gaze instability during the test, high FP rates, patient misunderstanding, or inattentiveness, the perimetrist was allowed to stop the test, reinstruct the patient, and restart the test from the beginning, thus discarding the interrupted test. However, once a test had been completed, it could not be deleted, and it was saved.

• **SAMPLE SIZE CALCULATION:** We strived for high statistical power because we aimed to study whether SITA Faster results were interchangeable with those of SITA Fast. We chose MD as the parameter for the calculation of sample size. When accepting an effect size of ≤0.5 dB in either direction between SITA Fast and SITA Faster, a type 1 error of 0.05, and a standard deviation (SD) of 1.5 dB, we needed a minimum sample size of 117 individuals. This SD was derived from test–retest data of SITA Fast tests collected for the calculation of glaucoma change probability maps for SITA Fast (unpublished data). In that dataset, the exact SD for SITA Fast was somewhat smaller (1.36 dB). In that large sample, the SD of SITA Standard was 0.94 dB, which was the similar to that reported by Chauhan and associates as moderate variability (1.0 dB) for the Full Threshold algorithm.[41]

• **ANALYSES:** All data were pooled and analyzed centrally. We registered test time, MD, and visual field index (VFI) values for the 3 testing algorithms SITA Fast, SITA Faster, and SITA Standard and also the intrapatient differences in these indices among the 3 algorithms. As expected, the distributions of MD and VFI values were not Gaussian, but the distributions of the individual differences were all Gaussian and were subsequently tested for significance using repeated measures analysis of variance with a Greenhouse–Geisser correction for lack of sphericity, as indicted by the Mauchly test. We used 1-sample *t* tests to explore pairwise comparisons when the analysis of variance showed significant differences among any of the 3 test algorithms. We chose not to correct for the type 1 error, typically done when conducting multiple comparisons, to avoid inflating the statistical power.

The numbers of depressed test point locations in pattern and total deviation probability maps at the $P < 5\%$ and $P < 1\%$ significance levels were compared in the same way. The 5% numbers thus included all significantly depressed points in the probability maps, while the 1% numbers included only points that were depressed at the $P < 1\%$ and $P < 0.5\%$ levels.

The results of the Glaucoma Hemifield Test (GHT) were registered for each test and the results presented in a table and a Venn diagram.

The distributions of FP answers were not Gaussian. Therefore, FP answers were presented in terms of medians and interquartile range (IQR) values for each strategy. The nonparametric Wilcoxon signed rank test

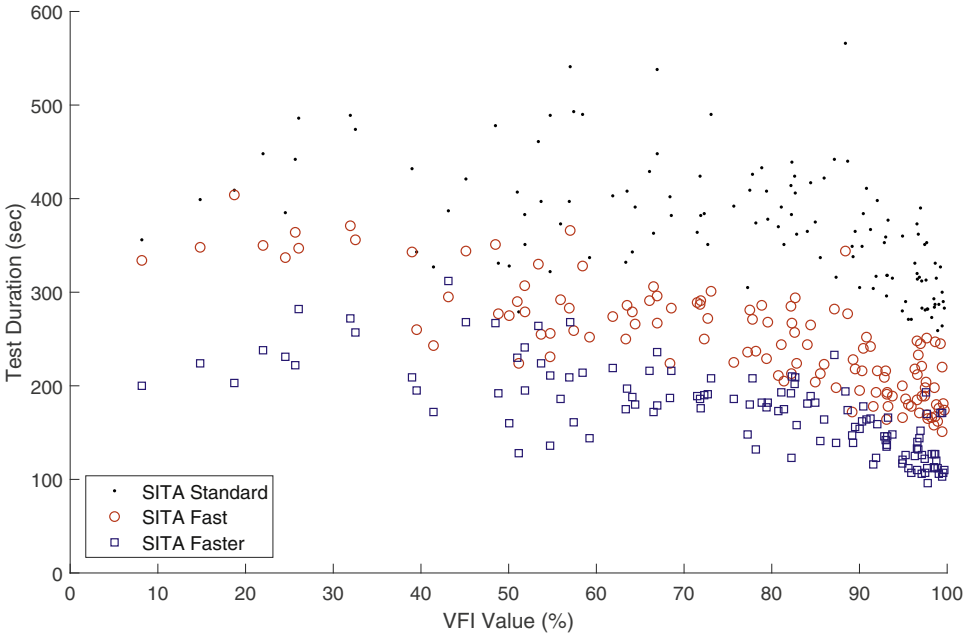


FIGURE 1. Test times vs stage of glaucoma. Test times were shortest in normal fields and fields with early glaucomatous field loss with all strategies. SITA = Swedish Interactive Thresholding Algorithm; VFI = visual field index.

for 2 related samples was used to test for significant differences between strategies.

All the above analyses were performed using only second-visit data (ie, when all patients had previous experience with the study protocol).

Bland-Altman plots were used to assess agreement in MD and VFI values between test strategies using data from the second visits and within strategies using data from both visits. Similarly, we used Bland-Altman plots to assess agreement in numbers of significant 5% and 1% points in total and pattern deviation probability maps.

Test–retest variability across the full range of threshold values was also calculated on a pointwise basis and means and 95% confidence limits were plotted vs threshold level. In this analysis, and in an analysis of the reproducibility of GHT results, we used data from both patient visits.

SPSS software (version 24.0; IBM Corp., Armonk, NY, USA), MATLAB R2017b (MathWorks, Natick, MA, USA), and MiniTab version 17 (Minitab Inc., State College, PA, USA) were used for the analyses.

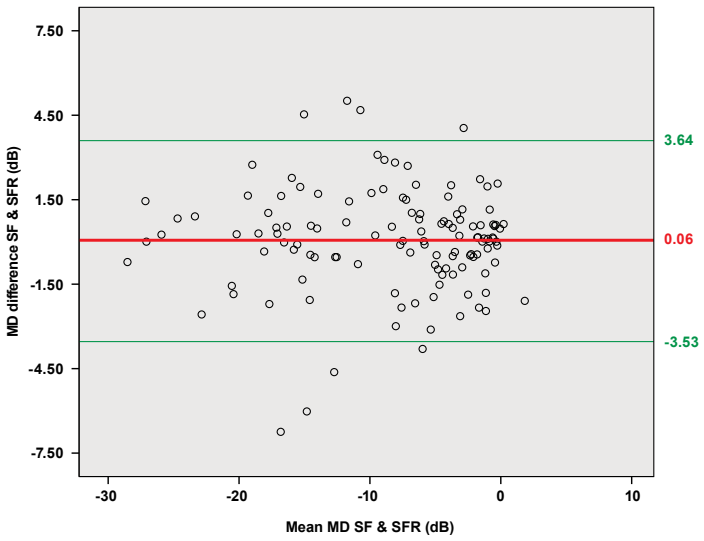
RESULTS

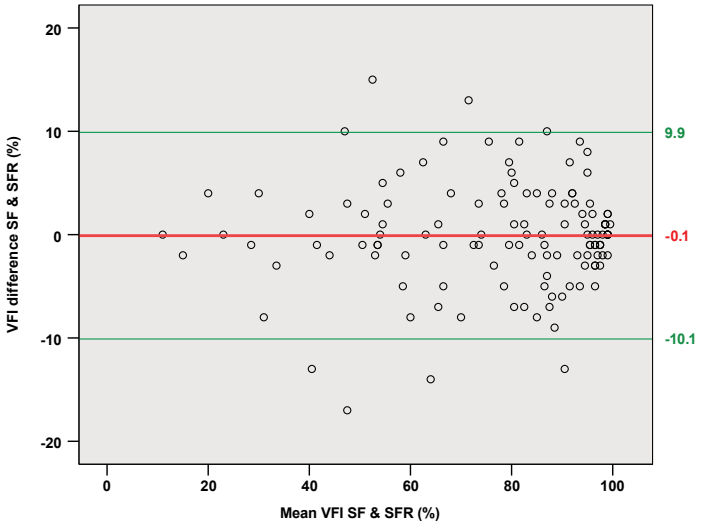
WE ANALYZED RESULTS FROM 125 PATIENTS, 64 WOMEN (51%) and 61 men. The mean age was 67 years (range 26-82 years). One outlier was excluded. Testing of this patient had been interrupted because of large eye movements. A new test was then started but fixation was still considered unacceptable.

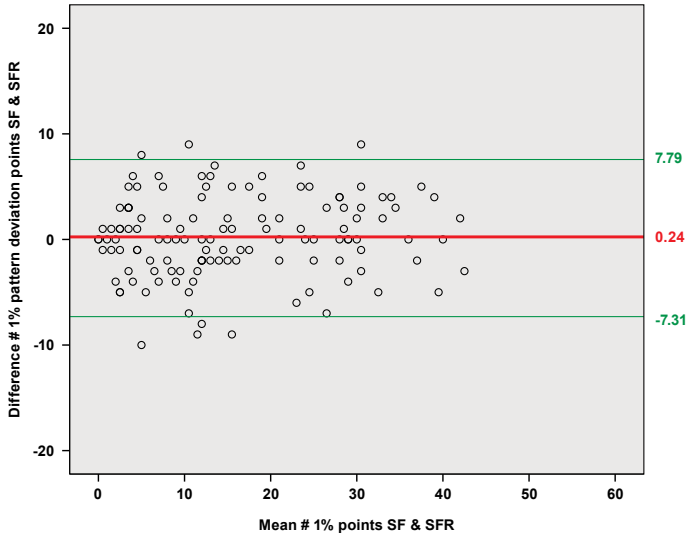
Mean test times and SDs were 171.9 (45.3) seconds for SITA Faster, 247.0 (56.7) seconds for SITA Fast, and 369.5 (64.5) seconds for SITA Standard ($P < .001$). The mean test time for SITA Faster was 30.4% shorter than that of SITA Fast and 53.5% shorter than that of SITA Standard. Differences in test time are shown in the Table 1 and were highly significant for all 3 pairwise comparisons ($P < .001$). Test time dependencies on visual field status were similar for all test strategies, with the shortest test times being found in normal or near normal fields (Figure 1).

MD values were similar among the 3 tests; median values were −6.44 dB for SITA Standard, −6.11 dB for SITA Fast, and −6.42 dB for SITA Faster. The median VFI values were 83.3%, 84.3%, and 84.3% for SITA Standard, SITA Fast, and SITA Faster, respectively. Differences between the strategies and significances are shown in Table 1, with no statistically significant differences for MD among the three test algorithms. VFI values were 1.2% lower with SITA Standard compared to both SITA Fast and SITA Faster.

The differences in the numbers of significantly depressed points in total and pattern deviation probability maps are also shown in Table 1. Numbers at the 5% level include points that were depressed at significance levels of 5% or higher (ie, all statistically significant points in the probability maps). Numbers at the 1% level include points that were depressed on the 1% level or higher (ie, 1% and 0.5% points). Differences between SITA Faster and SITA Fast were small for both types of probability maps and both levels of test point significance. There were no


7.50
4.50
1.50
-1.50
-4.50
-7.50
MD difference SF & SFR (dB)
3.64
0.06
-3.53
-30
-20
-10
0
10
Mean MD SF & SFR (dB)


20
10
0
-10
-20
VFI difference SF & SFR (%)
9.9
-0.1
-10.1
0
20
40
60
80
100
Mean VFI SF & SFR (%)


20
10
0
-10
-20
Difference # 1% pattern deviation points SF & SFR
7.79
0.24
-7.31
0
10
20
30
40
50
60
Mean # 1% points SF & SFR

statistically significant differences in three of the four different categories of test points among the three test algorithms, while the number of test points depressed at the $P <$ 1% level in the pattern deviation was slightly larger in SITA Standard test compared to both SITA Fast and SITA Faster.

Bland-Altman plots suggest good agreement between the 3 strategies without any systematic bias. The differences are evenly distributed over the range of mean MD and VFI values and the numbers of significant points in probability maps. The width of the 95% confidence interval of the interstrategy differences are similar but generally somewhat larger than those of the intrastrategy intervals. Plots showing the differences between SITA Faster and SITA Fast are provided in Figure 2, while the intrastrategy intervisit differences for the same parameters are provided as Supplemental Figure 1 (Supplemental Material available at AJO.com).

The same analyses for significantly depressed points at the 5% level in pattern deviation probability maps and at the 1% and 5% levels in total deviation probability maps are provided in Supplemental Figure 2 (Supplemental Material available at AJO.com). Comparing all 12 Bland-Altman plots on numbers of significant points, one can see that the widths of the confidence intervals between strategies are similar to but generally slightly wider than within the strategies.

The results of the GHT analyses are shown in Table 2 and Figure 3. Most tests were classified as outside normal limits, and the 3 algorithms had similar numbers of tests in each category. Most eyes had the same GHT classifications at the 2 visits. Tests with a classification of outside normal limits are shown in the Venn diagram, which shows that in many eyes with such classifications, the result was the same with all 3 test algorithms.

The median values and interquartile ranges for the number of FP responses were 3% (0-6) for SITA Faster, 2% (0-5) for SITA Fast, and 2% (0-4) for SITA Standard. No significant FP differences were seen between SITA Faster and SITA Fast ($P = .06$) and between SITA Fast and SITA Standard ($P = .17$). SITA Faster showed significantly more FP answers than SITA Standard ($P = .005$).

Test–retest variability of all threshold measures at each test point, means, and 95% confidence limits, stratified by threshold level are shown in Figure 4. The 3 algorithms gave similar results, and confidence intervals certainly overlap over the whole range of threshold values.

DISCUSSION

THIS PAPER DESCRIBES THE CONSTRUCTION OF SITA FASTER and the results of a multicenter clinical study evaluating its performance. Development of the original SITA programs was a long and complicated process. Many new concepts were introduced, and we were somewhat reluctant to introduce changes that were not a direct result of the new key elements of SITA: previous models, maximum posterior probability estimation of thresholds in real time, and a new timing algorithm.

SITA Standard was designed to replace the Full Threshold program and SITA Fast to replace Fastpac. When designing SITA Fast, we therefore constructed the test to be less precise than SITA Standard, and this was also shown by us and others in clinical tests.[12,13,18] However, differences were small, and some investigators concluded that the shorter test was an attractive alternative in clinical practice and for screening.[47,48] Later results have shown that SITA Fast and SITA Standard are equally effective for glaucoma detection, and analysis of a very large clinical perimetry database indicated that despite the fact that SITA Fast is slightly less precise in test points with poor sensitivity, this is unlikely to make a sizeable difference in the time needed to detect progression.[49] SITA Fast has therefore become a commonly used test program, and in many countries it is used by a majority of eye care professionals.

We should point out that the modifications made to SITA Fast in order to produce SITA Faster were relatively small, and the development of SITA Faster has not included major paradigm shifts compared with the original SITA strategies.

As stated in the description of the test development, earlier SITA programs started testing at primary points at 25 dB. This value was inherited from the first threshold test in the Humphrey perimeter, Full Threshold, and was implemented in the Full Threshold strategy even before we had any knowledge of normal age-corrected sensitivity values. This level is considerably supraliminal in normal vision, commonly requiring several steps of stimulus intensity reduction before reaching threshold. The risk of bias in

FIGURE 2. Comparisons of test results obtained with Swedish Interactive Thresholding Algorithm (SITA) Faster (SFR) and SITA Fast (SF) expressed as global index values and number of significantly depressed test points in probability maps. Top, Bland-Altman plot of the differences in mean deviation (MD) values between SF and SFR vs the mean MD value of the 2 tests. Middle, Differences in visual field index (VFI) values vs the mean VFI value of the 2 tests. Bottom, Differences in numbers of significant tests points at the 1% level in pattern deviation maps vs the mean value of the 2 tests. The red lines mark the mean differences, and the green lines show the 95% confidence intervals. These graphs may be compared with the intrapatient test–retest variability obtained when using the same algorithm, SFR, and SF, respectively, in Supplemental Figure 1 (Supplemental Material available at AJO.com). The red lines mark the mean differences, and the green lines show the 95% confidence intervals.

TABLE 2. Glaucoma Hemifield Test Results Obtained With the 3 SITA Strategies

Glaucoma Hemifield Test Classification	SITA Faster Tests, n	SITA Fast Tests, n	SITA Standard Tests, n
Outside normal limits	105	110	103
Borderline	5	8	9
Within normal limits	13	6	12
Abnormally high sensitivity	2	1	1
General reduction of sensitivity	0	0	0
Exact reproducibility of results at both visits	109	113	112

SITA = Swedish Interactive Thresholding Algorithm.

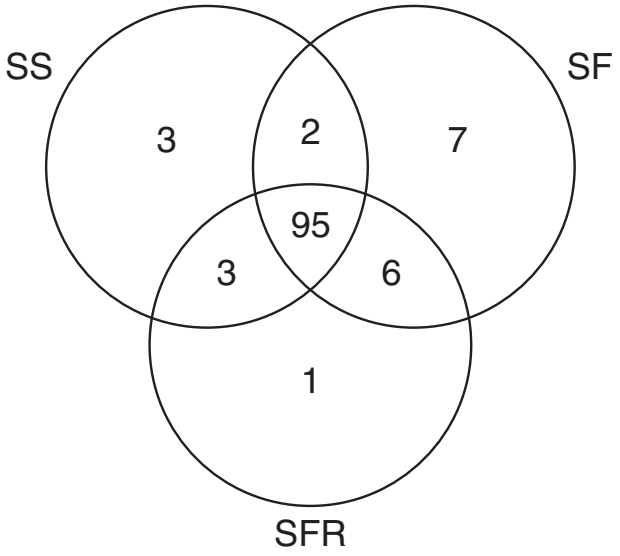


FIGURE 3. Venn diagram showing the agreement in eyes with the Glaucoma Hemifield Test classifications of outside normal limits with Swedish Interactive Thresholding Algorithm (SITA) Faster (SFR), SITA Fast (SF), and SITA Standard (SS).

threshold estimations increases with increasing differences between starting intensities and final intensities,[2,3,15] and therefore it is certainly less risky to start at or near the age-corrected normal threshold value as in SITA Faster.

SITA Faster requires only 1 reversal at primary test points instead of the 2 staircases used in earlier SITA tests. This is time-saving and logical because SITA Faster starts much closer to the expected threshold in the primary points.

One of the most important advantages of SITA compared with pre-SITA tests is the use of Bayesian models of the visual field. These models include age-corrected normal threshold levels. The original SITA models were based on normal values derived from Full Threshold program. Because SITA normal values are now known, it was obvious that the previous models should be updated, and SITA Faster prior models are now based on SITA results.

Assessing fixation by projecting stimuli into the blind spot, the so-called Heijl–Krakau method,[2] was introduced in the 1970s for perimeters that lacked any means for optical or video surveillance of patient gaze stability. The Heijl–Krakau method is simple but has several disadvantages: it requires catch trials (consuming time), it can only check fixation infrequently, and when the blind spot is inaccurately located, it is common for the fixation loss ratio to indicate poor fixation in tests where patients maintained good fixation. We have often seen users discard tests with high fixation loss ratios, even when gaze tracking results were good. Today gaze tracking is available, and this, coupled with perimetrist observations, can replace blind spot catch trials in our opinion.

In SITA Faster, we have abandoned FN catch trials. While such trials have been commonly used in computerized perimeters since the 1980s, it has been known for many years that FN rates depend more on visual field status than on the patient attentiveness. Glaucoma eyes have much higher FN rates than normal eyes, and in patients with unilateral field loss FN responses are much more common in the damaged eye, providing evidence that such responses are more indicative of glaucomatous field loss than of patient reliability.[50–52] The recent findings of Yohannan and associates[53] confirm the conclusions of Bengtsson and Heijl[51] that FN rate estimation adds marginal value at the expense of slowing testing time. Given that the primary goal of SITA Faster is to encourage and facilitate more frequent perimetric testing and improved progression detection, elimination of FN catch trials would seem well-supported. We believe that the advantages of giving up FN catch trials exceed the disadvantages.

In SITA Faster, we have also abandoned the old rule that test point locations found to be perimetrically blind should be rechecked by presenting a second maximum intensity stimulus. One reason for making this change is the negative patient experience associated with not seeing the stimulus for long periods of time, which occurs in patients with eyes having severe field loss when using the older SITA strategies. We noted in early pilot studies that patients with severe or end-stage glaucoma were those who noticed and appreciated SITA Faster the most.

The original SITA tests were released with much more effective timing routines than older threshold tests, continuously updating test pacing depending on the patient's response times. At that time, we were concerned that the test pacing might be too rapid, so we inserted an extra "safety" delay of 300 ms after unseen stimuli. When developing SITA Faster, we decided to test whether this delay could be deleted, because there was already a large safety margin between patients' response times and response

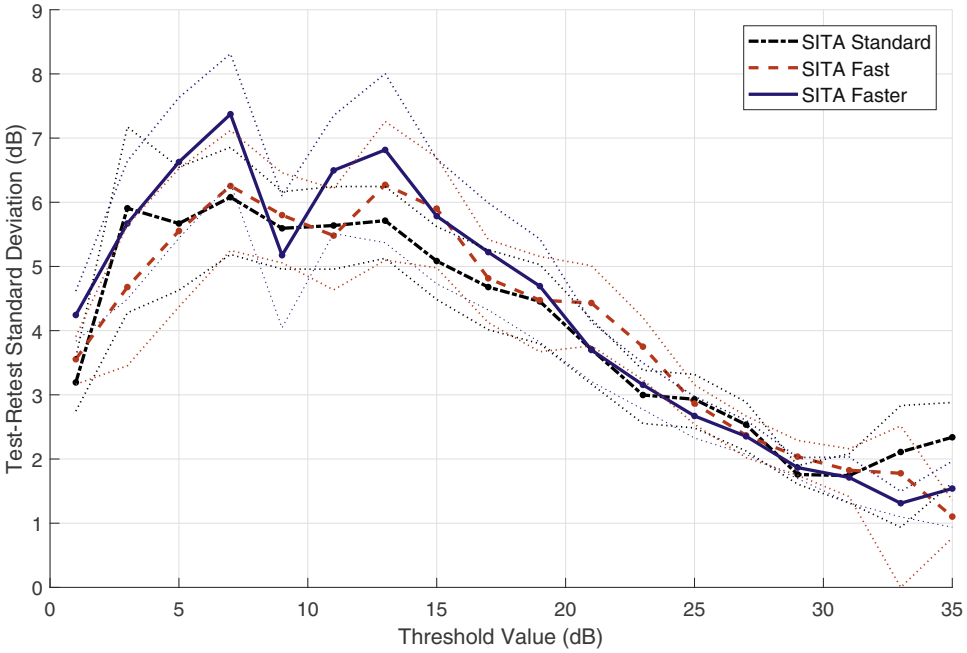


FIGURE 4. Mean pointwise test–retest threshold variability and 95% confidence intervals at all threshold levels with all 3 test algorithms. SITA = Swedish Interactive Thresholding Algorithm.

time windows. The first SITA Faster test series showed that the patients did not notice any subjective difference between the original and the newer timing, and test results did not differ.

This clinical study demonstrated a considerable reduction of test time with the SITA Faster algorithm compared with SITA Fast, which it was designed to replace. With SITA Faster, the average test time was around 2 minutes in eyes with early glaucomatous field loss and sometimes shorter in normal fields. Test time depended considerably on the stage of glaucomatous field loss, however, and in eyes with advanced loss and VFI values <40% the test time was often twice as long—around 4 minutes for SITA Faster, while going down slightly in end-stage fields. In poor fields, the time gained with SITA Faster compared with SITA Fast fields was also particularly large, around 2 minutes per test (Figure 1). Patients with such advanced or end-stage field loss were also those who most regularly noticed and appreciated that SITA Faster is a shorter test.

The MD index showed no statistically significant differences among the three algorithms. VFI was slightly and significantly lower with SITA Standard than with SITA Faster or SITA Fast while the VFI values with SITA Fast and SITA Faster were the same. There were also no statistically significant differences in the number of significantly depressed test points in probability maps among the three test algorithms in three of the four different categories of such points, SITA Standard identified slightly and significantly more 1% points in pattern deviation maps, and again the difference between SITA Fast and SITA Faster was negligible.

The small and statistically nonsignificant differences regarding test–retest variability of measured threshold values that were seen among the test algorithms probably have little importance clinically, at least the differences between SITA Faster and SITA Fast.

Multiple Bland-Altman analyses showed that the stage of glaucoma did not introduce a systematic bias; differences were balanced across the full range fields from normal to end-stage.

The number of FP responses did not differ significantly between SITA Faster and SITA Fast, while SITA Faster had statistically higher percentages than SITA Standard. Still a higher number of SITA Faster than SITA Fast tests exceeded the manufacturer's suggested limit of 15%. It has been known for >20 years that SITA Fast tests have higher FP numbers than SITA Standard. This is probably because in SITA Fast tests stimuli are presented at the expected 50% threshold, the peak of the maximum likelihood distribution, while SITA Standard uses a positive start bias, therefore showing more stimuli that are slightly easier to perceive The more difficult testing situation with SITA Fast is likely to influence how patients set their response criteria; they are probably willing to respond when less sure, which should increase the FP response rate. SITA Faster uses the same criteria to determine stimulus intensity, with the exception of the initial 4 starting points. In those, SITA Fast starts very supraliminal. This might explain higher FP rates in SITA Faster tests.

Generally, we found almost no differences in the results obtained with SITA Fast and SITA Faster except for FP

rates, while we saw small but statistically nonsignificant differences between SITA Faster and SITA Standard as well as between SITA Fast and SITA Standard. This must be considered logical and expected because SITA Faster is developed from and is similar to SITA Fast, while there are clear, but often small, differences between SITA Standard and SITA Fast, as shown in earlier studies.[20–22]

The clinical study has some strengths. One is that the eyes covering the full spectrum of field loss, or lack of such loss, seen in a glaucoma clinic were included. Patient ages also covered a wide range up to 82 years, and the mean age of 67 years at least similar to that seen in a glaucoma outpatient department. Other advantages are that tests could not be discarded because of high FN, FP, or fixation loss ratios noticed on the printouts after the test, and the multicenter design included patients of different ethnicities.

SITA tests often are used to identify and follow patients with field loss from diseases other than glaucoma,[31–33] and therefore one could consider the lack of inclusion of patients with such diseases as a weakness. This certainly was the case also when the early clinical studies of the SITA Standard and SITA Fast tests were published.[18,19,21,22] We are aware that the current article is the first clinical study published together with the first description of the new test. Future clinical studies will provide much useful information, hopefully also on the results obtained (eg, in patients with neurologic disease). We should emphasize, however, that we cannot think of any theoretical reasons why SITA Faster results should differ significantly from those obtained with SITA Fast in such patients, except for possibly showing a slightly higher rate of FP answers.

Our overall results indicate that SITA Faster can replace SITA Fast. It is natural to consider whether also to abandon SITA Standard in favor of SITA Faster. This decision, in our opinion, should depend on whether such a step will make it possible to increase the frequency of perimetric testing. More frequent tests are important for earlier detection of progression and for assessing the rate of progression.[41,54,55] Considering comparisons of SITA Standard and SITA Fast in this regard,[49] this new shorter test may be preferable, provided that the shorter test duration is used to increase test frequency. Future studies are needed to provide a definitive answer as to how to best choose tests in different clinical settings.

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