Comparison of Short Wavelength Automated Perimetry-Swedish Interactive Thresholding Algorithm (SWAP-SITA) and Standard Automated Perimetry- Swedish Interactive Thresholding Algorithm (SAP-SITA) in early detection of Glaucoma Conversion in Ocular Hypertension (OHT) Patients

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ABSTRACT

BACKGROUND: *The purpose of this study was to compare the two perimetric modalities, SWAP (short wavelength automated perimetry) and SAP (standard automated perimetry), on the point of conversion to glaucoma.*

PURPOSE: *To compare the sensitivity of SWAP-SITA and SAP-SITA visual field testing in diagnosing the point of conversion to primary open-angle glaucoma in subjects with a known diagnosis of ocular hypertension.*

METHODS: *125 patients diagnosed with ocular hypertension were recruited by non-probability consecutive sampling, in the longitudinal prospective study and followed for 2 years at Department of Ophthalmology, Allied Hospital Faisalabad. SAP and SWAP were performed at baseline and then 3 monthly for 2 years or until they converted to glaucoma whichever was earlier.*

RESULTS: *125 ocular hypertensive patients who were followed for 2 years, 19 patients (15.2%) converted to primary open-angle glaucoma. Two patients converted in both eyes simultaneously. SWAP showed earlier conversion in 5 patients (26.31%). In these patients, SAP conversion followed within 12 months. In 12 (63.15%) patients, the conversion happened simultaneously. In 2 (10.52%) eyes, SAP conversion occurred before SWAP. 106 (84.8%) patients remained non-converted during the study period.*

CONCLUSION: *SWAP is able to detect glaucomatous field detects earlier than SAP in a subset of patients. However, in the majority of patients, there was no difference in sensitivity between these two modalities.*

Keywords: Swedish Interactive Thresholding Algorithm, Short Wavelength Automated Perimetry, Standard Automated Perimetry, Glaucoma conversion, Ocular hypertension.

INTRODUCTION

Glaucoma is defined as a potentially progressive optic neuropathy that is associated with characteristic optic nerve head changes and corresponding visual field loss for which raised intraocular pressure is the key modifiable risk factor. It is the second leading cause of irreversible blindness after cataract and affects 2-3% of people over the age of 40 years and among these about 50% may be undiagnosed.[1]

Ocular hypertension which is present in 4-10% of the population is a significant risk factor for the development of primary open-angle glaucoma,[1] and the risk of this conversion can be reduced by lowering the intraocular pressure as was demonstrated in the ocular hypertension treatment study. As the damage in glaucoma is irreversible

therefore it is of utmost importance to diagnose it at an early stage. IOP lowering is the only intervention at present that can slow down the progression of glaucoma. To diagnose glaucoma at the earliest stages, various investigations are used. Some, such as OCT, HRT and GDx etc., detect structural changes in optic nerve head and retinal nerve fiber layer. Some investigations detect functional defects in visual fields. Standard Automated Perimetry (SAP) also known as white on white perimetry, has been the gold standard in diagnosing all kinds of glaucoma as well as documenting its progression overtime. But few studies pointed out that SAP cannot differentiate which particular type of ganglion cells are lost. It is estimated that more than 30% of ganglion cells are lost before SAP[2] is able to detect the first visual field defect. This means SAP is not sufficiently sensitive for early detection of glaucoma. So attempts were made to devise new strategies thatcould possibly pick up the glaucoma damage earlier than SAP does. Short-wavelength automated perimetry (SWAP) also called blue on yellow perimetry was then devised. It was said that SWAP technology can isolate the response of a subpopulation of retinal ganglion cells and the integrity of their specific pathway called the koniocellular pathway. It was claimed that SWAP was more sensitive and therefore could pick up conversion to glaucoma may be many months to years earlier.[3] But it was also found that SWAP had numerous disadvantages as well which could limit its use e.g. it is more tiring for the patient as it takes more time to complete, it gives more variable responses, patient learning curve is longer and it cannot be relied upon in nuclear sclerosis type of cataract as yellow lens will filter out blue light stimulus that is used in SWAP.[2]

This study was designed to look into whether SWAP is, in reality, more sensitive in picking up early glaucomatous damage as compared to SAP or not and whether we should screen people with ocular hypertension or those with suspicion of glaucoma with SAP or SWAP or both together.

MATERIALS AND METHODS

This study was approved by the Hospital's Research Ethics Committee and was done at the Department of Ophthalmology, Allied Hospital, Faisalabad. While conducting this research we adhered to the Helsinki Declaration and informed consent was obtained from all the participating subjects. 125 patients who presented in the outdoor department and were diagnosed with ocular hypertension on screening with age ranging from 35 to 65 years and fulfilling the inclusion/exclusion criteria were initially recruited by non-probability consecutive sampling and followed for 2 years. SAP and SWAP were performed at baseline and then 3 monthly for 2 years or until they converted to glaucoma whichever came earlier. Inclusion criteria werean untreated intraocular pressure above 23 mmHg measured by Goldmann applanation tonometer on two or more occasions, normal visual fields at baseline measured by SAP and SWAP on two occasions separated by 1 month, best-corrected visual acuity of at least 6/9 or better on Snellen's chart, an unremarkable fundus and slit-lamp examination, open angles on gonioscopy and clear media. The second visual field testing by both SAP & SWAP was included in the study to limit the patient learning effect.

Exclusion criteria included any media opacity/cataract, history of any intraocular surgery or laser, history of use of IOP lowering medications, uncooperative/mentally retarded/deaf & dumb patients, presence of any other ocular, systemic or neurological disease that could produce visual field defects e.g. pituitary lesions, brain SOL, diabetic retinopathy, retinitis pigmentosa, retinal detachment, retinal vein/artery occlusion, etc.

DATA COLLECTION PROCEDURE

Both SAP and SWAP were performed on theHumphrey Field Analyzer II (model 750 I, Carl Ziess Meditec Inc, Dublin, CA, USA) using the 24-2 SITA (Swedish Interactive Thresholding Algorithm) strategy. For SITA-SAP (White on white), a white stimulus of Goldmann size III with the maximal intensity of 10,000 asb (apostilb) and having a duration of 200 msec on a white background having an intensity of 31.5 asb was used. For SITA-SWAP (blue on yellow), a blue light stimulus of Goldmann size V, with a wavelength of 440 nm projected onto a yellow background of 530nm wavelength with a maximal brightness of 100 cd/m^{2}was used. The gaze was monitored by the automatic gaze tracker. All subjects received the same written instructions for the test to limit operator bias and the test was performed in the same sequence on all subjects (SAP followed by SWAP). Subjects were provided near refraction and given 5 minutes to adapt to the background light for 5 minutesbefore starting. A resting period of 5 minutes was given between each test and was performed on both eyes.

The reliability of each test report was taken into consideration before including them inthe study. The test was declared reliable only if fixation losses were <20% and false positives and false negatives were less than 15%. For the purpose of classification and analysis, the result of glaucoma hemifield test (GHT), the visual field index (VFI), the mean deviation (MD) and the pattern standard deviation (PSD) along with their respective probability (P) values were obtained from the visual fields printouts and were filled into a purpose made questionnaire, from where these were entered into the database.

DATA ANALYSIS

All the data was entered into and analyzed by using Statistical Package for Social Sciences (SPSSV-21) developed by IBM. All quantitative variables used in the study like age were expressed as the mean ± standard deviation.The qualitative variables like gender were presented in the form of frequency and percentage. Parametric variables were compared using independent Student's *t*-tests, whereas the chi-square test was applied for proportions. A *P*-value< 0.05 was taken to be statistically significant. Diagnostic accuracy, sensitivity, specificity, positive predictive value and negative predictive value of SITA SWAP was calculated by constructing a 2x2 table by taking SITA SAP as a gold standard.

RESULTS

125 participants were studied. Among these, 70 subjects (62.40%) were in the 35-45 years age group and 47 subjects (37.60%) were in the 51-65 years age group.Out of these 125 subjects, 70 were males (56%) and 55 were females (44%). Characteristics of the cohort including age, gender, baseline (untreated) intraocular pressure, and central corneal thickness (CCT) were analyzed. These are expressed in table no. 5. Of these, age and baseline intraocular pressure reached statistical significance ($P < 0.05$),(Table 1). A total of 19 patients (15.2%) converted during the follow-up period. 2 patients converted in both eyes simultaneously. SWAP showed earlier conversion in 5 patients (26.31%). In these patients, SAP conversion followed within 12 months. SWAP reproducible defects not meeting conversion criteria appeared in 5 more patients, but SAP fields in these patients remained normal or did not meet conversion criteria throughout the study period. In 12 patients, the conversion happened simultaneously (63.15%). In 2 eyes, SAP conversion occurred before SWAP (10.52%). 106 patients remained non-converted during the study period (84.8%). These details are explained in (Table 2 & 3). Sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy for SITA-SWAP was also calculated. Its details are given in (Table 4). The average of mean deviation (MD) and pattern standard deviation (PSD) was also derived from all the test reports for both SAP and SWAP and is expressed in (Table 5).

TABLE No. 1
Patient characteristics
n= 125

	Non-converters (n = 106)	Converters (n = 19)	*P*-value
Age(years)	45.32 ± 14.12	51.13 ± 10.35	0.0311[*±]
Male	59 (84.2%)	11 (15.7%)	0.9217[±]
Female	47 (85.4%)	8 (14.5%)	
Intraocular pressure (baseline, untreated), mmHg	25.2 ± 5.1	27.3 ± 3.2	0.0137[*±]
CCT (microns)	552 ± 25	555 ± 29	0.5754[*±]

Notes:

[*]*P*-value for *t*-test;

[+]*P*-value for chi-square test; significance level <0.05.

Abbreviation: CCT, central corneal thickness.

TABLE No. 2

RATEOF CONVERSION TO GLAUCOMA (n=125)

Glaucoma	No. of patients	%
Yes	19	15.2
No	106	84.8
Total	125	100

TABLE No. 3
Percentages of earlier detection of conversion (n=125)

Glaucoma	No. of patients	%
SAP	2	10.52
SWAP	5	26.31
BOTH Simultaneously	12	63.15
Total Converted	19	100

TABLE No. 4
Diagnostic accuracy of sita SWAP 24-2 to diagnose glaucoma in oht patients taking SITA SAP 24-2 AS Gold Standard (n=125)

SITA SWAP 24-2	SITA SAP 24-2	
	Positive	Negative
+ve	a (True Positive) 12 (9.6%)	b (False Positive) 5(4.0%)
-ve	c (False Negative) 2 (1.6%)	d (True Negative) 106(84.8%)
Total	a + c 14 (11.2%)	b + d 111 (88.8%)

Different parameters were calculated by using these formulas:

Sensitivity = a/a+c x 100=85.71%
Specificity = d/b+d x100=95.49%
Positive Predictive Value = a/a+b x100=70.58%
Negative Predictive Value =d/c+d x100=98.14%
Diagnostic Accuracy = TP+TN/TP+TN+FP+FNx100=94.4%

TABLE No. 5
Mean valuesof md and psd
(n=125)

Global Indices	Mean values for SAP	Mean Values for SWAP
MD	-2.63 dB	-5.58 dB
PSD	+2.54 dB	+3.54 dB

DISCUSSION

In our study, 15.2% of ocular hypertensive patients converted to primary open-angle glaucoma. 26.31% of glaucoma conversions were picked earlier with SITA-SWAP, 63.15% were detected simultaneously in both SITA-SWAP and SITA-SAP, and 10.52% were only picked by SITA-SAP and not detected with SWAP during the follow-up period. Moreover, 4% of patients demonstrated some sort of visual field defects on SITA-SWAP that did not show up on SITA-SAP during the follow-up period. The percentage of patients in whom SWAP detected either earlier or simultaneous conversion with SAP was 89.47%. The percentage of patients in whom SAP detected either earlier or simultaneous conversion with SWAP was 73.68%. As SAP is considered the gold standard for visual fields,

SWAP values were compared to SAP values in 2 by 2 tables to calculate sensitivity, specificity and accuracy for SWAP. From these results it evident that in a subset of patients, SWAP is able to detect glaucomatous field detects earlier than SAP does. However, in the majority of patients, both of these modalities were equally good as both picked the findings simultaneously. In another smaller subgroup, SAP was better than SWAP. So it appears that if both of these tests are performed together, sensitivity is significantly increased and none is definitely superior to others in all patients.

Numerous studies in the past reported that SWAP can not only pick glaucomatous field defects earlier than SAP but also the rate of progression is more with SWAP in early stages of glaucoma.[3-7] On the contrary, some other studies are contradicting these findings e.g. a study by van der Schoot et al reported that63% of conversions occurred earlier in SAP.[8]Soliman et al also reported similar findings that SAP is more efficient in detecting VF loss in Glaucoma and in OHT. He concluded that the normative database used by machines is flawed and not from the same population.[9]Takada et al and Mattos et al also reported that SAP with stimulus size-I is more sensitive than SWAP with stimulus size-V in detecting early glaucomatous defects.[10,11]

The normative database used by SAP and SWAP comes from different populations. The criteria to detect VF abnormalities weredifferent in SAP and SWAP. It is important to reconfirm any VF defects because they can appear by chance as was shown in the Ocular Hypertension Treatment Study which said 86% defects picked in the first report were absent in the second one due to patient learning effect.[12]The assumption that a subset of ganglion cells either magnocellular or koniocellular that are tested in FDT and SWAP respectively may not be true. Others have found that glaucoma affects all kinds of ganglion cells even in early stages.[13-18]

LIMITATIONS IN OUR STUDY

The learning effect for SWAP is longer than that of SAP and the patient's experience in SAP does not apply to SWAP. In other words, the defects picked only by SWAP could be learning artifacts instead of true defects.[19-21]This the study only looked at the ability of SAP and SWAP to pick the first visual field defect at the point of conversion from OHT to POAG.

CONCLUSION

It appears that if both of these tests are performed together, sensitivity is significantly increased and none is definitely superior to others in all patients. No single test is perfect in all situations and one should consider using both SAP and SWAP visual fields with re-confirmation of the defects if evident in the first report, as well as utilizing the technologies that detect structural changes corresponding to the functional loss in optic nerve head, nerve fiber layer and ganglion cell complex.

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