Original Article

Validating tablet perimetry against standard Humphrey Visual Field Analyzer for glaucoma screening in Indian population

Parul Ichhpujani[1], Sahil Thakur[1,2], Roopjit K Sahi[1], Suresh Kumar[1]

Purpose: The aim of this study was to determine the correlation between the perimetric outcomes using a free application program of the iPad, 'Visual Fields Easy' (VFE), and Humphrey Visual Field Analyzer (HVFA), in normal as well as eyes with glaucomatous damage of varying severity. **Methods:** In this prospective, cross-sectional, observational pilot investigation, visual field testing was carried out in 210 eyes of 210 patients (60 Normal, 150 Glaucoma), using suprathreshold VFE application (Version 8) on the iPad and Standard White-on-White using HVFA. Severity of glaucoma was categorized using Hodapp-Anderson-Parrish criteria for visual field defects. The results of the VFE program were compared to the 24-2 SITA FAST HVFA. **Results:** Data of 210 patients, 100 (47.6%) females, and 110 (52.4%) males, age ranging from 42 to 78 years, Mean 56.64 ± 10.67 years, was analyzed. The Spearman correlation coefficient showed a significant inverse relationship between missed points on the VFE app with MD (S = –0.783) and a parabolic relationship with PSD (S = 0.646) values obtained with the HVFA. As regards missed points, for mild glaucoma, missed points were 37.5, sensitivity was 77.8% and specificity was 52.6%; for moderate glaucoma, missed points were 33.5, sensitivity was 90% and specificity was 48% while for severe glaucoma, missed points were 23, sensitivity was 97% and specificity was 70%. AROC for eyes with mild glaucoma versus normal was 0.419 (95% CI: 0.343-0.495), moderate glaucoma versus normal was 0.705 (95% CI: 0.630-0.780) and severe glaucoma versus normal was 0.857 (95% CI: 0.806-0.908). **Conclusion:** Suprathreshold perimetry using VFE is not suitable as a rapid screening tool for mass screening of glaucoma. VFE cannot be used as a substitute for HVFA in clinic because of its inability to detect early or moderate glaucoma.

Key words: Suprathreshold testing, tablet perimetry, Visual Fields Easy

Glaucoma is an optic neuropathy with associated raised intraocular pressure (IOP), along with optic nerve head changes and corresponding visual field changes.[1] Glaucoma is very rightly labeled as the *silent thief of sight* as it generally does not present with any symptoms in its early stages, resulting in many patients being unaware that they suffer from it until the patient develops significant visual field loss.

Currently, achromatic perimetry using Humphrey's visual field analyzer (HVFA) is the "gold" standard to assess the visual field loss.[1] HVFA however is a bulky, non-portable and an expensive device, therefore its utility is limited in rural areas.[2] Additionally, patients with glaucoma who are sick and/ or non-ambulatory cannot visit a hospital facility frequently for getting their visual fields assessed using HVFA.[3,4] An alternative method of visual field testing would be helpful to monitor disease progression for such patients. In this digital era, technology has been developed to provide solutions for almost every human problem. Application programs (apps) are now used to monitor physical activities; to check blood sugar levels, to remind patients of their medication schedule and for many more health-related issues.[5] In recent times, applications on tablets have also been developed for visual field screening.[2]

Visual Fields Easy (VFE), developed by George Kong software, is a "free of cost" application available on iPad that uses the iPad screen to perform a fast screening test of the visual fields.[2,3,6] This app uses the suprathreshold method of visual fields testing to detect gross abnormalities in the visual field. It is now possible to perform visual field screenings in remote areas of the world where access to bulky medical equipment is limited using tablet-based applications like VFE.[6] The only cost involved is the cost of the tablet, which is minimal (approximately Rupees 35,000) as compared to that of an HVFA (cheapest device also costs approximately Rupees Ten lakhs).

A study in Nepal has shown the app to be of use in detecting visual field loss in patients with glaucoma and diabetic retinopathy.[6] Johnson *et al.* correlated their results with an HVFA using 24-2 SITA Standard tests. Since no such study has been conducted in India where the majority of the population resides in resource-limited areas, this study might help us to evaluate the utility of this app for established glaucoma patients. The present study aimed to determine the correlation

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between the perimetric outcomes using 'Visual Fields Easy' app and HVFA using 24-2 SITA Fast tests, in normal as well as eyes with glaucomatous damage of varying severity.

Methods

The current study was a prospective, cross-sectional, observational pilot investigation. We conducted this as a pilot study hence no sample size was calculated. Consecutive subjects with refractive errors presenting to Ophthalmology Outpatient services were enrolled as controls while consecutive patients with primary open-angle glaucoma (POAG), attending the Glaucoma Services of a tertiary care center of North India, were enrolled as cases after approval from the Institutional Review Board. Written informed consent was obtained from all recruited individuals. The study adhered to the tenets of the declaration of Helsinki.

Inclusion criteria

Subjects of either gender, in the age range of 18 to 70 years were enrolled. Controls had no ocular pathology while individuals with POAG,[7] with varying severity classified on the basis of the Hodapp, Anderson, and Parrish (HAP) classification[8] formed the patient group. The diagnosis of POAG was made if the patient had gonioscopically open angle and evidence of optic nerve damage from either, or both optic disc/RNFL structural abnormalities and reliable reproducible visual field defects. All enrollees had best-corrected visual acuity better than or equal to 20/40 to undertake the VFE test.

All controls as well as patients underwent a detailed slit lamp examination. The fundus examination and visual field assessment was done by a trained glaucoma specialist.

To ensure that patients with a full range of glaucomatous damage are included; selection was based partially on the amount of optic disc damage. The Disc Damage Likelihood Scale (DDLS) was used to evaluate the extent of optic disc damage caused by glaucoma. The DDLS generates a score from 1 to 10 based on the rim/disc ratio (rather than cup/disc ratio) and the size of the optic nerve. The IOP was measured using Goldmann Applanation Tonometer. Only one eye (better eye) per patient was included for study.

Exclusion criteria

Patients with significant cataract (greater than LOCS III grade 2), corneal opacity or degeneration, history of trauma or recent ophthalmic surgery, ocular inflammatory condition such as uveitis, history of diabetes, concomitant retinal or macular disease were excluded. Patients with any medical condition, which precluded them from providing reliable and valid data (e.g., cognitive impairment, Parkinson's disease, Alzheimer's disease and any other neurological or musculoskeletal disease) were also not enrolled. Disc suspects and any patient with an abnormal appearing disc such as tilted disc or congenital disc anomalies were also excluded from the study.

Achromatic perimetry with the HVFA

All subjects underwent achromatic perimetry on the Humphrey's Field Analyzer HFA 750 II (Carl Zeiss-Humphrey Systems, Dublin, California, USA), using the 24-2 SITA-Fast strategy. The visual fields were considered satisfactory if false-positive (FP) and false-negative (FN) errors did not exceed 20% and fixation errors did not exceed 25%.

Visual Fields Easy

The VFE app (https://apps.apple.com/us/app/visualfields-easy/id495389227) was downloaded from the iOS App platform. The VFE program tested 96 visual field locations within the central 30 degrees, using a background luminance of 31.5 apostilbs (10 cd/m²), a size V target (when placed at 33 cm test distance) and a 16 dB suprathreshold static perimetry target for screening purposes. A red fixation point was presented to one corner of the display and one visual field quadrant was assessed, followed by movement of the fixation point to the other corners of the display to test the other three quadrants. Participants responded to detection of a stimulus that was presented for a fixed period of 200 milliseconds by touching the display screen. There was an interval of approximately 1 second between target presentations; however, this could be changed using the setup menu. The images obtained using the test [Fig. 1] were subsequently processed using a parser program manually to provide the results (targets detected, targets missed, FP responses, FN responses) (Parser program was provided to us by the developer of the app). Testing with the VFE app could be completed in less than 4 minutes per eye (Mean: 3 minutes 37 seconds), and preliminary results indicated good screening performance. All our glaucoma subjects had previous experience with achromatic perimetry using HVF analyzer, but none of the participants has a prior experience with perimetry on an iPad. Normal subjects were given single or if needed two trials both on HVF analyzer and the tablet. The tablet was calibrated and positioned using a stand so that the subjects' eye and head location were positioned in line with the fixation target. The testing was monocular, and the other eye was occluded with an eye patch. The tablet was cleaned after every use to make sure no smudges obscured the view of the screen.

Statistical analysis

All statistical analyses were carried out using IBM Statistical Package for Social Sciences (SPSS Version 21 for Windows). Descriptive statistics like mean and standard deviation were calculated for all quantitative variables. Both methods were correlated using Spearman's correlation coefficient. A correlation test was carried out between the number of missed test locations for the VFE screening test demonstrated with the HVFA MD and PSD values. The area under receiver operating curves (AROC) for varying severity of glaucoma were also plotted.

Results

Data of 210 eyes of 210 participants, 84 (40%) females and 126 (60%) males, age ranging from 42 to 78, Mean 56.64 ± 10.67 years, was analyzed. The subgroup distribution is shown in Table 1.

The Spearman correlation coefficient showed a significant inverse relationship between missed points on the VFE app with MD (S = –0.783) and a parabolic relationship with PSD (S = 0.646) values obtained with the HVFA [Fig. 2].

AROC for eyes with mild glaucoma versus normal was 0.419 (CI: 0.343-0.495), moderate glaucoma versus normal was 0.705 (CI: 0.630-0.780) and severe glaucoma versus normal was 0.857 (CI: 0.806-0.908) [Fig. 3].

As regards missed points, for mild glaucoma, missed points were 37.5, sensitivity was 77.8% and specificity was 52.6%; for moderate glaucoma, missed points were 33.5, sensitivity was 90% and specificity was 48% while for severe glaucoma, missed points were 23, sensitivity was 97% and specificity was 70%.
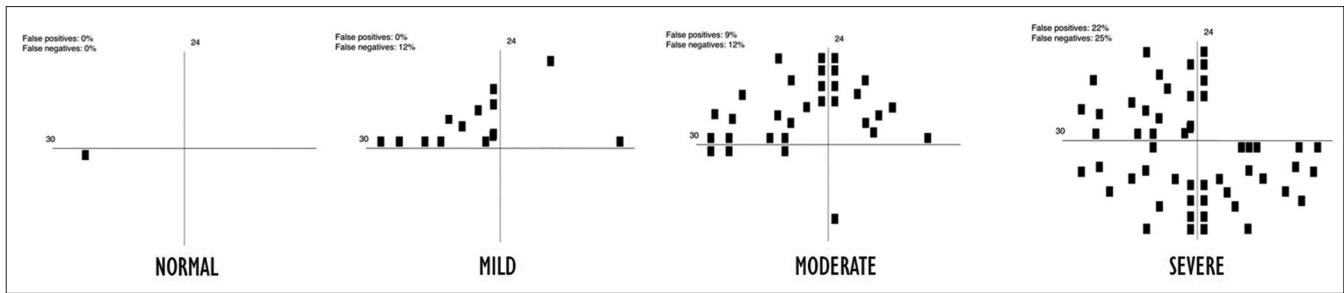
Figure 1: Visual Fields Easy (VFE) output images for normal, mild, moderate and severe glaucoma subjects
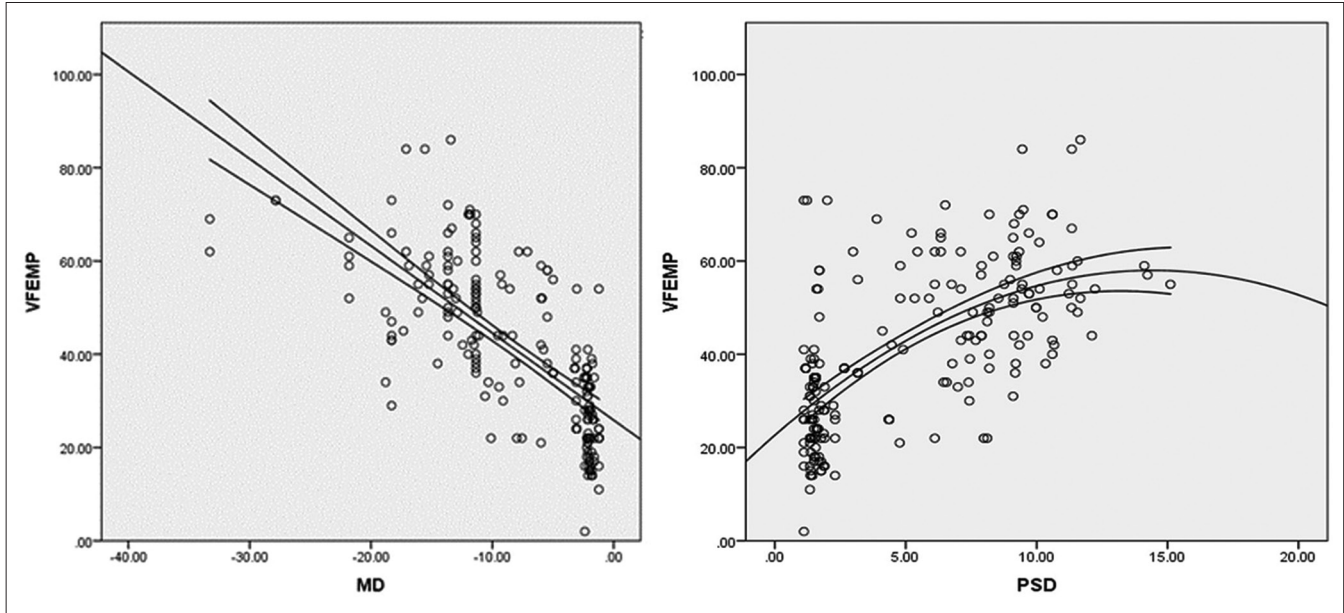

Figure 2: Number of Visual Fields Easy (VFE) missed points (MP) for 210 participants are plotted as a function of Mean Deviation (MD) for a subsequent HVFA 24-2 SITA Standard Program (top left). Number of VFE points that were missed are plotted as a function of Pattern Standard Deviation (PSD) for a subsequent HVFA 24-2 SITA Standard Program (top right). The r values are -0.783 and 0.646 respectively with $P < 0.0001$ for both
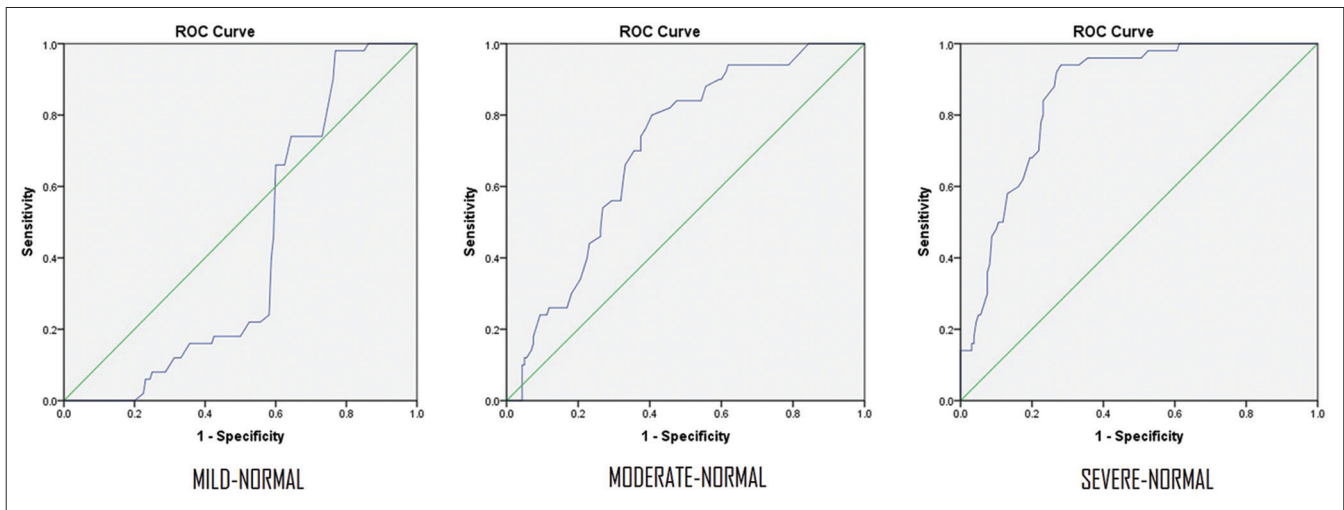

Figure 3: The Receiver Operating Characteristics (ROC) Curves for mild, moderate and severe glaucoma

Discussion

VFE is one of the currently available "free of cost" tablet-based visual field assessment tool that can help clinicians in developing countries to screen patients with increased efficiency and effectiveness.[3,6] With more stress on the functional aspect of glaucomatous field loss, applications like VFE may offer clinicians a cost-effective, practical yet scientifically robust tool

Table 1: Demographic characteristics of the study population (Values: Mean±SD)

	Control	Mild	Moderate	Severe
Subjects (*n*)	60	50	50	50
Gender (M/F)	35/25	30/20	29/21	32/18
Age (years)	50.22±8.67	52.12±7.23	54.78±8.11	60.11±12.33
HVFA				
MD	-2.05±0.45	-3.13±0.60	-8.55±1.39	-17.03±4.85
PSD	1.54±0.31	2.36±1.28	8.61±1.26	8.42±3.39
VFE				
MP	23.50±8.07	36.46±10.01	49.08±13.49	56.88±12.19

VFE: Visual Fields Easy; HVFA: Humphrey Visual Field Analyser; MD: Mean Deviation; PSD: Pattern Standard Deviation; MP: Missed Points

that can effectively reduce the burden of severe glaucoma. The use of these tablet-based visual field analyses along with portable nonmydriatic fundus cameras and IOP measuring devices can effectively give us all parameters needed to diagnose a patient of glaucoma according to current diagnostic guidelines.[4,7] The ability of VFE to predict visual field loss in glaucoma and neurological lesions has previously been documented.[2,3,6]

Previously Santos *et al*., in a study of 137 eyes (77 patients) demonstrated a specificity and a positive predictive value of 100% and a sensitivity of 91% with a negative predictive of 90%.[2] They reported a mean test duration of 3 minutes 21 seconds for VFE and 7 minutes 50 seconds for HVFA. Our results are similar to them but we obtained a sensitivity of 97% and specificity of 70% for a value of 23 missed points for detection of advanced glaucoma using ROC curve analysis.

Our results for early and advanced glaucoma are similar to Johnson *et al*., who demonstrated the efficiency of VFE in the detection of glaucoma and diabetic retinopathy.[6] In our study, the ability to detect moderate disease was poorer than what was reported by Johnson *et al*. They evaluated 206 subjects (411 eyes): 210 normal, 183 glaucoma and 18 with diabetic retinopathy. They reported that VFE was able to detect most visual field deficits with moderate (MD of -6 to -12 dB) and advanced (MD worse than –12 dB) loss, but had greater difficulty in detecting early (MD better than –6 dB) loss, and attributed this to elevated FP response rates in this subset.

The VFE app demonstrated the ability to accurately predict visual field loss in patients with advanced glaucoma. In our study, we also observed the floor effect of the PSD as the MD increased. This resulted in a parabolic relationship that has also been described by Johnson *et al*.[6,9] We also noted a striking difference in the mean duration time between the two tests; the VFE application had a mean test duration of 3 minutes and 37 seconds which was only about half of the mean test duration using the standard HVFA test (6 minutes 30 seconds). Reitner *et al*. have shown that shorter testing times result in increased compliance of patients and lesser fatigue-induced artifacts.[10]

We noted several limitations that affect the VFE application. Primarily the requirement for subjects to touch the display created smudges, that had to be cleaned as these smudges lead to a decrease in quality and contrast sensitivity of the target. Initial targets were also missed in some patients but we gave a trial to all (once or twice, if needed) our patients with the VFE application and hence had considerably less FP and

FN rates. In our experience the need of manual dexterity for accurate dot tracking on the screen, lack of monitoring of gaze/head tracking, inability to retest the spots with bracketing and need of manual processing of VFE printouts with a companion program to get parametric information seem to be the limiting factors in the widespread adoption of this particular application as a means to screen patients with early glaucoma.

We suggest that the suprathreshold perimetry using VFE is not suitable as a tool for mass screening of glaucoma. Our results are not robust enough to support using VFE for screening general populations, although we suggest using this tool for high-risk groups, such as for people with limited or no access to eyecare and nonambulatory or debilitated elderly in old age homes, that way at least cases with advanced glaucoma will get detected. Additionally, VFE cannot be used as a substitute for HVFA in clinic because of its inability to detect early or moderate glaucoma. The developers of VFE have recently come out with an enhanced application for tablet perimetry, called MRF (Melbourne Rapid Fields) that offers a thresholding algorithm and gives output as mean deviation and pattern deviation that are easier to statistically analyze.[11-14] However, the paid nature of the complete application and limited availability and compatibility across iOS platforms/store availability, deters the use of the same for research and screening purposes.

Contrast sensitivity based programs like SPARCS (Spaeth Richman Contrast Sensitivity Test) may offer more flexibility and accuracy in detecting early glaucomatous field loss for screening purposes.[15,16] However, these are computer based and require additional resources like internet connectivity. Development of contrast sensitivity based tablet applications can perhaps bridge the borders between practicality, clinical application, and reliability. This offers an exciting field for further introspection and innovation. Conventional visual field testing till then remains the gold standard but can be used with more efficiency and cost-effectiveness after the preliminary screening with these novel 'wireless' perimetry applications. Even in developed countries with better distribution of health resources, nearly 50% of glaucoma goes undetected; which highlights the need for more versatile, smartphone or tablet-based testing tools for reducing the burden of undiagnosed disease. Although future of technology appears uncertain, newer Artificial Intelligence-based perimetric advancements would definitely add a new dimension to glaucoma screening.[17]

Conclusion

The results of our study show that suprathreshold perimetry with VFE is unsuitable as a rapid screening tool for mass screening for glaucoma. VFE cannot be used as a substitute for HVFA in the clinic owing to its suboptimal sensitivity and specificity to detect early or moderate glaucoma.

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Conflicts of interest
There are no conflicts of interest.

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