Is the 'Visual Fields Easy' Application a Useful Tool to Identify Visual Field Defects in Patients Who Have Suffered a Stroke?

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JS and AB designed the study, wrote the protocol and wrote the first draft of the manuscript. Author JS performed the statistical analysis. Authors AB and CC assisted in the analyses of the data. Author JS managed the literature searches. All authors read and approved the final manuscript.

Article Information

Original Research Article

ABSTRACT

Aims: To determine the level of agreement between the visual Fields easy application (VFE) for iPad and a standard clinical test for assessing peripheral vision in stroke survivors.
Study Design: This was a prospective cross-sectional study comparing the VFE application to the Humphrey Field Analyser (HFA) SITA Fast c30-2 program in identifying and diagnosing visual field defects post-stroke.
Place and Duration of Study: The ophthalmic department at Imperial College Healthcare NHS Trust. Data collection was undertaken between January 2016 and August 2016.
Methodology: A total of 50 participants with a diagnosis of stroke and a suspected visual problem were recruited to the study. Normative data was collected from 50 participants with no history of stroke or visual loss. Analysis comprised of comparing the extent of the visual field loss detected by both the VFE and HFA, and clinically assessing the results for normality.
Results: Bland-Altman analysis demonstrated that with more severe visual field loss, the agreement between both modalities was found to decrease. There was a higher proportion of false negatives

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with the VFE compared to the HVF. The bias towards detecting more missed test locations with the VFE application compared to the HFA was 6% for the normal participants and 2% for the stroke participants. The limits of agreement between the two modalities were large; 20% and 40% for the normal and stroke participants respectively. The sensitivity of the VFE application to determine an abnormal visual field in comparison to HFA was 88% and specificity was 76% in the stroke cohort based upon a clinical impression of its findings. The majority of stroke participants (88%) found the VFE test more comfortable to perform.

Conclusion: As a screening tool, the VFE application is quick and easy to administer, preferred by patients and has good sensitivity and specificity for detecting the presence of an abnormal visual field when compared to HFA. In patients with extensive visual field loss, the VFE may overestimate visual field reduction.

1. INTRODUCTION

Stroke is a common condition in the United Kingdom, estimated to occur in approximately 152,000 people per annum [1] and is a leading cause of adult disability [2]. Any visual dysfunction following stroke can affect the overall rehabilitation of the patient and their overall quality of life [3–6]. Approximately 60% of patients suffer visual impairment immediately post-stroke [3,7,8]. If correctly identified, patients with visual field loss after stroke may be eligible for treatments to help with restitution of the visual field or use of compensatory strategies [9].

A reduction in the visual field is observed in 8-67% of stroke survivors, but this may also be related to previous strokes or ocular pathology [3,5,10–13]. The wide variation in the cited incidence of visual field defects could be related to the timing of the visual field assessment [14], and the limitations of bedside visual field testing, including its subjective nature, inter-observer variability, and variations in methodology and documentation [15]. The diagnostic accuracy of referrals by the multidisciplinary stroke team is lower when there are no visible ocular 'signs' of dysfunction such as with visual field loss [16]. It is also acknowledged that many stroke patients are not referred for a visual assessment, as a problem is not suspected. Indeed 10% of stroke patients with a visual field defect are not subjectively aware of a problem [3].

Automated visual field assessment with static testing strategies, such as those employed by the Humphrey Visual Field analyser, (The HFA II-I, Humphrey Instruments, Dublin, CA), are extensively used to identify field abnormalities in neurologic diseases [17,18]. However, to comply with formal testing, patients are required to have sufficient mobility, be able to sit upright at the perimeter, and sufficient cognition to concentrate for approximately 20 minutes. Should a patient not be able to concentrate or manoeuvre to perform a Humphrey visual field assessment, the confrontation visual field assessment is often the only viable alternative.

The confrontation method of visual field assessments is a gross, qualitative method, whereby a clinician will ask the participant to cover one eye and identify a hand or finger in the periphery while concentrating on a point, usually the clinicians eye. Notable advantages are that it does not require any special equipment and is therefore inexpensive and available to underdeveloped settings worldwide. It can also be performed in a variety of environments including a non-upright patient position. The test is quick to perform, and maintains direct interaction with the patient, making the assessment less intimidating [19]. However, the confrontation test is less than ideal for several reasons. It is not a standardised procedure and several variations of the method exist [20]. There is significant inter-examiner variation in technique, sensitivity and documentation [21,22]. It requires a skilled and experienced professional to administer and evaluate the test and is therefore costly in terms of clinician time. Even then only gross visual field defects are detected [19].

The limitations of the confrontation method and subsequent attempts at developing alternative strategies demonstrate the need for a quantitative, simple, fast, accurate and portable method of visual field testing, suitable for those with impaired mobility and concentration. The development of smartphone and tablet based technologies, such as the Apple iPad (iPad model 2, by Apple Inc, USA.), and their use in healthcare and research has become more

widespread [23]. Applications have been developed to examine the visual field on tablet computers. In order to evaluate the usefulness of such applications in stroke patients and controls, the visualFields easy application has been selected for investigation, to establish its sensitivity to detect visual field defects in the stroke population.

2. METHODOLOGY

This was a prospective cross-sectional study comparing the visualFields easy app to the HFA SITA Fast c30-2 program in identifying and diagnosing visual field defects post-stroke. All stroke survivors referred to the Visual Field Service at Imperial College Healthcare NHS Trust who met the study criteria were offered inclusion.

The target population comprised of a census of patients with any undifferentiated visual difficulty following a stroke. Referrals were made from inpatient wards, rehabilitation units, and community service or outpatient stroke and ophthalmology clinics. Participants were excluded if they were under 18 years, had only suffered a transient ischaemic attack or had a history of self-reported visual field loss prior to the stroke. All participants had a visual acuity of 6/60 Snellen or better in either eye.

Normative data were collected from an equal number of healthy volunteers who were recruited from hospital staff, students and volunteers. They were required to meet the same inclusion criteria as the stroke survivors, and all of them had no history of stroke.

All participants provided full written consent before participation in the study. Block randomisation was used as to which modality and which eye was tested first, to help reduce the effects of fatigue and any learning effect seen in visual field assessment [24]. The right eye was primarily used for analysis but a repeat analysis was also performed on data from the left eye, to check for consistency.

2.1 Instruments

Visual field assessments were performed using the HFA SITA Fast c30-2 program on the Humphrey Field Analyser (HFA) II- model and the visualFields easy app (VFE) on an iPad. The hardware used was the iPad model 2 developed by Apple Inc., USA. The software was the visualFields easy application version 8.0 developed by George Kong Softwares. Although every effort was made to ensure test conditions were as similar as possible between tests, such as the ambient room lighting there were technical differences between the two tests. A summary of the technical specifications and differences between the modalities is provided (Table 1).

Instructions of the testing process were included on the participant information sheet; this was supplemented with detailed verbal instructions on how to perform a visual field test during the assessment. Participants completed the demonstration programme of both modalities, which acted as a brief practice of the test procedure. Assessment with the HFA perimeter was performed as per manufacturer guidelines [25]. Participants sat upright at the perimeter with head positioned against a bar and chin rest and eye aligned with the central point. Each eye was assessed as per block randomisation whilst the other eye was occluded with a patch. Corrective lenses were used according to their age and known refractive error. Stroke participants held the buzzer with their strongest hand at the time of testing and the dominant hand was used in the control group. Participants used the same hand to press the buzzer or tap iPad screen in both tests. The principal investigator observed the accuracy of the test by monitoring fixation losses and false negatives. Patients were given reminder prompts as to the test instructions when fixation losses occurred. The procedure was then repeated with the alternate eye. A minimum of 1-minute rest was allowed between testing each eye to help minimise error from fatigue. There was no on demand pause facility available for the VFE test, however a pause was possible before the machine moved from testing one quadrant of the visual field to the next.

For the VFE application, manufacturer instructions were brief (Fig. 1), but perimetry was undertaken with the following considerations. The participant sat with the iPad held at 33 cm and wore their own glasses for this test if they had a pair. The iPad was supported by a height adjustable table, but the examiner also supported the iPad with a hand to prevent it falling or being pushed further back by the participant. The examiner observed the head position of the participant to ensure the correct head position remained as close as possible to the 33 cm required distance. The participant was required to focus on a red fixation target, which was placed in one corner of the iPad screen and tap

on the screen every time the white stimulus light was shown, each quadrant of the visual field was tested sequentially. The examiner manually observed fixation to ensure the eye remained

Table 1. Technical specifications of hardware and software for the visual fields easy application and Humphrey Visual Field Analyzer (HFA) SITA Fast c30-2 program

|	Visual fields easy app	HFA II-i SITA Fast c30-2
Number of locations tested	96	76
Background luminance	31.5 apostilb	31.5 apostilb
Ambient lighting	Dimmed in clinic room + iPad screen fixed at default setting	Dimmed in clinic room
Fixation target	Corner of display	Central point
Programme Threshold	Suprathreshold	Threshold
Stimulus Size (cf Goldmann)	Goldmann size V	Goldmann size III
Stimulus Luminosity (decibels)	16 dB	varied over 51 dB
Pace (seconds)	Stimulus display 1s, delay 0.4s	Adaptive
Static/Kinetic	Static	Static
Test distance (cm)	Free space at 33 cm	Fixed at 30 cm
Test area (degrees)	30°horizontal; 24°vertical	30°horizontal; 24°vertical
Refractive correction	Own lenses	Integrated lens holder
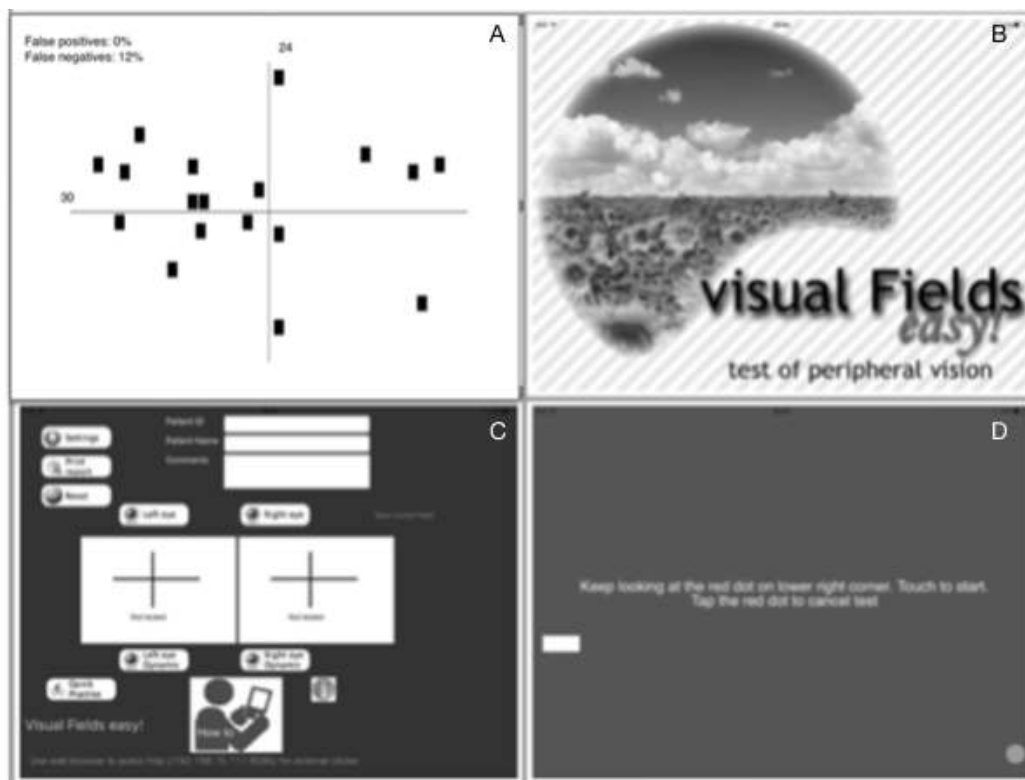
Fig. 1. Screen captures from the VFE application interface pages. Image [A] Sample copy of visual field report graphic for a right eye assessment. Image [B] Application title page. Image [C] User interface for patient details and test selection. Image [D] Patient instruction page prior to testing a quadrant of the visual field

still. However, observing patient's fixation was difficult without the aid of an internal camera or telescope as with other perimeters. Information on false positive and negative responses was not available during the test and could only be examined after the test had finished. A minimum of one minute's rest was given between assessments. A record of the duration of the VFE test was performed manually by the principal investigator as the application did not provide this data.

2.2 Visual Field Status

The visualFields easy app provides raw data on the number of unseen test points, in addition to false positive and negative responses, allowing for an assessment of field validity.

This was compared directly to the age and sensitivity-adjusted decibel data of the pattern deviation map provided by the HFA; a test point was considered "missed" if it deviated by p <1% [26].

Due to the different number of test locations between the modalities, a percentage of missed test stimuli on the application was compared to the percentage of missed test stimuli on the HFA. Statistical agreement between the measures was assessed using the Bland-Altman technique [27].

The ability of the application to detect a normal or abnormal visual field was compared to the results from the HFA SITA Fast c30-2. The HFA would classify visual fields as normal, abnormal or borderline. The assessment of normality for the VFE was made by the principal investigator based upon clinical impression in a later review of all the VFE results. The investigator was blinded to the results of participant identity and the results of the HFA, when assessing the visual field for normality. Sensitivity, specificity, positive and negative predictive values were then calculated with Fisher's exact test using Graphpad Prism V6 for Mac, USA.

All of the required assessments were completed within a 24-hour period and the majority were completed within one patient encounter, to minimise any effect of changes within the visual field. The year of stroke incidence ranged from 1988 to 2016, this was skewed as several patients were referred to the department a number of years after their stroke. A clear majority of participants (86%) experienced their stroke during the recruitment period of the study.

2.3 Qualitative Feedback

Following the assessment of both visual field tests participants were asked the following closed questions:

1. With which test did you find it easier to keep your eyes still?
2. Which test felt the most comfortable to perform?
3. Would you be interested in testing your own visual field with an application at home?

2.4 Sample Size Justification

As recommended by Bland [3] a total of 100 participants were recruited to this study for Bland-Altman analysis, comprising 50 stroke participants and 50 from normative group who were analysed as separate groups and in a combined data plot.

2.5 Ethical Approval

This Study was approved by Stanmore Research Ethics Committee (Reference16/LO/0102) and Imperial College Healthcare NHS Trust.

3. RESULTS AND DISCUSSION

3.1 Background Results

Overall 62 patients were referred to the Orthoptic and Visual Field Service for assessment during the recruitment period of this study. Of those not recruited, reasons included: declined to be involved as felt unwell (n=3), transferred/ discharged before enrolment commenced (n=4), known history of previous visual field loss (n=4). A total of 51 patients were recruited into the study, one patient was able to complete the iPad assessment but not able to sit at the HFA and was excluded at that point. Of the patients recruited from the stroke population 70% were male (n= 35) and 30% female (n=15). The mean age was 62 years (range 27-88: SD 17 years). A total of 50 healthy participants were recruited to generate normative data, 64% were female ,due to a higher proportion of female staff and students at the hospital (n=32) and 36% male (n=18). The mean age of the normative group was 46 years (range 20-91: SD 19 years).

3.2 Comparing the Extent of Visual Field Loss

The extent of visual field loss was assessed by totalling the number of unseen test points from each modality. This was then expressed as a percentage as the number of test locations varied between modalities, with 76 test point locations for the HFA C30-2 program and 96 for VFE. A paired t-test was performed on the data collected from the HFA and VFE for both stroke and normal groups with right and left eyes. The t-test was used to investigate any significant difference between the extent of visual field loss detected between the two tests.

In the control group the HFA demonstrated statically fewer missed test points than the VFE, assessed by a paired t-test in the right eye, t (49) = 5.7, $P = <.005$ and left eye t (49) = 4.9, $P = <.005$, data sets. However, for the stroke population the paired t-test showed no statistically significant difference in the number of missed test points, between the HFA and VFE for both the data collected from the right eye t (49) = 0.82, $P = .41$ and left eye, t (49) = .06, $P = 0.94$.

The level of agreement was further assessed through Bland-Altman plots. Fig. 2 shows right eye data for the stroke group. Fig. 3 shows combined stroke and control group data from the right eye. The plots show that as more missed points are detected, the agreement between the two modalities reduces. The charts also demonstrate wide limits of agreement between both modalities.
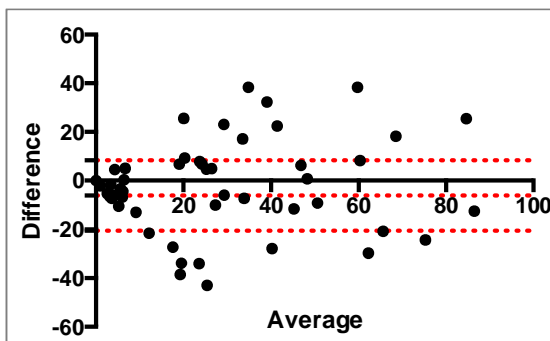

Fig. 2. Bland-Altman plots of unseen test points (%) between the HFA and VFE for the right eye of stroke groups
The middle scored line represents the mean bias. The upper and lower scored lines represent the upper and lower 95% Limits of Agreement. N=50
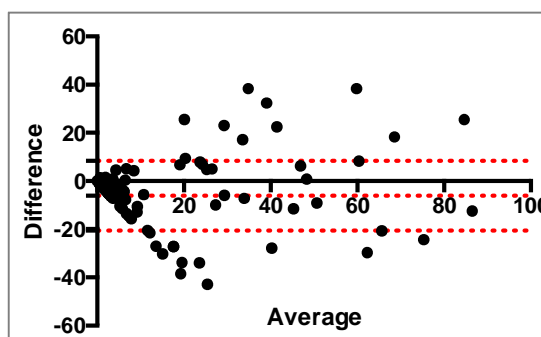

Fig. 3. Bland-Altman plots of unseen test points (%) between the HFA and VFE for the right eye of stroke and control groups combined
The middle scored line represents the mean bias. The upper and lower scored lines represent the upper and lower 95% Limits of Agreement. N=100

Descriptive statistics to accompany the agreement plots are provided in Table 2.

3.3 Detecting an Abnormal Visual Field

To establish if the VFE application could be used to detect the presence of an abnormal visual field, sensitivity and specificity values were calculated using Fisher's exact test. Values relating to the applications ability as to detect an abnormal visual field are given in Table 3.

3.4 Test Duration

A comparison of test times between the HFA and VFE was performed with a paired samples t-test. In the stroke group HFA had a longer mean test time by 01:36 (mm:ss) (95% CI, 02:01 to 01:10) than VFE, t=7.491, p < .0005, effect size was large at d=1.0. In the control group VFE had the longer test time by 00:08 (mm:ss) (95% CI, 00:01-00:16) than the HFA, t= 2.3, p<.020, effect size was small d=0. 3. The largest range for test time was for the HFA analyses of stroke patients (Fig. 4).

3.5 Participant Feedback

In the stroke group 88% of participants found the VFE test more comfortable to perform, and 22% indicated they would be interested in using the application to test their visual field at home. In addition, 64% of the stroke group found it easier to fixate on the central target with the VFE application. In the control group 58% found the VFE application the more comfortable, and 56% found it easier to hold steady fixation with the HFA.

Table 2. Descriptive statistics for Bland-Altman analysis

	% of unseen test points identified		
	Stroke group RE	Normal group RE	Combined groups RE
Bias (mean)	-2.39	-6.14	-4.17
SD of Bias	19.21	7.36	14.55
Lower 95 % Limit of agreement	-40.04	-20.58	-32.69
Upper 95% Limit of agreement	35.26	8.298	24.33
Coefficient of agreement	37.31	14.33	29.29

Data collected for the right eye (RE) of the Stroke and Normal populations, and both populations together in a combined group

Table 3. Sensitivity and specificity, and predictive values for detecting visual field loss with the VFE application

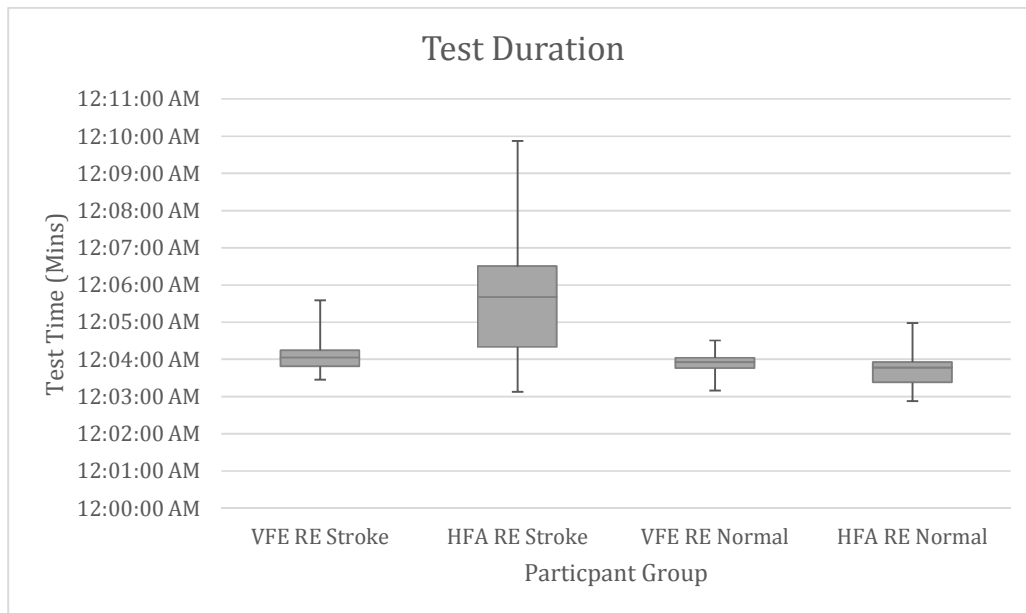|	RE stroke group (95% CI)	LE stroke group (95% CI)
Sensitivity	0.89 (0.73-0.96)	0.85 (0.67 – 0.94)
Specificity	0.76 (0.55-0.89)	0.77 (0.57- 0.90)
+VE predictive value	0.83(0.66- 0.93)	0.82 (0.64 – 0.92)
-VE predictive value	0.84 (0.62-0.94)	0.81 (0.6 – 0.92)
P value	<.001	<.001

Fig. 4. Test durations for data gathered from the right eye for the stroke and control groups with both test types

3.6 Discussion

This study compared the VFE application to the HFA SITA Fast C30-2 programme in stroke survivors and in a control population. When assessing the agreement between the modalities a visual inspection of the Bland-Altman plots highlighted that when the magnitude of field loss was small there was good agreement between both measures. This suggests that the VFE can be a useful tool in ruling out diffuse dense visual field loss. However, there was a larger disagreement as the magnitude of field loss increased.

When assessing the extent of visual field loss, there is a tendency for the VFE application to detect a higher proportion of unseen test points. The mean bias for the normal group was an overestimation of missed visual field test points

by 6% and 2% in the stroke population in comparison to the HFA 'Gold Standard'. For the purpose of screening for stroke related visual field loss this figure may be of only limited clinical significance.

However, for both the normative and stroke populations the upper and lower 95% Limits of Agreement are large and provide clinically ambiguous data, the results of the Bland-Altman analysis suggest the VFE is not an identical comparison to the HFA c30-2 reference test.

In order to validate the tests usefulness as a screening tool in stroke patients, the VFE results were classified as normal or abnormal and results then compared to the HFA. This is possibly of most clinical significance in screening for visual field loss and an essential function of the confrontation method [28]. For the stroke group, sensitivity was high at 89% and 85% respectively for right and left eyes. Specificity was lower at 76% which fits with previous explanations that the VFE application is hypersensitive to field loss [29]. Positive and negative predictive values were also high at 0.83 and 0.84. Cassidy [15] found the standard confrontation method to have 94% sensitivity for detection of visual field loss on patients admitted for stroke, however, this fell to 56% in subsequent weeks as the visual field improved. Studies on the confrontation method concluded its sensitivity and specificity depended on the type, density and cause of the visual field defect as well as the type of confrontation method used [28]. In Kerr's study [28] the highest levels of sensitivity and specificity were 74% and 93% respectively on confrontation.

Comparing the test duration times between the HFA SITA Fast c30-2 and the VFE demonstrated a longer test time when using the VFE in the normative group. Although the increased test duration was on average 8 seconds, this was not clinically significant. For the stroke population, which comprised patients with visual field loss, the VFE application was quicker by an average of 1 minute 36 seconds. Whilst the HFA c30-2 algorithm rechecks test locations on multiple occasions at various light intensities, this is not true of the VFE which checks using the same stimulus intensity at every location. However the lesser test time of the VFE for stroke survivors may be of some clinical significance for initial assessments as stroke survivors are more prone to fatigue [30] which can impact on the reliability of visual field tests [31].

Qualitative results of the patient's experience with the tests were interesting. In this study 88% of stroke survivors found the VFE test more comfortable to perform, relatively few patients (22%) were interested in evaluating their visual field at home using the VFE.

The results suggest that the VFE is a promising screening tool for visual field assessment in stroke survivors but is not intended to replace standard perimetry. Further study should compare it to the visual fields to conformation method which is the main alternative used in bedside visual field assessments. Further study would include collection of longitudinal data make comparisons of the applications sensitivity and specificity over time and examine the repeatability of the test. Repeated testing with the application may have improved the overall accuracy of the assessment and shortened testing time, due to the known learning effects in visual field assessment [32]. It would also be beneficial to study a census of patients in the stroke unit, as the population studied here were preselected to have a likely visual problem, and the ability to attend the outpatient clinic. Assessments of visual neglect which can be confused with visual field loss were not controlled for as part of this study. Similarly, to the confrontation fields method the VFE application is a portable, quick and easy to use method of visual field assessment, which was well tolerated by patients. However, from experience the confrontation field method is a more rapid method of assessment, and it is easier to observe the patient's fixation during the process. The VFE application has the additional advantages of producing electronic reports which can be added to patient records and may be delivered by all types staff with minimal training.

4. CONCLUSION

As a screening tool, the VFE application was quick and easy to administer, preferred by patients and demonstrated good sensitivity and specificity for detecting the presence of an abnormal visual field when compared to HFA. The VFE app had a similar test time in the normative group to the HFA and in the Stroke group was faster by 1 minute 36 seconds which has the potential to be clinically advantageous. There was a tendency for the VFE application to over-detect missed test points, which was more evident in the normative group. The application has several advantages over the confrontation method and could be a useful adjunct to the bedside vision assessment. It may bridge the

gap until patients are able to perform verified perimetry.

CONSENT

All authors declare that written informed consent was obtained from the patient (or other approved parties) for publication of this paper and accompanying images.

ETHICAL APPROVAL

This study was approved by Stanmore Research Ethics Committee (Reference 16/LO/0102) and Imperial College Healthcare NHS Trust.

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Stroke Association. Stroke Statistics; 2013.
2. Adamson J, Beswick A, Ebrahim S. Is stroke the most common cause of disability? J. Stroke Cerebrovasc. Dis. [Internet]. 2004;13(4):171–7.
3. Rowe F, Brand D, Jackson CA, Price A, Walker L, Harrison S, et al. Visual impairment following stroke: Do stroke patients require vision assessment? Age Ageing. 2009;38(2):188–93.
4. Jones SA, Shinton RA. Improving outcome in stroke patients with visual problems. Age Ageing. 2006;35(6):560–5.
5. MacIntosh C. Stroke re-visited: Visual problems following stroke and their effect on rehabilitation. Br. Orthopt. J. 2003; 60:10–14.
6. Ramrattan RS, Wolfs RC, Panda-Jonas S, Jonas JB, Bakker D, Pols HA, et al. Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: The Rotterdam Study. Arch. Ophthalmol. 2001; 119(12):1788–94.
7. Khan S, Leung E, Jay WM. Stroke and visual rehabilitation. Top. Stroke Rehabil. 2008;15(1):27-36.
8. Gray CS, French JM, Bates D, Cartlidge NE, Venables GS, James OF. Recovery of visual fields in acute stroke: Homonymous hemianopia associated with adverse prognosis. Age Ageing. 1989;18(6):419–21.
9. Pollock A, Hazelton C, Henderson CA, Angilley J, Dhillon B, Langhorne P, et al. Interventions for visual field defects in patients with stroke. Stroke. 2012; 43(4):37–38.
10. Suchoff IB, Kapoor N, Ciuffreda KJ, Rutner D, Han E, Craig S. The frequency of occurrence, types and characteristics of visual field defects in acquired brain injury: A retrospective analysis. Optom. - J. Am. Optom. Assoc. 2008;79(5):259–265.
11. Zhang X, Kedar S, Lynn MJ, Newman NJ, Biousse V. Homonymous hemianopia in stroke. J. Neuro-Ophthalmology. 2006; 26(3).
12. Gilhotra JS, Mitchell P, Healey PR, Cumming RG, Currie J. Homonymous visual field defects and stroke in an older population. Stroke. 2002;33(10):2417–20.
13. Falke P, Abela BM, Krakau CE, Lilja B, Lindgärde F, Maly P, et al. High frequency of asymptomatic visual field defects in subjects with transient ischaemic attacks or minor strokes. J. Intern. Med. 1991; 229(6):521–5.
14. Rowe F. Symptoms of stroke-related visual impairment. Strabismus. 2013;21(2):150–4.
15. Cassidy TP, Bruce DW, Gray CS. Visual field loss after stroke: Confrontation and perimetry in the assessment of recovery. J. Stroke Cerebrovasc. Dis. 2001;10(3):113–117.
16. Rowe FJ. Accuracy of referrals for visual assessment in a stroke population. Eye. 2011;25(2):161–167.
17. Wong AM, Sharpe JA. A comparison of tangent screen, goldmann and humphrey perimetry in the detection and localization of occipital lesions. Ophthalmology [Internet]. 2000;107(3):527–44.
18. Keltner JL, Johnson CA. Automated and Manual Periemetry-A Six-Year Overview. Ophthalmology. 1984;91(1):68–85.
19. Smith C. Confrontation visual field testing: detecting gross visual field defects. Int. J. Ophthalmic Pract. 2011;2(5):200.

20. Bass SJ, Cooper J, Feldman J, Horn D. Comparison of an automated confrontation testing device versus finger counting in the detection of field loss. Optometry. 2007; 78(8):390–395.

21. Miller NR, Walsh FB, Hoyt WF. Walsh and Hoyt's clinical neuro-ophthalmology. 6th ed. London: Lippincott Williams & Wilkins. 2005;3.

22. Elliott DB, North I, Flanagan J. Confrontation visual field tests. Ophthalmic Physiol. Opt. 1997;17:S17–S24.

23. Smith Aaron. U.S. Smartphone Use in 2015 | Pew Research Center. US; 2015.

24. Horani A, Frenkel S, Yahalom C, Farber MD, Ticho U, Blumenthal EZ. The learning effect in visual field testing of healthy subjects using frequency doubling technology. J. Glaucoma. 2002;11(6):511–6.

25. Humphrey HFA II-i - Perimetry (HFA) - Glaucoma - Medical Technology | ZEISS International.

26. Koiava N, Ong Y-H, Brown MM, Acheson J, Plant GT, Leff AP. A 'web app' for diagnosing hemianopia. J. Neurol. Neurosurg. Psychiatry. 2012;83(12):1222–4.

27. Martin Bland J, Altman D. Statistical methods for assessing agreement. Lancet. 1986;327(8476):307–310.

28. Kerr NM, Chew SSL, Eady EK, Gamble GD, Danesh-Meyer HV. Diagnostic accuracy of confrontation visual field tests. Neurology. 2010;74(15):1184–1190.

29. Johnson C. Use of an iPad to perform visual field screening in Nepal. American Academy of Ophthalmology (AAO) 2014 Annual Meeting. 2014;Abstract PO412.

30. Puchta AE. Why am I so tired after my stroke? J. Vasc. Interv. Neurol. 2008; 1(2):63–4.

31. Hudson C, Wild JM, O'Neill EC. Fatigue effects during a single session of automated static threshold perimetry. Invest. Ophthalmol. Vis. Sci. 1994;35(1): 268–280.

32. Bagnis A, Corallo G, Scotto R, Iester M. Learning effect in perimetry: The role of chromatic discrimination. Am. J. Ophthalmol. 2011;152(6):1075–1076.

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