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Can Home Monitoring Allow Earlier Detection of Rapid Visual Field Progression in Glaucoma?

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Purpose: Recent developments in electronic technology are making it possible to home monitor the sensitivity of the central visual field using portable devices. We used simulations to investigate whether the higher test frequency afforded by home monitoring improves the early detection of rapid visual field loss in glaucoma and how any benefits might be affected by imperfect compliance or increased variability in the home-monitoring test.

Design: Computer simulation, with parameter selection confirmed with a cohort study.

Participants: A total of 43 patients with treated glaucoma (both open-angle and closed-angle), ocular hypertension or glaucoma suspects (mean age, 71 years; range, 37–89 years), were followed in the cohort study.

Methods: We simulated series (n = 100 000) of visual fields for patients with stable glaucoma and patients with progressing glaucoma for 2 in-clinic (yearly and 6-monthly) and 3 home-monitoring (monthly, fortnightly, and weekly) schedules, each running over a 5-year period. Various percentages of home-monitored fields were omitted at random to simulate reduced compliance, and the variability of the home monitored fields also was manipulated. We used previously published variability characteristics for perimetry and confirmed their appropriateness for a home-monitoring device by measuring the device's retest variability at 2 months in a cohort of 43 patients. The criterion for flagging progression in our simulation was a significant slope of the ordinary least squares regression of a simulated patient's mean deviation (MD) data.

Main Outcome Measures: The sensitivity for identifying rapid visual field loss (−2 decibels [dB]/year loss of MD).

Results: Although a sensitivity of 0.8 for rapid field loss was achieved after 2.5 years of 6-monthly testing in the clinic, weekly home monitoring achieved this by 0.9 years despite moderate test compliance of 63%. The improved performance of weekly home monitoring over 6-monthly clinical testing was retained even when home monitoring was assumed to produce more variable test results or be associated with low patient compliance.

Conclusions: Detecting rapid visual field progression may be improved using a home-monitoring strategy, even when compliance is imperfect. The cost-benefit of such an approach is yet to be demonstrated, however. *Ophthalmology 2017;■:1–8 © 2017 by the American Academy of Ophthalmology*

Although vision loss in primary open-angle glaucoma is typically slow, a small proportion of patients will lose vision at a rapid rate.[1] Determining those persons who have a rapid rate of loss is a challenge given that visual field measures are variable. For example, with annual visual field testing it can take 5 years or more to detect rapid visual field progression (≤−2 decibels [dB]/year) using a linear regression over time of the summary index mean deviation (MD). Even longer times are required if the rate of progression—rather than the mere presence of progression—is to be reliably estimated.[2]

Testing strategies have been proposed to improve the ability to reliably estimate progression rates within a shorter period. For example, Chauhan et al[3] have advocated that performing 6 visual field tests spaced over the first 2 years provides appropriate power (>0.8) to detect rapid progression, and these recommendations have informed official guidelines for how glaucoma should be monitored.[4,5] Crabb and Garway-Heath[6] have suggested a modified approach, in which a similar number of fields are clustered at baseline and after a 2-year period. Key to both methods is that increased frequency of testing allows for the effects of visual field noise to be reduced, and significant visual field progression therefore found earlier. Despite the potential benefits of increased testing frequency, patients with glaucoma typically perform only 2 to 3 visual fields in the first 2 years after diagnosis, with some patients taking in excess of 10 years to achieve the 6 visual fields recommended by guidelines.[7]

It is possible that alternative methods might be used to increase the frequency with which a patient's visual field is assessed. Traditional visual field testing devices, such as the Humphrey Field Analyzer (HFA) (Oberkochen, Germany), require patients to attend a clinic to have their visual field

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measured. Several devices recently have been developed that could allow visual field assessments away from clinical settings and potentially could be performed without direct supervision of a trained clinician. These include tablet-based devices[8–10] and head-mounted displays.[11,12] It has been shown that the visual display performance of tablets can be appropriately calibrated for visual psychophysics.[8,13] The advent of these devices raises the possibility that patients newly diagnosed with glaucoma could monitor their visual field status at home. Such monitoring would allow a dramatic increase in assessment frequency compared with in clinical settings, thereby potentially increasing the ability to estimate the rate of visual field change earlier. In addition, some patients find clinical settings to be full of distractions,[14] and so it may be that home monitoring allows for testing in a relatively more relaxed and distraction-free environment. The feasibility of home monitoring for ophthalmic disease has been recently demonstrated by the Age-Related Eye Disease Study 2 (AREDS2)-Home study, which showed that a home-based psychophysical vision test not only improved the detection of neovascular age-related macular degeneration onset but also gave better vision outcomes than did standard clinical reviews.[15] The acute nature of this vision loss lies in contrast to the comparatively slow vision loss seen in glaucoma. Therefore, the benefits of home monitoring seen in age-related macular degeneration may not be replicated in glaucoma.

A number of questions need to be considered regarding whether home monitoring for glaucomatous visual field loss may be of benefit. First, a home-based test may be of shorter duration than conventional perimetric tests and will likely have poorer control over such factors as ambient lighting.[9] As such, the variability of some home-based tests may be increased, which could offset some of the benefits predicted to arise from increased test frequency. Furthermore, the greatly increased number of tests means that the potential for false-positives may be increased. Therefore, how best to use the increased data generated from home monitoring needs to be considered.

In this article, we use simulation methods to quantify what benefits might be expected from using home monitoring for visual field progression in glaucoma, for a range of different test variabilities, monitoring frequencies, and test compliance rates.

Methods

Test Variability for Glaucoma Home Monitoring

Previous simulation work by Chauhan et al[3] was based on test variabilities established for the HFA, specifically, test standard deviations (SDs) for the MD index of 0.5, 1.0, and 2.0 dB for "low," "moderate," and "high" variability categories, respectively. To justify using similar categories in the current simulation, we wanted to establish their applicability to a home-monitoring device. Although the within-session (same day, after a 5-minute break, for most patients) retest performance of a tablet perimeter suitable for home monitoring (Melbourne Rapid Fields [MRF]) has been described,[10] the influence of variability between test sessions—as would appear in longitudinal monitoring—has not been investigated. Therefore, we evaluated between-session variability for a single eye of 43 patients with treated glaucoma (both open-angle and closed-angle), ocular hypertension or glaucoma suspects (mean age, 71 years; range 37-89), recruited from the Glaucoma Clinic of Cambridge University Hospital NHS Foundation Trust. The MD of the eyes ranged between 1.23 dB and −22.15 dB (average −7.40 dB). All patients had a comprehensive eye examination that included visual field testing on the HFA; gonioscopy; slit-lamp biomicroscopic examination of the optic nerve head, posterior pole, and peripheral retina; optical coherence tomography; and optic disc photography. One eye of these 43 patients was randomly selected for the study provided it met the inclusion criteria. All eyes had a visual acuity of 6/12 (20/40) or better. All patients had repeated HFA testing in the past and therefore were experienced in performing HFA visual field tests. Participants were excluded if they had retinal or corneal disease, required an English interpreter (because they would not be able to follow the verbal instructions automatically provided by the MRF), or had intraocular surgery within 6 months of the study. Lens status was not an explicit criterion for exclusion, although in practice substantial opacities would be excluded through our visual acuity inclusion criterion. Patients performed tests on both the iPad tablet-based MRF perimetry application (iPad 3, Apple, Cupertino, CA) within a supervised clinical environment as previously described by Kong et al,[10] along with visual fields on the HFA (24-2, SITA Standard; analysis not presented). All patients had reliable indices on the HFA (fixation loss ≤30%, false-positive ≤15% and false-negative ≤20%). Patients returned after 2 months to repeat the tests. The study conformed to the tenets of the Declaration of Helsinki and was approved by institutional and national ethics committees (Integrated Research Application System ID: 204698), with all participants providing informed consent.

Melbourne Rapid Fields Details

The MRF has 2 test grids available to sample a 30°×24° central field: a 66-point radial grid and a 58-point 24-2 grid with 4 macula points added at 1° eccentricity. The background luminance is 5 cd/m^2, with the MRF software overriding any user-defined iPad brightness settings for the duration of the test. Stimulus size increases with eccentricity, from approximately size III to just less than size V, to produce an approximately fixed contrast threshold across the visual field in normal observers. Stimuli are presented for 300 ms, followed by a random variable delay (700−1100 ms), with patients responding by a Bluetooth keyboard or a screen touch in a predefined zone. A 3-step Bayesian procedure produces pointwise estimates of threshold in 7 discrete steps over the 0 to 30 dB range, with points retested if thresholds differ from those expected given neighboring thresholds. Each eye's visual field is assessed in approximately 4 minutes. False-positive and negative catch trials are interspersed throughout the test, and fixation is assessed via the Heijl−Krakau blind-spot monitor method.[16] The test has voice-over instructions in English that reminds patients to wear their normal reading glasses, to occlude the fellow eye (with a tissue over the lens), and to ensure the proper viewing distance (33 cm) is used for testing.

For our study, participants performed the test in a dimly lit room and used the same room for retesting. The iPad was placed inside a specially designed viewing box that fixed the viewing distance and shielded sideways stray lights. We analyzed data collected on the 66-point radial grid only.

Simulation Details

We simulated MD values for series of visual fields for a group of nonprogressing glaucoma patients (true, underlying rate of visual