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Choosing two points to add to the 24-2 pattern to better describe macular visual field damage due to glaucoma

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ABSTRACT

Background/aims A recent study has shown that the paracentral upper visual field in the macular region is often affected in glaucoma and suggested that two test locations within the central 10° should be added to the Humphrey 24-2 visual field test pattern to detect such damage. This study employed data collected using a different visual field test pattern to determine whether the same two-test locations are supported as the most informative regarding visual field loss.

Methods A data set of 62 patients with glaucoma and 48 controls had visual field assessments on the Medmont perimeter M700 (Central Threshold or Glaucoma test). Twelve 24-2 locations within central 10° of visual field were derived by interpolation of the nearest neighbours of the Medmont data. The remaining 24 Medmont locations in the central 10° of the glaucomatous set were labelled as abnormal if their thresholds fell outside the lower 5th centile of the age-corrected values for the same location from the control group. All possible pairs of the 24 locations were then assessed for diagnostic power by counting the number of patients that had 0, 1 or 2 abnormal locations in a pair.

Results Overwhelmingly, pairs of locations in the superior macular region were more often abnormal than pairs in the inferior. About 50 pairs of locations had equivalent ability to detect damage, with the best pair having 74% of patients with at least one of the locations as abnormal, and 52% both.

Conclusions Adding a pair of locations to the superior macular region of the Humphrey Visual Field 24-2 pattern increases the number of abnormal locations identified in individuals with glaucoma.

INTRODUCTION

There is considerable evidence for macular involvement in glaucoma[1] (references therein). Clinically, glaucomatous damage in the macular region is observed using ocular coherence tomography, and results in spatially localised[2 3] as well as diffuse[4 5] visual field (VF) loss. However, the most common VF test used clinically for glaucoma (Humphrey VF analyser 24-2 pattern, Carl Zeiss Meditec, Dublin, California, USA) has only four test points within the central 8°. An alternate current strategy is to use the 10-2 test pattern, which tests on a 2° grid, however this requires an additional test to be performed by the patient. Typically 10-2 VFs are not conducted routinely on people at risk of glaucoma, but are used when glaucoma is seen to be threatening fixation. Recent work by Hood and *et al*[1 6] demonstrates that macular scotomata can exist in the absence of peripheral VF loss in glaucoma and can be missed entirely by the 24-2 VF pattern.

Performing a detailed test of central and mid-peripheral vision might be advantageous for detecting and monitoring field loss (eg, the 10-2 and 24-2); however, it increases the test duration and has logistical limitations. Hence, it has been suggested that a practical solution is to add several additional test locations to the 24-2 pattern in the macular region. Hood *et al*[6] determined that if only two points were to be added, the most useful locations would be at (±1°, 5°). These locations were determined from 10-2 data from 31 people with glaucoma.

In this paper we take data collected on the Medmont M700 perimeter (Medmont International, Nunawading) which collects thresholds in arcuate rings and samples more densely than the 24-2 test pattern in the macular area (see figure 1). The thresholding algorithms between the Humphrey Field Analyser (HFA) and the Medmont differ, including spatial postprocessing of the threshold data for the Swedish Interactive Thresholding algorithm[7] and the spatial order in which the points are tested. Consequently, algorithmically derived spatial dependencies within the measured VFs may vary between these two measurement techniques, and these might influence the apparent best test points for detecting damage. Our aim was to determine which two locations could be added to the central 10° of the 24-2 pattern to improve the detection of macular damage due to glaucoma and to confirm whether the locations were the same as previously derived using VFs measured with the HFA.

METHODS

Participants

Our data set includes 110 participants who underwent between one and three Medmont VF tests during a 3-year period while enrolled in other studies in our laboratory. The data set includes 62 people with glaucoma (median age: 72.1 years; range: 52.8–87.1 years) and 48 visually normal controls (median age: 65.5 years; range: 48.8–84.8 years). Individuals with glaucoma had an ophthalmological diagnosis of primary open-angle glaucoma based on clinical findings, VFs (typically 24-2 HFA fields) and optic disc appearance. All had prior experience in taking VF tests before visiting our laboratory. All were currently being treated, had refractive errors no greater than ±6 dioptres spherical and no more than 2D of cylinder, and had visual acuity better than 6/9. Control participants had the same refractive error and visual

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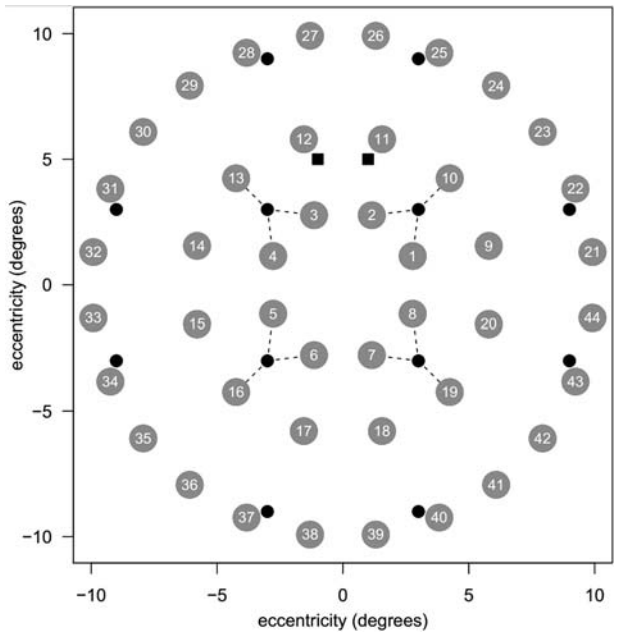

Figure 1 Grey circles show the Medmont M700 test locations, numbered for later reference. Black circles show the 24-2 test locations, with dashed lines showing which Medmont locations were interpolated to get the threshold values for these locations. The two black squares indicate the test locations recommended by Hood *et al*.[6]

acuity criterion, had normal findings on a comprehensive ocular examination including slit-lamp biomicroscopy, optic nerve head evaluation and applanation tonometry. Optic disc evaluation was also conducted using the Heidelberg Retinal Tomograph II (Heidelberg Engineering, Germany), and all were normal on the Moorfields Regression Analysis or Glaucoma Probability Score Tool. All participants provided written informed consent, in accordance with a protocol consistent with the Declaration of Helsinki.

For the purpose of this study, only one eye per subject was used. If data from both eyes was available, only the right eye was used. If only the left eye data was available, its test locations were mapped to a right-eye format for analysis. Therefore, 62 eyes from the glaucoma group and 48 eyes from the control group were selected from their most recent VF tests. All thresholds were corrected to age 50 years using an age-correction factor of −1 dB/decade. The median Average Defect and Pattern Defect scores in the glaucomatous group were −1.80 (range: −7.45 to 2.51) and 9.43 (range: 0 to 20.61), respectively. The Average Defect and Pattern Defect scores on the Medmont are similar in principle to the Mean Deviation and Pattern SD of the HFA, but have some differences in the calculation.[8]

Visual field tests and locations

VF data were collected using the Medmont perimeter M700 (Central Threshold or Glaucoma test), which is a fully automated, hemispherical bowl perimeter (300 mm radius).[9 10] In this VF test, stimuli, Goldmann size III (0.43°), are produced by LEDs of 565 nm wavelength that retroilluminate fixed points within the bowl with a background illuminance of 10 apostilbs (3.2 cd/m^2).[9] A ZEST (zippy-estimation by sequential thresholding) procedure is used to determine thresholds. All participants were tested by a trained perimetrist who ensured that fixation was maintained during the test and provided rest breaks during testing as required. Ninety-five per cent of participants had fixation losses less than 30%. The other 5% were observed carefully by the perimetrist and showed good fixation via direct observation. The rate of false-positive responses was also estimated in catch-trials, which was less than 21%.

Medmont VF measurements were recorded with test locations distributed on seven circles at eccentricities of 3°, 6°, 10°, 15°, 22°, 30° from the foveal centre. Because only the macula is of interest in this study, measurements from the test locations at eccentricities of 3°, 6°, 10° were analysed. Figure 1 shows the test locations as grey circles. Also shown as black squares are the two test locations, (±1°, 5°), recommended to be added by Hood *et al*.[6] Henceforth we refer to these two locations as the Hood Pair.

Analysis

As we were interested in adding two locations to the 24-2 pattern, we excluded from our analysis those locations in the Medmont field that would be represented in a 24-2 examination. However, as none of the 24-2 points fell directly on the Medmont locations (one of the attractions of using this data set for this study), we derived which locations to exclude using the nearest neighbours of the Medmont pattern, which are shown using dashed lines in figure 1. We then examined all possible pairs of Medmont locations that had not been used to derive the 24-2 pattern (grey circles in figure 2). There were 276 possible pairs ($^{24}C_2$) of locations, and for each pair in the glaucoma data set we counted the number of points below the fifth percentile of the controls for those locations (left panel in figure 2). Thus each pair can contribute 0, 1 or 2 abnormal points to the 24-2 pattern. We counted the number of patients that have either exactly two abnormal points, or more than zero abnormal points.

To place our results in the context of a 24-2 examination, we also derived threshold values for the 24-2 locations by averaging (after antilogging) the nearest neighbours, and counted abnormal locations in the 24-2 pattern in the same way as for the Medmont locations (figure 2).

RESULTS

Figure 2 left hand panel shows the dB values that correspond to the fifth percentile of the control data. Figure 2 right hand panel shows the number of patients that were abnormal in each location. As can be seen, the highest numbers are in the superior field. Figure 3 shows the proportion of patients with abnormal points in each pair of locations. The top panels only show the 44 best performing pairs, while the histograms give data for all 276 pairs. The error bars in the top panels indicate the upper end of a 95% CI derived using bootstrapping. Thus, for all the pairs in the top left panel, the upper end of their 95% range of the number of patients with one or two abnormal locations includes the mean for the best pair (indicated with the dashed line). For the top right panel, only the first 23 pairs have 95% ranges that include the best mean.

DISCUSSION

Our analysis confirms that the Hood Pair is a reasonable choice of two points to add to the macular region of the 24-2 pattern to improve the detection of macular loss. This confirmation provides confidence to the original findings of the Hood study, as an entirely different data set was used, collected with a different perimeter, different test pattern and different test algorithms than the Hood *et al*[6] study. Of the 11 patients that showed no macular damage on the 12 24-2 locations within the macula, 5 had abnormalities at one or both of the Hood Pairs (figure 4, white bars). Of the four patients who had one abnormal

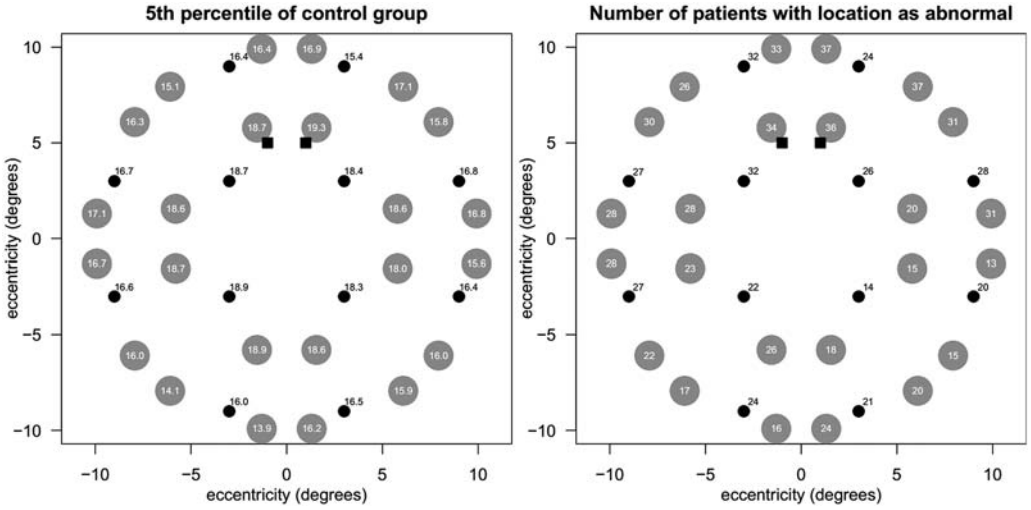

Figure 2 Grey circles show the candidates for adding to the 24-2 pattern (black circles). The numbers in the left panel give the lower fifth percentile of the control data for each location in dB. The numbers in the right panel give the number of patients that had that location as abnormal.

location on the 24-2 macula test locations, one had a further abnormality in the Hood Pair. While there are other pairs in the superior macular region that perform equally well as the Hood Pair (figure 3), there is no clear reason to prefer these other pairs.

Other schemes exist for choosing extra locations to add to the 24-2 pattern.[11 12] Aoyama *et al*[11] suggested that if the gradient between four test points is large, an additional test location should be placed at the centre of the four points. This is because the VF sensitivity in areas of high gradient is difficult to predict by simple interpolation. By applying this gradient method, we expect the gradient of the four 24-2 locations in the superior macular region to be larger than the gradient between the four inferior locations. If this is the case, then the added location would be at (0°, 6°), between and slightly superior to the Hood Pair, but not that far away. Indeed, in our data set, we found that the average gradient of these four points in the superior field across the control group and across the glaucomatous group are 0.52±0.22 dB/deg and 0.91±0.68 dB/deg interval, respectively. Not surprisingly, they are larger than the average gradients in the lower VF, 0.43±0.22 dB/deg and 0.80 ±0.73 dB/deg interval, respectively.

Another method to determine the distribution of test locations is to maximise an assumed structure-function relationship.

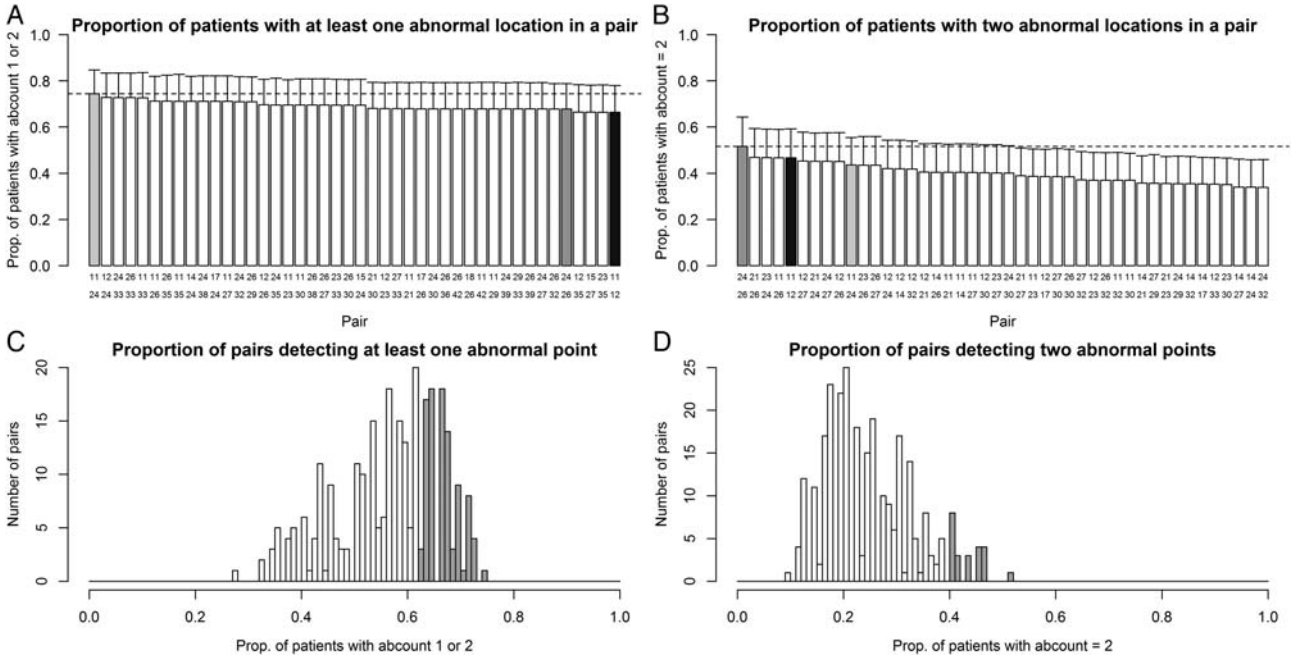

Figure 3 For the best 44 pairs of locations, the proportion of patients that had at least one abnormal point in the pair (A) and both locations abnormal in the pair (B) are shown. Bars show the mean, and error bars 1.96 times the SD of 100 bootstrap samples for each pair. The dark grey bar in each plot represents the pair (24, 26), the light grey (11, 24) and the black the Hood Pair (11, 12). The frequency distribution of the proportion of patients with one or two abnormal in the pair (C) and exactly two abnormal in the pair (D) is also shown. The shaded areas of the histogram indicate the number of pairs whose mean plus 1.96 times SD does not drop below the best performing mean.

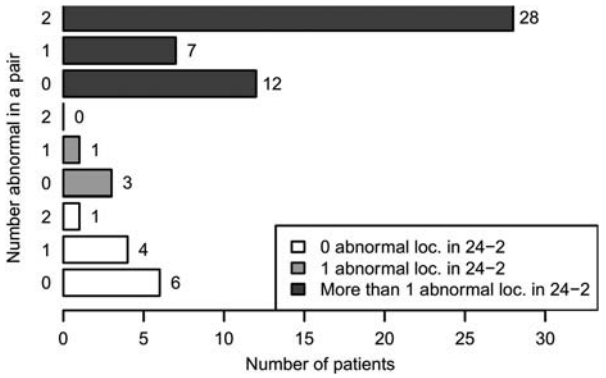

Figure 4 Each group of three bars represents a number of abnormal points in the set of 12 macular 24-2 locations. Within each group, the number of patients that had 0, 1 or 2 of the Hood Pair as abnormal is shown.

For each 12 clock-hour sector of the optic disc, Asaoka *et al*[12] chose four test points so that the correlation between VF thresholds and retinal nerve fibre layer thickness was maximised. Interestingly, two of the selected test points in their scheme are close to the Hood Pair, namely, (3°, 5°) and (−1°, 4°), and the Hood Pair is far from those test points that have the weakest structure-function relationship in the macula. This provides further evidence that the Hood Pair may be a good choice for adding to commonly used test patterns.

A further issue to consider that falls outside the scope of the current study is to determine the optimal number of test points to be added to 24-2 tests to maximise benefits. Here we specifically chose two test points to be added in order to compare with existing studies, with the specific aim of determining whether there was spatial concordance with the two test locations previously predicted as most useful. The key aim was to verify these locations using an independent data set, collected using a different visual field algorithm and pattern. Future work may address the question of the relationship of the number of additional test points and the cost-benefit trade-off between time taken for testing and information gain.

In summary, in this study, we confirmed that test locations around the Hood pair, (±1°, 5°) can improve the detectability of glaucomatous functional damage in the macula over a basic 24-2 pattern.

Contributors All authors listed have been involved in the conception and design, acquisition of data or analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, and final approval of the version published.

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Patient consent Obtained.

Ethics approval This study was conducted with the approval of the University of Melbourne Human Research Ethics Committee, Melbourne, Australia.

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