VI.2 Multi-flash campimetry and other psycho-physical tests in chronic open angle glaucoma

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Abstract

Multi-flash campimetry (MFC) is a computer implemented psycho-physical technique which allows sampling of temporal resolution at 120 points of a 40 degree visual field. The technique is rapid (about 20 minutes per eye), reproducible and easy to perform. We compared MFC to Octopus perimetry, colour vision and spatial contrast sensitivity in a series of thirty eyes of 30 observers. Nine were early glaucomatous eyes, 10 were glaucoma suspect eyes and 11 were normal controls.

Analysis of variance show MFC in the early glaucoma and suspect eyes to be significantly different from the control eyes ($p<0.05$). This was not found for colour vision and contrast sensitivity. All five eyes with abnormal Octopus fields had abnormal MFC. Conversely, nine eyes had abnormal multi-flash fields and normal Octopus fields. MFC is likely sensitive to alterations of both temporal and luminance sensitivity.

Introduction

The aim of psycho-physical testing in the chronic glaucomas is to detect and follow the evolution of optic nerve dysfunction and/or damage. Recent studies have concentrated on the significance of alterations of the differential light threshold as determined by static perimetry (1,14), of spatial contrast sensitivity [2], and of colour vision [11]. A loss of temporal resolving power in glaucomatous eyes was first appreciated by investigators using a flickering stimulus target on the tangent screen [16, 22]. In 1959, Campbell and Rittler found abnormal flicker fields in 19 of 23 chronic simple glaucoma eyes with equivocal or normal tangent screen fields [9]. More recently, abnormality in time-related visual function in glaucoma has been demonstrated with other psycho-physical methods which test a localized area of the visual field: the double-flash test in the central 10 degrees

[15]; 5 degree stimulus fields presenting a flickering, diffusely illuminated target or a counterphase flickering target viewed centrally [3, 4], and in the periphery [18, 20, 21]; and both sustained and transient-like functions as determined by quantitative layer-by-layer perimetry [12, 13].

Multi-flash campimetry is a computerized, reproducible clinical method developed in our laboratory [8]. It allows a rapid assessment of temporal resolving power in 120 points of the central 40 degrees of visual field. Multi-flash campimetry shows definite abnormalities in optic nerve disorders such as multiple sclerosis [8, 17, 23], in which the speed of nerve conduction is known to be impaired. We have studied this technique in control, glaucoma suspect and early glaucoma eyes which were also tested for colour vision, spatial contrast sensitivity, and static perimetry.

Methods

Subjects

The study group consisted of thirty eyes of 30 different observers, separated into three groups: early glaucoma, glaucoma suspect and control of 9, 10 and 11 eyes respectively. These groups had similar distributions with means of 52, 49 and 49 years respectively. All of the eyes had a best corrected acuity of 6/7.5 or better, and no other ocular disease. The suspect group was comprised of eyes with intraocular pressure consistently greater than 21 mm Hg, normal optic nerve heads, and reproducible normal Armaly-Drance visual fields on the Goldmann apparatus [10]. The early glaucoma group consisted of eyes with elevated intraocular pressure (>21 mm Hg), early disc changes and/or early reproducible visual field defects such as a nasal step or a paracentral scotoma.

Apparatus

Both mutli-flash campimetry and the spatial sensitivity gratings were implemented on a PDP11/10 computer interfaced with a large screen CRT (Hewlett Packard 1310A equiped with a p15 phosphor). The sine wave gratings were produced by Wavetek function generators under the control of the PDP11/10. Colour testing was performed with the American Optical H-R-R Pseudoisochromatic plates (HRR) and the Farnsworth-Munsell 100-hue test. An Easel Lamp (Macbeth Corporation) was used for the colour tests. Computerized perimetry was performed with either program 38 or G1 on the Octopus 500R perimeter.

Procedure

All 30 eyes were tested for temporal resolution (multi-flash campimetry), spatial contrast sensitivity, and computerized static perimetry. Twenty-six of the 30 eyes were available for the colour tests.

Multi-flash campimetry samples temporal resolution at 120 points of a 40 degree visual field. The visual display consists of 6 concentric circles: the eccentricities subtend 0.625, 1.25, 2.5, 5.0, 10.0 and 20.0 degrees of visual angle. The stimuli points subtend 5 minutes, and are presented simultaneously lit in one randomly chosen quadrant at a time. A randomly chosen point is then manipulated to assess the ability to perceive a 5 Hz flicker. In each 200 ms cycle, the duty cycle (period of cycle that is lit) of the stimulus is systematically decreased and the off period increased by 2.8 ms (1.4 percent) until the observer perceives flicker and hits the response key. Prior to the testing session, a display of 15 points with one point located in the blind spot is used for practice. This is repeated until the observer feels comfortable with the task and the point in the blind spot is not responded to. The average luminance of the display is 3 cd/m^2 and the viewing distance 57 cm.

Following the testing period, a complete printout of the multi-flash thresholds (off-period needed to perceive flicker) for the individual points is obtained. Statistically deviant points are replicated immediately to avoid misinterpretation due to momentary lapses of attention or occasional eye movements. A point is considered statistically deviant if the threshold is 7 standard errors greater than the circle mean or 21 standard errors greater than the general mean. Finally 2- and 3-dimensional maps are created which allow for easy interpretation of the results.

The spatial contrast sensitivity functions were generated using the 'Anticipated Threshold Technique' [6]. This allows for a rapid assessment of 5 spatial frequencies. For this study we used spatial frequencies of 1.00, 1.82, 3.31, 6.03 and 10.99 cycles per degree (c/d). Delayed intervals and catch trials were used to avoid habituation responses. The average luminance was 5 cd/m^2, the viewing distance was 1 meter and the target subtended 8 x 8 degrees. The task is to depress the paddel when the static gratings are just perceived.

Conventional instructions were given for the colour tests except that no time limits were imposed to complete the FM 100-hue test.

Results

An analysis of variance (ANOVA) was performed on the mean multi-flash thresholds across retinal eccentricity. The results show a statistically significant difference between groups ($F(2,27) = 3.718$, $P<0.05$). No statistical difference was found between groups for the spatial contrast sensitivity test or the FM 100-hue test. No errors were made on the HRR colour plates.

Figure 1 demonstrates the mean multi-flash thresholds of the different groups as a function of retinal eccentricity. Average standard error bars for the individual diagnostic categories are given. Post hoc Sheffé tests reveal that the glaucoma suspect group is different from the controls at 5, 10 and 20 degrees of eccentricity. The glaucoma group is different from the controls at all eccentricities.

For a more individualized analysis, the multi-flash data were compared to a 95% confidence interval obtained from the control data. This was done separately for the younger age group (20–49), and the older age group (over 50). If the mean multi-flash threshold of at least 1 concentric circle fell beyond the normal range the multi-flash field was considered abnormal. Similarly, the spatial contrast sensitivity data was considered abnormal if at least one of the five spatial frequencies tested was beyond the 95% confidence level obtained from our controls. The FM 100-hue error score was defined as abnormal using a similar

Table 1. Information of abnormality for each patient across different measures

	MFC*	Octopus	FM-100	Spatial+
20–49 glaucoma				
Patient 1	4	Normal	N	0
Patient 2	6	Generalized depression	N	3
Patient 3	0	Normal	A	0
Patient 4	0	Normal	A	1
20–49 suspects				
Patient 5	5	Superior depression	N	2
Patient 6	6	Normal	–	5
Patient 7	2	Normal	A	1
Patient 8	0	Normal	–	4
Patient 9	4	Normal	N	2
50-over glaucoma				
Patient 10	2	Local paracentral scotoma	N	1
Patient 11	4	Gen. & local NFBD	N	0
Patient 12	2	Normal	A	3
Patient 13	3	Sup. & inferior NFBD	N	1
Patient 14	6	Normal	N	3
50-over suspects				
Patient 15	0	Normal	N	0
Patient 16	0	Normal	N	1
Patient 17	4	Normal	N	1
Patient 18	4	Normal	N	2
Patient 19	5	Normal	N	1

* Values represent number of abnormal eccentricities (mean MFC score) over a total of 6 eccentricities.

+ Values represent number of abnormal spatial contrast sensitivities over a total of 5 spatial frequencies.

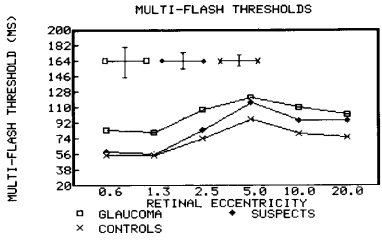

Figure 1. Mean multi-flash threshold (ms) for each diagnostic category as a function of eccentricity. Average standard error bars are given for the individual conditions.

95% confidence interval. These data are shown in Table 1 along with the Octopus fields as blindly assessed by our clinician (GB).

When Octopus fields were abnormal multi-flash campimetry fields were always abnormal. This is not the case for colour or spatial contrast sensitivity data. Further, multi-flash was abnormal in 9 instances where no abnormality could be measured by Octopus perimetry. The test showing the most frequent abnormality was the spatial contrast sensitivity test. However, this may be biased by our normality criterion: in MFC, we have averaged 20 points for each eccentricity, whereas in the spatial contrast sensitivity, we have averaged 5 measurements for each spatial frequency. Seven of the eyes with spatial contrast sensitivity abnormality had a deficiency for only one spatial frequency. Only 4 of the 17 patient group eyes demonstrated abnormal FM-100 scores, 3 in the glaucoma group and one in the suspect group.

Discussion

Our results are consistent with the notion that temporal resolution is reduced in glaucoma. The possibility that Y or transient cells are damaged early in glaucoma has been suggested by quantitative histopathological and psycho-physical studies [3, 19, 20]. It is expected that the loss of such cells would affect the temporal resolution of the visual system. Of importance is the finding that all 5 abnormal Octopus perimetry fields are reflected by abnormal multi-flash data, and that 9 eyes with normal Octopus fields also had abnormal MFC. The Ferry-Porter law states that the ability to perceive flicker is directly dependent on the luminance of the flickering target [5]. This renders MFC sensitive to alterations of both temporal and light sensitivity.

Multi-flash campimetry has the additional advantage of sampling 120 points across the visual field in about 20 minutes per eye. It also presents the data in two and three-dimensional maps for rapid assessments. Figure 2 shows two- and three-dimensional maps of a multi-flash field from a 27-year-old normal observer. Figure 3 shows two and three-dimensional multi-flash maps and Octopus fields of

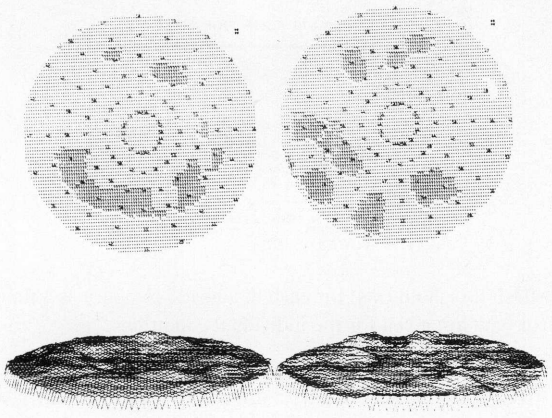

Figure 2. Two- and 3-dimensional multi-flash maps of a 27-year-old normal observer. Loss of resolution is represented by darker shading and higher mountains respectively. Square symbols beside the 2D maps represent the angle of presentation for the 3D maps.

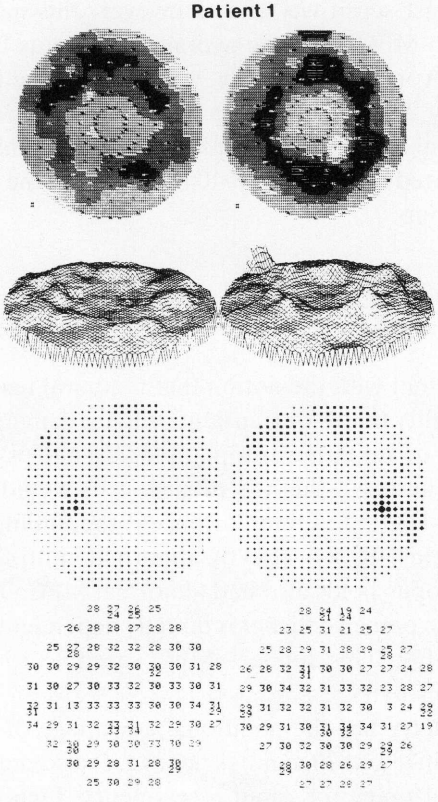

Figure 3. Two- and 3-dimensional multi-flash maps and Octopus field maps (#38) of a 24-year-old patient with an early glaucomatous left eye and a glaucoma suspect right eye.

a 24-year-old patient with glaucoma in the left eye (abnormal disc) and suspected glaucoma in the right eye.

The multi-flash data presented in Table 1 limits our interpretation of specific localized defects. We are presently developing numerical measures of variability, and generalized and localized defects of multi-flash fields [7].

A long term follow-up study is being conducted to test whether multi-flash campimetry is predictive of glaucomatous optic nerve damage.

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