Motion detection threshold and field progression in normal tension glaucoma

Karin A Baez, Andrew I McNaught, Jonathan G F Dowler, D Poinoosawmy, Fred W Fitzke, Roger A Hitchings

Abstract

Psychophysical tests may demonstrate abnormalities of visual function before the appearance of conventional visual field loss in glaucoma. Motion detection thresholds (MDT) were measured in the normal fellow eye of 51 patients with confirmed normal tension glaucoma and initially unilateral field loss. Humphrey visual fields from the initially normal eye covering a mean follow up of 3·4 years were assessed using pointwise linear regression analysis. In 22 of the 51 eyes with normal visual fields at presentation, field deterioration occurred at one or more Humphrey locations within a mean of 1·7 (SD 1·6) years. An initially abnormal MDT test showed a sensitivity of 73% and a specificity of 90% in predicting field deterioration within the cluster of four Humphrey locations closest to the original MDT test site. Sensitivity was lower (40%) in predicting progression at retinal locations distant from the MDT test site, though specificity remained high (90%).

(*Br J Ophthalmol* 1995; 79: 125–128)

It has been shown that there may be loss of up to 30% of ganglion cell axons before the appearance of visual field defects in glaucoma suspects,[1] moreover, there may be preferential early loss of large diameter axons.[1] In the primate there are two parallel visual pathways: the magnocellular and parvocellular. The magnocellular system receives input from the A ganglion cells which have large diameter axons.[2] The magnocellular pathway is thought to subserve motion perception.[3] A test of motion sensitivity may therefore provide earlier detection of loss of visual function in glaucoma. We describe a computerised test of motion sensitivity (motion detection threshold, MDT) and which has been previously shown to predict the future development of conventional visual field loss in a group of patients with suspicious optic disc appearance.[4]

The purpose of the study was to determine whether abnormal motion sensitivity precedes the appearance of visual field defects in initial field undamaged fellow eyes of patients with normal tension glaucoma.

Patients were selected if they had strictly unilateral visual field loss. The diagnosis of normal tension glaucoma was established in the field damaged eye and the normal fellow eyes were considered to be at high risk of conversion of glaucoma. Single location MDT testing was performed in the initially normal eye and subsequent progress was closely followed with frequent Humphrey perimetry.

The perimetry results were then analysed using custom software (PROGRESSOR) which performs pointwise linear regression analysis on each retinal location at each successive field test. This analysis permits recognition of locations which are deteriorating most rapidly. The PROGRESSOR software has been described previously.[5]

The relations between the initial MDT and later visual field outcome are described.

Patients and methods

Fifty one patients were selected in whom the diagnosis of normal tension glaucoma was supported by optic disc appearance, 24 hour intraocular pressure phasing (IOP <21 mm Hg) and the presence of glaucomatous field loss in one eye only. In the better eye, the first three fields were examined: for confirmation of field normality two out of the first three fields were required to fulfil the normal definition. A normal field was defined on the Humphrey pattern deviation plot as no clusters of two or more adjacent locations with symbols representing significant ($p<0·01$) departures from the normal database. The eye with the undamaged visual field underwent MDT testing at a single location just above the blindspot at 15 degrees eccentricity. Changes of visual fields were then monitored with a median of four fields per year over a mean follow up period of 3·4 (range 2·3–8·5 (SD 2·3)) years using linear regression at each test locus with the PROGRESSOR program.

MOTION DETECTION THRESHOLD

The motion detection threshold (MDT) test is performed using a vertical line stimulus (2 degrees by 2 minutes of arc in size) which is presented on a green phosphor VDU screen. During the test, the stimulus undergoes brief lateral displacements (2·5 Hz) of varying magnitudes (10 random presentations of 10 different displacement magnitudes: 0–18 minutes of arc): the value of MDT represents the minimum stimulus displacement in minutes of arc that is perceived by the subject on 50% of 10 separate presentations. Thus a high value of MDT indicates that only large displacements of the stimulus were consistently seen. For the purposes of this study we have defined a first MDT in excess of 9 minutes of arc as abnormal since this 'cut off' has been shown previously to separate normal from glaucomatous eyes.[6] MDT has been found to

Moorfields Eye Hospital, London EC1V 2PD
K A Baez
A I McNaught
J G F Dowler
D Poinoosawmy
R A Hitchings

Institute of Ophthalmology, Bath Street, London EC1V 9AT
F W Fitzke

Correspondence to:
Mr R A Hitchings, Glaucoma Unit, Moorfields Eye Hospital, City Road, London EC1 2PD.

Accepted for publication 15 September 1994

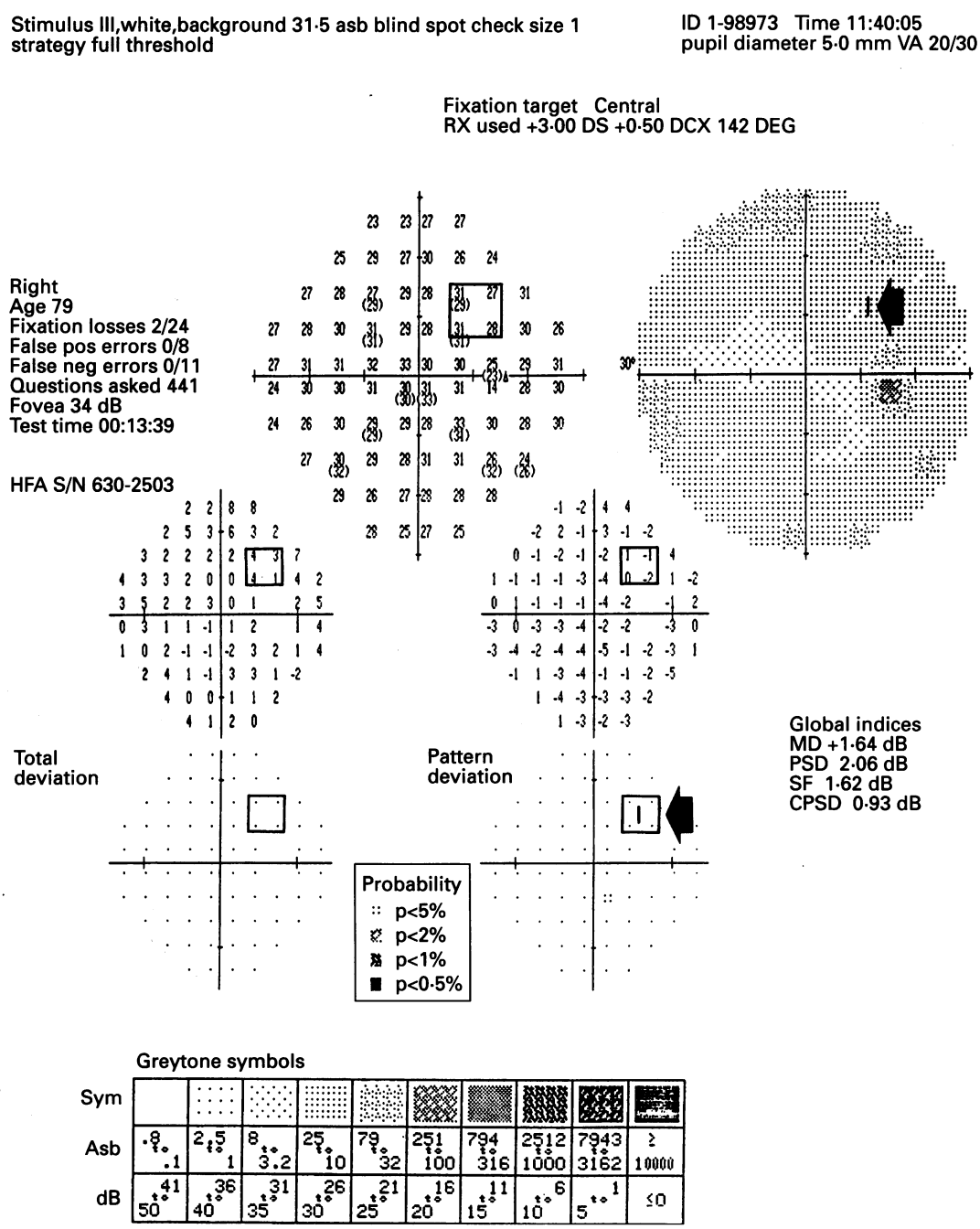

Figure 1 Humphrey STATPAC printout of the first field of one of the subjects. The location and dimensions of the motion detection threshold (MDT) stimulus are shown superimposed on the Humphrey test grid (vertical bar indicated by arrow). The relation between the MDT test stimulus and the four surrounding Humphrey locations (MDT 'cluster') is shown on the other STATPAC plots (locations are enclosed in the box).

be relatively resistant to the effects of pupil size, media opacity (stimulated with neutral density filters), and refractive blur. The test is rapid (approximately 10 minutes) and easy for the subject to perform.[6]

PROGRESSOR (POINTWISE LINEAR REGRESSION)

The PROGRESSOR software uses all consecutive Humphrey visual field tests from an eye and performs linear regression analysis at each retinal location at each field test. The analysis of all fields is then presented as a single colour coded graphical display which highlights those locations with a statistically significant negative regression slope. Locations which show sensitivity decay are then clearly displayed.

For this study we have defined progression of the visual field as the presence of at least one location with a statistically significant regression slope ($p<0·05$) and rate of loss faster than 1 dB per year. This rate of sensitivity loss is approximately 10 times faster than the normal age related decay.[7] This definition of progression has been found to correlate closely with the Humphrey STATPAC 2 'Glaucoma change probability analysis' software.[8] The results of PROGRESSOR analysis of the 51 subjects were inspected blind to the initial MDT thresholds. We excluded the outer ring of the 30-2 field test and the blindspot to reduce the effect of the excessive intertest fluctuation characteristic of these locations. The presence and location of progressing locations was recorded as well as

Table 1 Relation of visual field progression to MDT

Visual field outcome	*Mean MDT*	*Min MDT*	*Max MDT*	*SD*	*n*
Progression at >1 location	8·88	3·60	15·90	2·88	22
No progression	7·43	3·59	10·95	1·77	29
Progression in MDT cluster	10·40	6·50	15·90	2·96	11
No progression in MDT cluster	7·41	3·59	10·95	1·77	40

MDT=motion detection threshold.

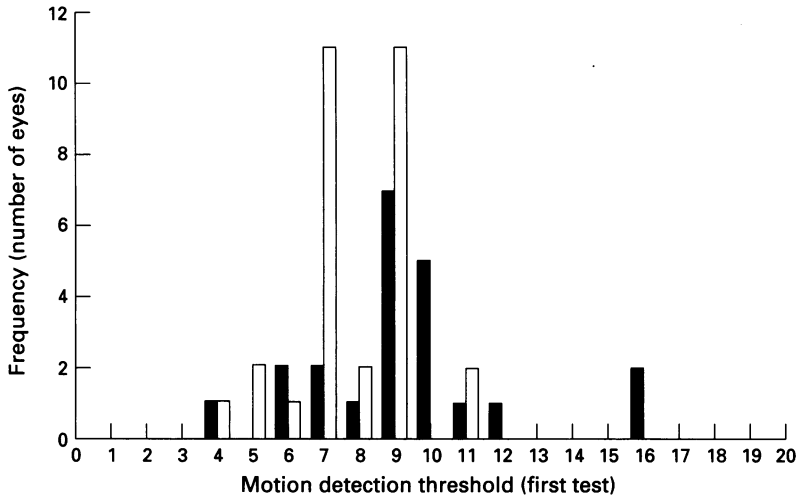

Figure 2 Distribution of initial motion detection threshold values. (■) = Visual field deterioration at more than one location at any site in visual field. (□) = Visual field stable.

the time from first MDT test that progression first appeared.

The four Humphrey test locations closest to the original MDT test site (just above blindspot) were designated the 'MDT cluster'. Figure 1 shows the location of the MDT test site relative to the Humphrey field test sites and the four Humphrey locations designated the 'MDT cluster'.

Results

Within the cohort of 51 patients, 22 of 51 initially normal eyes developed visual field progression at more than one location within the visual field within a mean elapsed time of 1·7 (SD 1·6) years. Of the 22 eyes which showed field deterioration, eight eyes showed at least one location which progressed within the 'MDT cluster'. The mean time to progression at those retinal locations comprising the MDT cluster from the date of the first MDT was 3·0 years.

The mean initial MDT value for all eyes was 8·05 (SD 2·4, range 3·59–15·9). Table 1 shows the distribution of MDT values for eyes which demonstrated field progression and those that showed stability. This is shown as a histogram in Figure 2.

To compare the distribution of initial MDT values for progressing/non-progressing eyes we performed a non-parametric test of significance (Mann-Whitney rank sum). There was a statistically significant difference ($p=0·023$) between the initial MDT values of eyes which showed field progression and those eyes which remained stable. This difference in initial MDT value was more marked ($p<0·001$) when progression or stability within the MDT cluster locations only was considered. This more marked difference in distribution of initial MDT values is shown as a histogram in Figure 3.

An initial abnormal MDT (>9 minutes of arc) predicted local field progression at those locations within the MDT cluster with a sensitivity of 73% and a specificity of 90% (Table 2). For the prediction of progression within the field as a whole – that is, all retinal locations, sensitivity was 41% specificity 90% (Table 3).

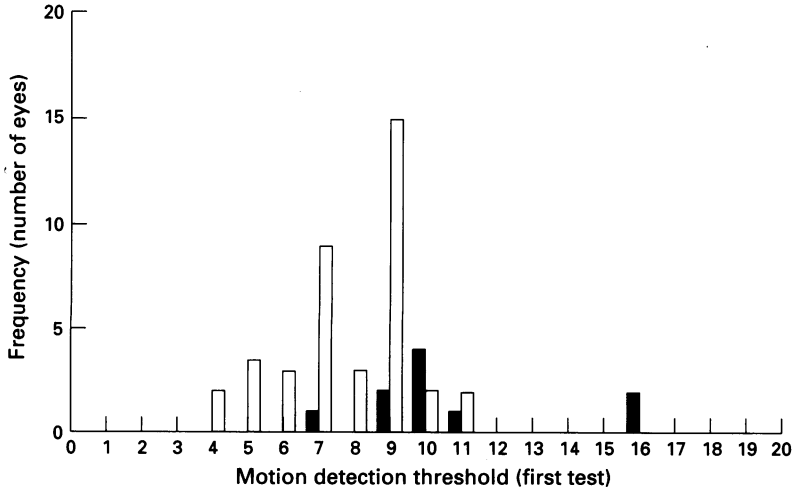

Figure 3 Distribution of initial motion detection threshold (MDT) values. (■) = Visual field deterioration at more than one of the four Humphrey locations closest to initial MDT test site (MDT 'cluster' of locations). (□) = Visual field stable at locations close to MDT test site.

Discussion

We describe a group of untreated patients with normal tension glaucoma (NTG) selected because they demonstrated asymmetrical field loss. We have documented their progress over time using automated perimetry: 43% of eyes with initially normal visual fields showed visual field progression.

Other workers have described field change over time in NTG subjects, albeit using different definitions of field deterioration. Glicklich *et al*[9] reported field progression in 53% of subjects within 3 years.[10] Zeyen *et al*[11] reported that in 15 patients with unilateral visual field defects from primary open angle glaucoma 25% of patients developed visual field progression within a mean of 6·1 years in the initial normal eye.

We describe a pointwise linear regression technique which clearly indicates progression at any location if the rate of sensitivity loss is faster than 10 times that of the normal age related decay. This definition has been found to correspond closely to the level of sensitivity demonstrated in the Humphrey STATPAC 2 'Glaucoma change probability' analysis program.[8]

We report on the use of MDT testing to attempt to predict which eyes will develop field progression. In this group we have found that in initially field undamaged eyes an abnormal MDT predicts the future development of field loss in those locations close to the original MDT test site with a useful degree of accuracy. MDT shows a lower sensitivity in predicting change at field locations distant from the test

Table 2 Predictive value of initial MDT to visual field outcome

	Visual field stable	*Visual field progression*	*Row total*
MDT normal <9 min/arc	n=26 (89·7%) specificity	n=13 (59·1%)	n=39 (76·5%)
MDT abnormal >9 min/arc	n=3 (10·3%)	n=9 (40·9%) sensitivity	n=12 (23·5%)
Column total	n=29 (56·9%)	n=22 (43·1%)	n=51 (100%)

MDT=motion detection threshold.

Table 3 Predictive value of MDT to MDT outcome

	MDT cluster locations stable	*MDT cluster progressing*	*Row total*
MDT normal <9 min/arc	n=36 (90·0%) specificity	n=3 (27·3%)	n=39 (76·5%)
MDT abnormal >9 min/arc	n=4 (10·0%)	n=8 (72·7%) sensitivity	n=12 (23·5%)
Column total	n=40 (78·4%)	n=11 (21·6%)	n=51 (100%)

MDT=motion detection threshold.

site, although the specificity remains high. These findings suggest that local motion sensitivity abnormalities sometimes precede local luminance sensitivity loss, but that luminance loss at sites distant from the MDT test site is not usually preceded by generalised depression in motion sensitivity. Of the 12 eyes with abnormal MDT values, three eyes have demonstrated stable visual fields to date. These may represent genuine false positives or they may show field progression with future observation.

As a result of the findings from this study we are developing a multilocation MDT test which will test at least four locations within the central visual field: we anticipate higher sensitivity in predicting conventional field loss at all points within the field without extending the MDT test time greatly.

A I McNaught is funded by the Friends of Moorfields charity. F W Fitzke is funded by the National Retinitis Pigmentosa Foundation and the Medical Research Council.

1 Quigley HA, Dunkelberger GR, Green WR. Chronic human glaucoma causing selectively greater loss of large optic nerve fibres. *Ophthalmology* 1988; **95:** 357–63.
2 Leventhal AG, Rodieck RW, Dreher B. Retinal ganglion cell classes in the old world monkey: morphology and central projections. *Science* 1981; **213:** 1139–42.
3 Livingstone MS, Hubel DH. Psychophysical evidence for separate channels for the perception of form, colour, movement, and depth. *J Neurosci* 1987; 3416–68.
4 Fitzke FW, Poinoosawmy D, Wu JX, Hitchings RA. Motion detection thresholds for predicting visual field loss in low tension glaucoma suspects. Amsterdam: 4th Congress European Glaucoma Society (abstract). 1992: 12.
5 Noureddin BN, Poinoosawmy D, Fitzke FW, Hitchings RA. Regression analysis of visual field progression in low tension glaucoma. *Br J Ophthalmol* 1991; **75:** 493–5.
6 Fitzke FW, Poinoosawmy D, Nagasubramanian S, Hitchings RA. Peripheral displacement threshold in glaucoma and ocular hypertension. In: Kriegelstein GK, ed. *Perimetry update 1988/89.* Amsterdam: Kugler, 399–405.
7 Heijl A, Lindgren G, Olsson MS. Normal variability of static perimetric values across the central visual field. *Arch Ophthalmol* 1987; **105:** 1544–9.
8 McNaught AI, Crabb D, Fitzke FW, Hitchings RA. Diagnosis of visual field progression: comparison of point-wise linear regression analysis with current methods. Presented at Joint American/European glaucoma society meeting, Rekjkavik, Iceland, July 1993.
9 Glicklich RE, Steinmann WC, Spaeth GL. Visual field change in low-tension glaucoma over a five-year follow-up. *Ophthalmology* 1989; **96:** 316–20.
10 Hitchings RA, Anderson SA. A comparative study of visual field defects seen in patients with low-tension glaucoma and chronic simple glaucoma. *Br J Ophthalmol* 1983; **67:** 818.
11 Zeyen TG, Caprioli J. Progression of disc and field damage in early glaucoma. *Arch Ophthalmol* 1993; **11:** 62–5.