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THE COMPUTERISED VISUAL FIELD: THE COMPLEXITIES OF ITS ANALYSIS. A LITERATURE REVIEW

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Abstract

Computerised perimetry has revolutionised the examination of the visual field by its ability to provide reproducible quantitative threshold measurements of the "hill of vision". There is a growing body of research describing the complexities of obtaining these precise measurements and interpreting the information obtained in the computerised visual field printout. This report aims to extend the orthoptist's knowledge of how to interpret the computerised field printout. It presents an overview of current research, describing the factors that cause variation in threshold measurement, and methods that can be used to determine the presence or absence of visual field defects. Clinical examples using the Humphrey Visual Field Analyser are included to demonstrate important concepts.

Key words: *Automated perimetry, variability, visual threshold, visual field, glaucoma.*

INTRODUCTION

The development of computerised perimetry has made it possible to obtain quantitative static threshold measurements of the visual threshold at different points across the visual field. This has provided many avenues for data analysis and comparison of visual thresholds both between subjects and over time, and consequently has made a major impact on the detection of diseases affecting the visual pathway, primarily glaucoma.

There has also been a growing awareness that variability of these threshold measurements may occur as a result of the testing procedure and be independent of the disease process. Therefore considerable research has been directed towards describing the complexities of measuring visual threshold and factors that influence the interpretation of results for normal, ocular hypertensive and glaucoma subjects.

The aim of this report is to draw together the conclusions and suggestions made by researchers regarding:

1. Factors that contribute to variation of results,
2. Identification of abnormal from normal field results,
3. Classification of visual defects identified by static perimetry,
4. Limitation of statistical global indices.

Differential Light Threshold

Before considering the complexities of interpretation of computerised visual fields, it is necessary to consider the basic principle of static perimetry: the differential light threshold (DLT).

The ability of a subject to see a stimulus depends on the luminance, duration and size of the stimulus, and the background illumination. Flammer, Drance and Zulauf[1] define the DLT

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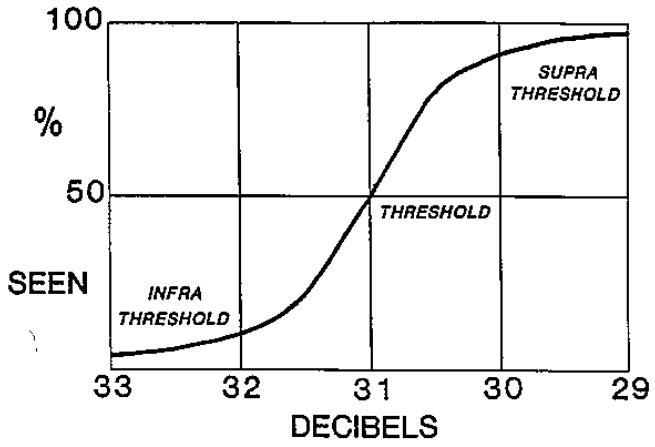


Figure 1: Probability of seeing curve.

as "that light stimulus that can be recognised above the background with a probability of 50% in a given retinal location". Therefore the threshold levels on the printout represent the 50% point on the "probability of seeing curve" (Figure 1). This graph represents the curve between the stimulus rarely seen (ie slightly brighter than infrathreshold) and the stimulus almost always seen (ie barely dimmer than suprathreshold).

1. VARIABILITY OF VISUAL FIELD RESULTS

Automated visual field testing will always give rise to some variability of results during the test and from one test to another. A knowledge of factors contributing to this variation helps in the ability to control them and interpret the visual field printout.

Werner, Adelson and Krupin[2] consider that variability may be either nonrandom or random.

Nonrandom Variability

These are external factors and include pupil size, uncorrected refractive error, cataracts and actual progression of the visual field defect. If the first three are identified, they can be controlled when performing the test and considered when analysing the field results.

(a) Pupils: Small pupils have a greater effect on static perimetry than kinetic perimetry. Pupils less than 3 mm cause an apparent constriction in the field. It is recommended that miotic pupils be dilated to greater than 3.5 mm, and that repeat field examinations be performed with the same sized pupil.

(b) Uncorrected refractive error: This has the largest effect on threshold values within 10°, and even as low as 1.00 dioptre miscorrection can effect threshold values.[3] The effect of correcting versus not correcting moderate to large astigmatic errors has not yet been evaluated.

(c) Cataract: This causes a overall depression of the threshold values across the field and can be detected by examining the statistical analysis.

Random Variability

This occurs as a result of the actual testing process and nature of the visual system and generally cannot be controlled by the operator. Factors include performance effects such as patient reliability and the learning effect, and fluctuations both during the test and between tests.

(a) Performance Effects

(i) Patient Reliability

The "reliability" of the visual field test is measured by most automated perimeters. The Humphrey Visual Field Analyser (HVFA) tests fixation losses (FL), false positive (FP) and false negative (FN) responses and subjects with >33% FN or FP, or >20% FL are labelled unreliable.

Katz and Sommer[4,5] studied these statistics in normal, ocular hypertensive and glaucoma subjects. Normal subjects with >33% FN had an average 7dB depression when compared with normal subjects with low FN rates. Glaucoma subjects with a high FN rate had an average 9dB depression of the visual field results, when compared with glaucoma subjects with low FN rates. They also found that glaucoma subjects have a higher incidence of FN errors and suggest that the increased FN rate in glaucoma subjects may not be due to patient attention, rather increased visual fatigue associated with the disease.

The defects shown on the field printout of subjects with high FN errors were mostly in the superior nasal and nearby arcuate area, and the results of unreliable normal subjects looked identical to those of reliable glaucoma subjects.

The incidence of fixation losses also affects the final interpretation of visual fields. Katz and Sommer[5] found that when glaucoma subjects with previously identified field loss were reassessed with computerised field testing; those with poor fixation (>20%) showed less depressed fields and fewer localised defects were localised. The HVFA assesses fixation by presenting a stimulus in the blindspot, if the subject responds a fixation loss is recorded regardless of whether there was an actual loss of fixation. In fact Sanabria, Feuer and Anderson[6] found that nearly half of the recorded fixation losses were due to artifacts in the testing procedure and could be easily minimised by the operator taking corrective measures early in the testing procedure. The main artifact found by these researchers occurred when the blind spot of the eye being tested was not located where the stimulus was presented. They suggest that the perimetrist closely observe the beginning of the test and correct the location of the blindspot before more than two losses of fixation are recorded.

When considering the sensitivity (identification of abnormal fields as abnormal) and specificity (identification of normal fields as normal) of automated perimetry, Sommer[7] found that the HVFA Statpac analysis of results is highly influenced by reliability measures. For a reliable subject the field results have a sensitivity of 98% and specificity of 93%, but for the unreliable subject the sensitivity drops to 86% and specificity maybe as low as 52%. Therefore for the unreliable patient Statpac analysis will classify a large number of normal fields as being abnormal.

(ii) Learning Effect

This is an artifact demonstrated in computerised fields where improvement in threshold values occurs as a result of experience with the testing procedure. Fields of inexperienced subjects are characterised by concentric narrowing of the field. Figure 2a shows the visual field printout of a subject's initial test result showing generalised constriction of the visual field. Figure 2b is the same subject's field performed 10 months later.

Several researchers have examined this effect in normal, ocular hypertensive and glaucoma subjects.[2,8-11] Heijl, Lindgren and Olsen[10] found that normal subjects show a minimal learning effect, only 1-2 dB, and a similar finding was made by Werner[2,11,12] for glaucoma and ocular hypertensive subjects. Most of the improvement occurs in the mid-periphery, points near fixation remaining stable.

(b) Fluctuation

Due to the nature of the DLT, methods used to measure it, and the fact that perimetry is a subjective test, the visual field results obtained by computerised perimeters will always show variability. When this occurs during one field test it is termed short-term fluctuation (STF), and from one field test to another long-term fluctuation (LTF).

(i) Short-term Fluctuation

Two components of STF need to be considered: local and global STF. Local fluctuation refers to the threshold variability that occurs at each discrete visual field location (noted on the HVFA by comparing the threshold values in brackets). Werner and Drance[12] demonstrated that in the fields of glaucoma suspects points in the visual field showing local STF subsequently developed field loss.

Global fluctuation is computed as the root mean square of fluctuation across the whole field. Research by Flammer, Drance, Fankhauser and Augustiny[13] shows that this global STF varies between patients and is not affected by age, reaction time or pupil size.

(ii) Long-term Fluctuation

Since glaucomatous field changes occur over a period of months and years it is important to determine if changes recorded are due to LTF or actual field change. If considering the visual field as a "island of vision", Lieberman and Drake[14] suggest the analogy of LTF representing strong winds blowing across an island that is planted with wheat, where the overall contours remain the same but will vary from one point in time to another.

Katz and Sommer[15] studied LTF in normal

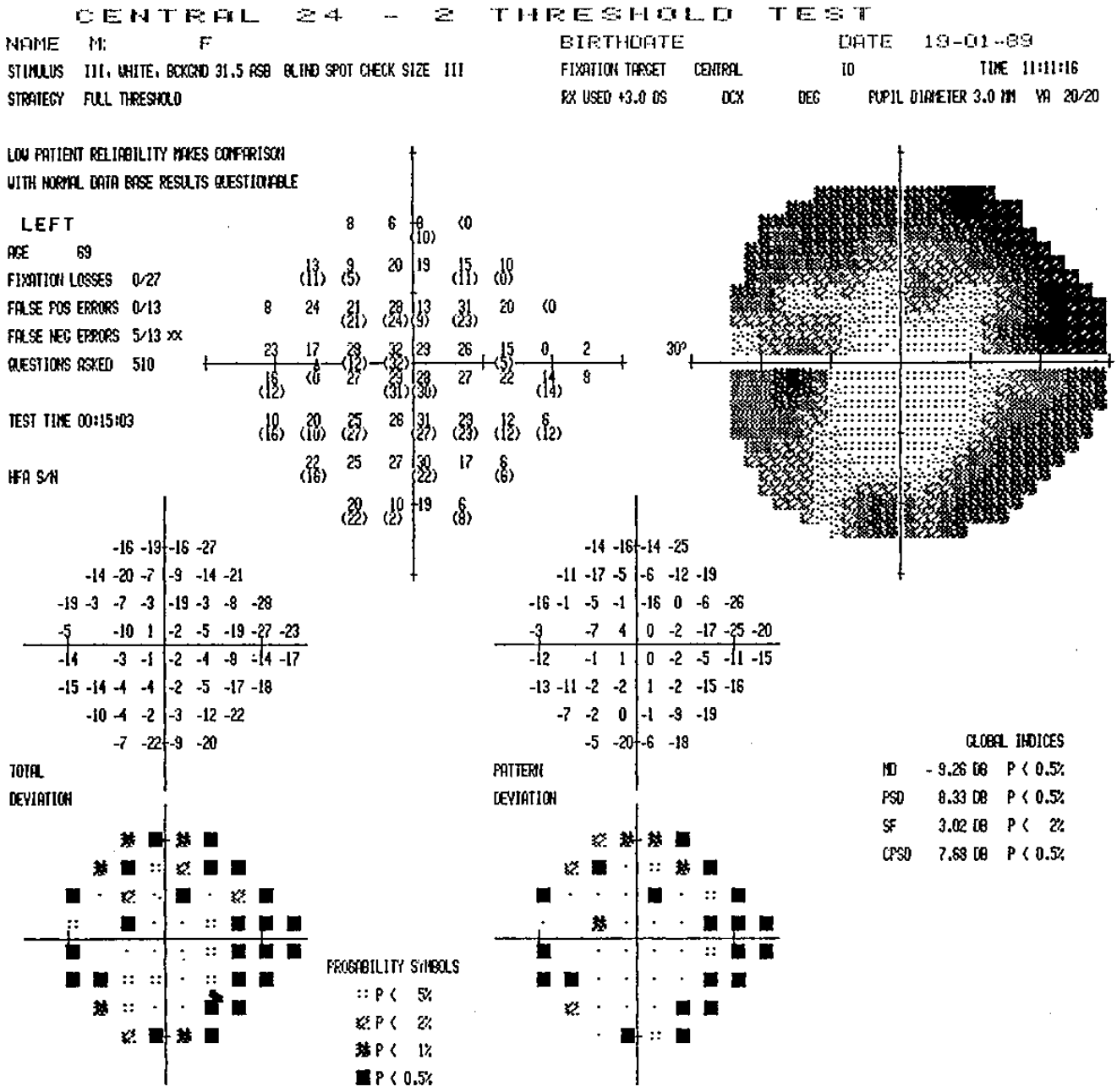


Figure 2a.

subjects three times over a period of one to two years and found that the average variation was 3.3 dB. They also found that LTF varies with the patient's age and location in the visual field. For subjects under 60 years it varies by an average 1.9 dB, whereas for subjects over 60 years this variation was 4.8 dB. Areas of greatest variability were in the superior field between 20 and 30°.

Heijl, Lindgren and Lindgren[16] examined LTF in glaucoma subjects and found that the normal areas of the field had the least LTF and abnormal areas the greatest variation, sometimes up to 16 dB difference in threshold value being recorded from one test to another occurring by pure chance. They conclude that caution is needed before interpreting localised threshold changes between two tests as a sign of visual field progression. Both the defect depth and point location needs to be considered when looking for

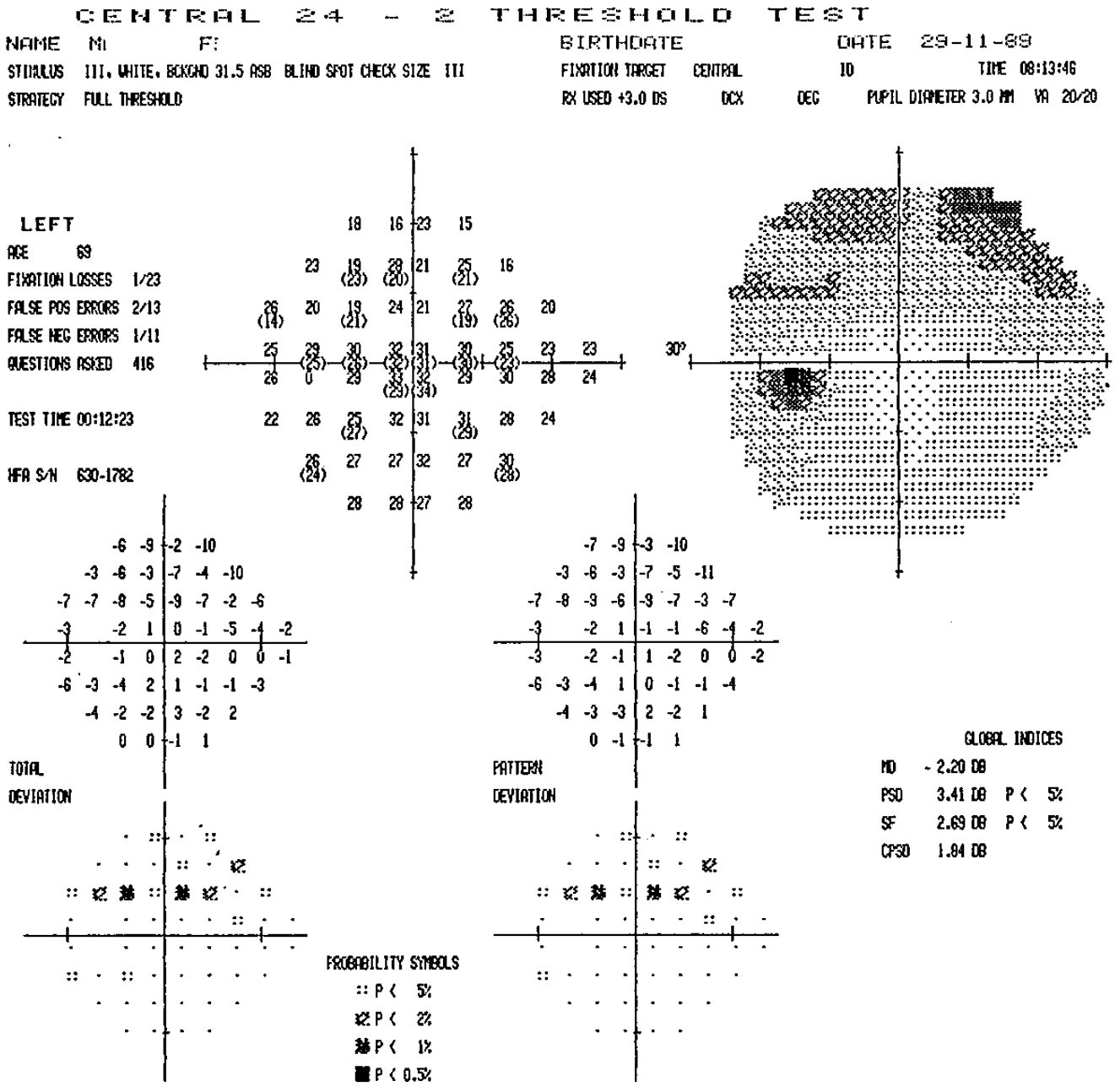


Figure 2b.

field changes and the sum total of variation across a series of fields should be zero. Figure 3 shows a series of six visual field results with large LTF of several threshold points (circled). Despite these variations of individual points from one field to the next, the overall change in the visual field is minimal.

2. IDENTIFYING ABNORMAL FIELDS FROM NORMAL FIELDS

What is normal?

A prerequisite of recognising a pathological visual field loss is a knowledge of normal values. Manufacturers of automated perimeters have spent a great deal of time collecting data on a

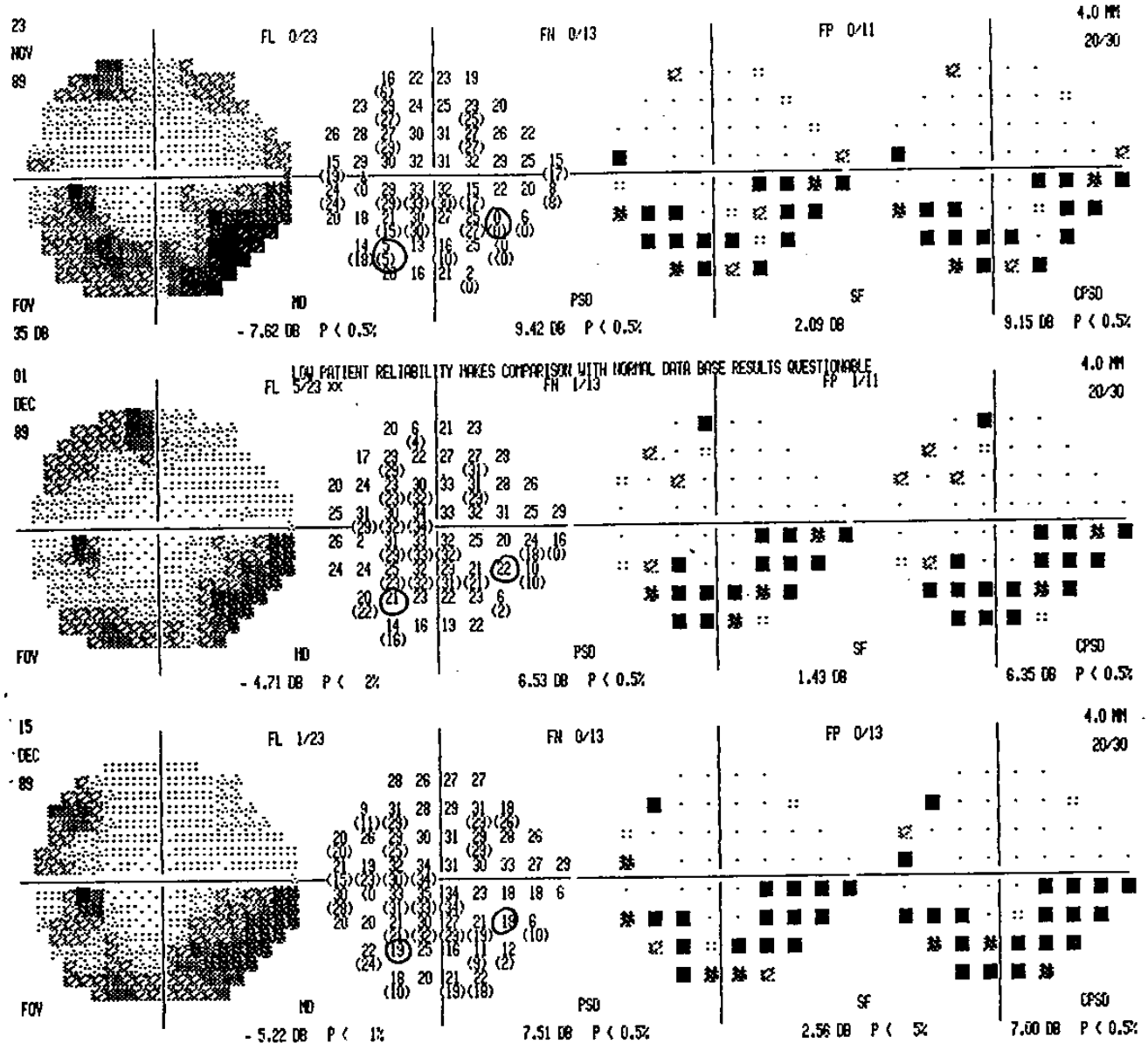


Figure 3.

wide age range of subjects. However, due to the variability of perimetric thresholds described above the differentiation of normality from abnormality is far from easy.[17] For this reason other techniques of analysing data are becoming available such as mirror image analysis[18] (where points in the superior half of the field are grouped and compared to corresponding groups in the inferior half of the field), and comparison of a patient's present field with their own previously defined values.[19]

Haas, Flammer and Schreider[20] and Jaffe, Alvarado and Juster[21] have studied the influence of age on the visual field of normal subjects. In kinetic perimetry age changes are seen as a reduction in size of isoptres. For static perimetry the DLT reduces in sensitivity throughout life by approximately 0.58 dB per decade, with the upper half of the field being more affected. The central points and area at 30° are also more affected, with the rate of decline at 30° being twice as much as at fixation. Jaffe et al consider

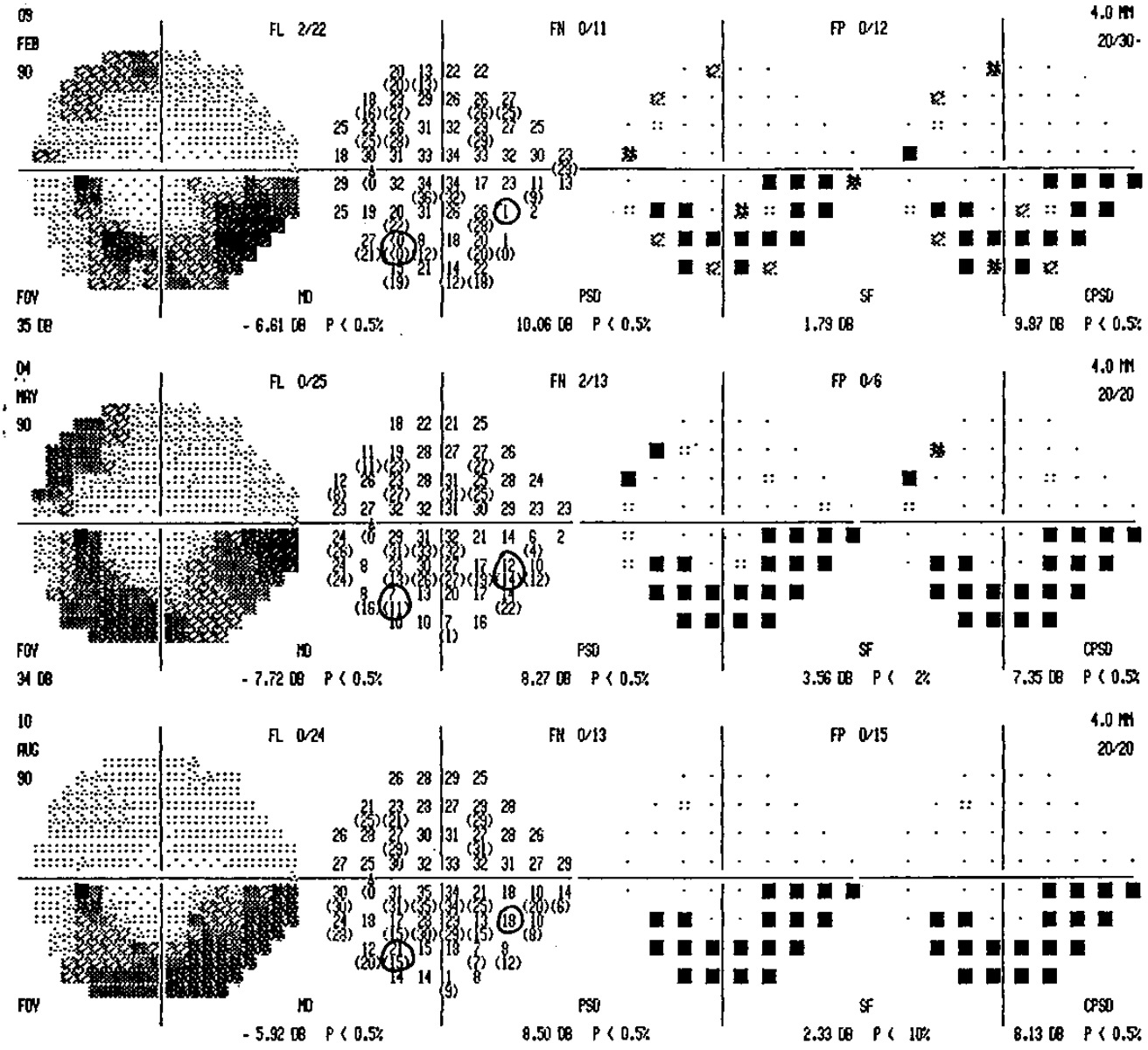


Figure 3 continued.

this to be due to a functional or anatomical loss of photoreceptors, ganglion cells and higher structures.

3. CLASSIFICATION OF VISUAL FIELD DEFECTS IDENTIFIED BY STATIC PERIMETRY

Although the classification of visual field defects can become daunting, Lieberman and Drake[14] suggest grouping them into diffuse depressions and localised defects.

Diffuse Depressions

This refers to a generalised depression of the DLT across the whole visual field, but with the contour of the visual field closely matching the contour of the normal visual field. Diffuse depressions are characterised on the HVFA by a depressed total deviation plot and normal pattern deviation plot, and a reduced Mean Deviation index but normal Pattern Standard Deviation value.

Reasons for diffuse loss include cataract,

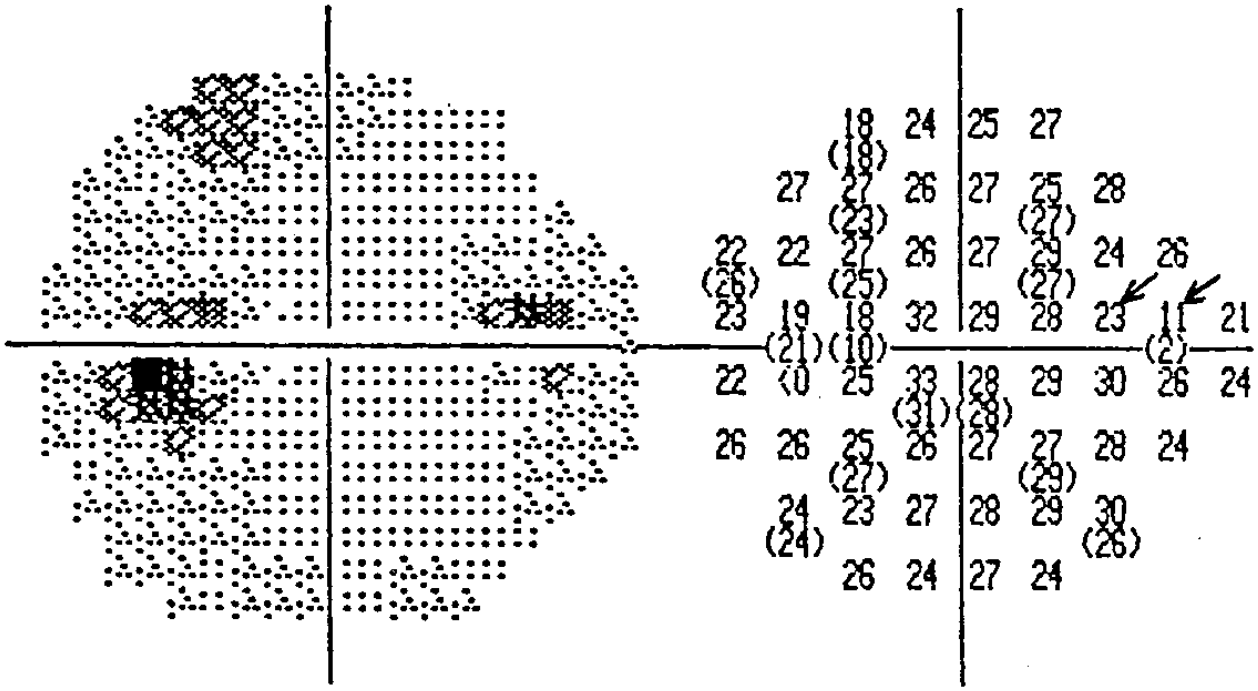


Figure 4. Localised depression.

uncorrected refractive error and, rather more controversial, a sign of early pathology of glaucoma damage.[22]

Localised Depressions

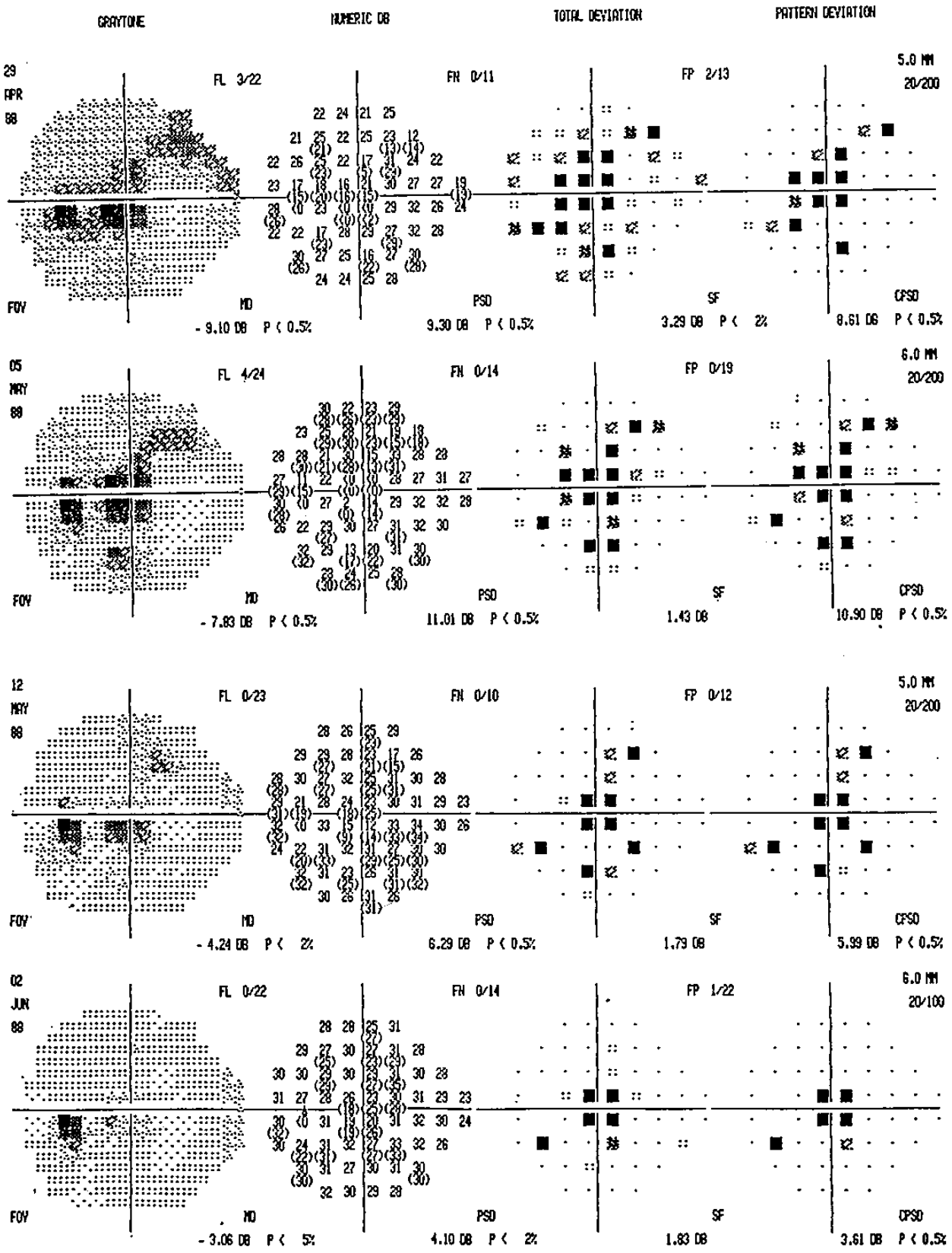
These defects are limited to small areas of the visual field and the use of static testing has increased their detection. However, in order to determine that a localised depression is in fact a field defect and not just due to variability of the DLT Heijl[23] and Lieberman and Drake[14] suggest considering the following:

- the location of the depressed point: if in the superior field beyond 20° it is likely to be a false positive,
- the sensitivity of the neighbouring points surrounding the depression: local STF suggests that isolated depressed points will occur randomly across the visual field. However, two points slightly depressed and adjacent to each other are more likely to be an actual localised depression,
- large localised fluctuation: this may be due to the fact that the visual system is weakened and is not able to produce a consistent response. If an area of increased fluctuation is adjacent to a depressed point then this further suggests an actual field defect (see Figure 4).

4. LIMITATIONS OF STATISTICAL GLOBAL INDICES

Global indices attempt to describe the visual field by a mathematical statement of probability. In the case of HVFA the Mean Deviation (MD) index estimates the uniform part of the field and the Pattern Standard Deviation (PSD) index estimates the irregular, non-uniform part of the visual field. Irregular visual fields with localised defects increase the PSD. On the other hand the MD can be reduced by both diffuse and localised field loss.[24] Unfortunately the global indices do not take into consideration the important information about the position of the depression that is needed to differentiate abnormal from normal variation in results.

For example, Figure 5 shows a sequence of four fields. The mean deviation in the first two fields is misleading as it indicates an overall improvement in the second field. However, on


NAME
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29 APR 88
FL 3/22
FN 0/11
FP 2/13
5.0 MM
20/200
FOV
MD
- 9.10 DB P < 0.5%
PSD
9.30 DB P < 0.5%
SF
3.29 DB P < 2%
CPSD
8.61 DB P < 0.5%
05 MAY 88
FL 4/24
FN 0/14
FP 0/19
6.0 MM
20/200
MD
- 7.83 DB P < 0.5%
PSD
11.01 DB P < 0.5%
SF
1.43 DB
CPSD
10.90 DB P < 0.5%
12 MAY 88
FL 0/23
FN 0/10
FP 0/12
5.0 MM
20/200
MD
- 4.24 DB P < 2%
PSD
6.29 DB P < 0.5%
SF
1.79 DB
CPSD
5.99 DB P < 0.5%
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FL 0/22
FN 0/14
FP 1/22
6.0 MM
20/100
MD
- 3.06 DB P < 5%
PSD
4.10 DB P < 2%
SF
1.83 DB
CPSD
3.61 DB P < 0.5%

Figure 5:

examining the central threshold values it can be seen that they have in fact become worse, the improvement in mean deviation suggesting a performance effect where learning has occurred and points beyond 20° have improved. In these examples the Total Deviation and Pattern Deviation plots in the last field better highlight the central depression and aid in the field's interpretation.

CONCLUSION

Although computers are now responsible for performing much of the visual field test, the orthoptist plays an important role both before, during and after the test. Understanding the factors that influence the reliability and reproducibility of results is required in setting up the patient and during the testing sequence. Knowledge of the meaning of threshold values, statistical data and normal variation needs to be combined with information about the disease process, associated visual field defects and patient clinical data. Only when all have been considered can the field results be adequately interpreted and related to the management plan for each patient.

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