IV.5 Dynamic representation of the visual field

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Abstract

Computerized perimetry has not eliminated the need for operator's intervention throughout the examination. This article describes a new technique for the representation of the visual field which provides the information necessary for a precise follow-up of the examination.

It includes a graphic display of the estimated map of sensitivity thresholds which is updated according to the patient's response after each stimulus presentation. Other graphic informations indicate the status of each testing point and its evolution along the examination.

Introduction

The dependance of the visual field examination results upon the communication between the patient and the operator has already been stressed: 'One principal psychological defect of computer perimetry is the disconnection of patient and operator. This disconnection is not desirable and means have to be provided to reestablish it'. There are reasons to conceive stability of threshold as a function of time as a communicatory problem between perimetrist and patient [5].

The presently available automated perimeters are not suitable for such purpose as the operator has very little means of understanding the examination process.

Interactivity is also needed in order to cope with situations not expected in the examination protocol [2]. Most experienced visual field technicians feel extremely frustrated when operating a computerized system. They are often left with a supervision task when the computer system spends lengthy periods of time analysing areas presenting little or no interest without any consideration about the patient's exhaustion or distress.

The purpose of the present work is to develop new graphic, real time display techniques suitable for an interactive control of the examination and compatible

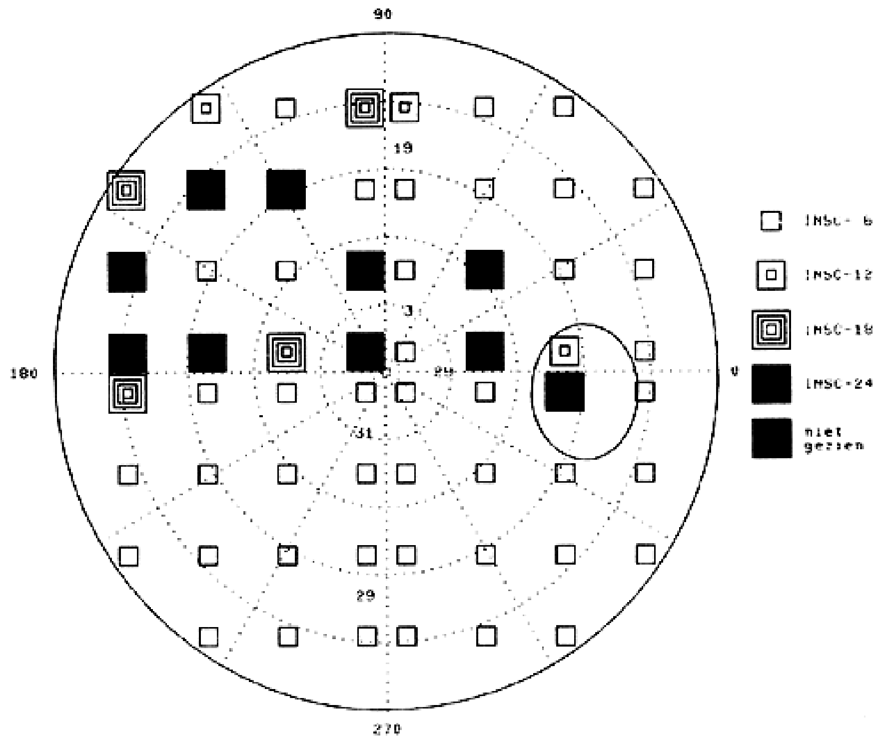

Figure 1. Representation of visual field data with a map of symbols (from Greve et al. [6]).

with the amount of information and real time constraints involved in a clinical situation.

Background

In manual perimetry, most representations are bidimensional, due to the fact that only one parameter of the stimulus is changed at a given time: eccentricity versus the meridian angle in kinetic perimetry, luminance versus the eccentricity in profile static perimetry, or sensitivity versus the meridian angle in static perimetry along a given parallel [10].

Computers have introduced examination protocols which implicate the simultaneous variation of several parameters. For instance, visual stimuli are displayed at random, in order to avoid patient's anticipation and local photoadaptation effects.

Several methods have already been proposed for the representation of visual field 3 dimensional data. First of all, maps of numbers of symbols (Figure 1) indicate the sensitivity threshold values in each test location. These maps do not provide a rapid understanding of the visual field as the evaluation of the shape and location of scotomas from a large array of numbers is rather difficult and time consuming.

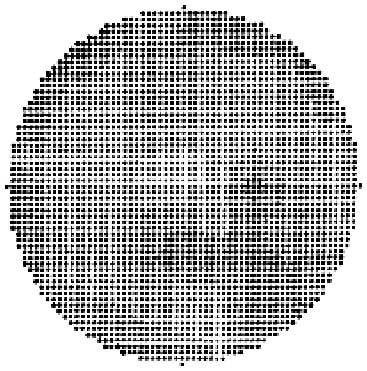

Figure 2. Representation of the visual field with an interpolated map (from Jay and Yavitz, [8]).

Another solution is the use of a map interpolated between the measuring points (Figure 2) as initially proposed by [4]. By means of a half tone display, the perception of the visual field topography is greatly improved. However, it should be emphasised that these interpolated maps have to be used very cautiously. Most often, less than 100 of the 2000 or so displayed points are really measured. A scotoma located in between the measuring points does not show up and values different from the real threshold are displayed in the exact same location.

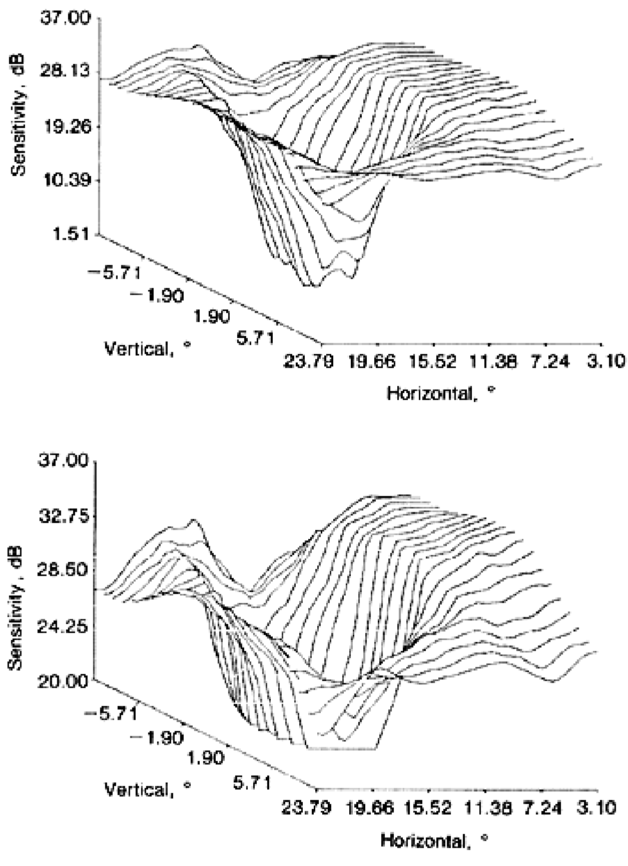

Figure 3. Three-dimensional representation of the visual field (from Hart and Hartz [7]).

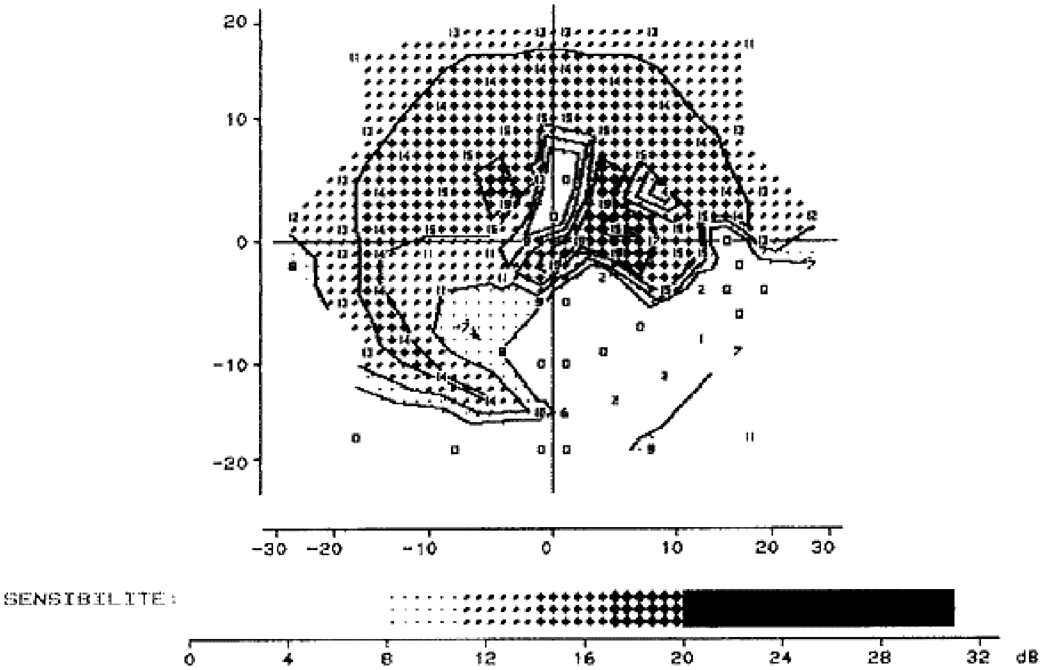

Figure 4. New representation of the visual field sensitivity.

Furthermore, these maps provide an erroneous feeling of precision about the definition of the scotoma shape and location.

Several authors have also proposed the use of 3-dimensional representations [7] and even 4-dimensional representations [9] (Figure 3). These representations are quite attractive. However, their clinical applicability is limited by the deformations resulting from the perspective view which impede a direct quantitative evalution of deficits.

Static representation of the visual field

The problem of the static representation of the static visual field (i.e. after completion of the examination session) will first be assessed as a simplification of the problem of the dynamic representation (i.e. throughout the examination).

The two maps which have been described previously appear to be complementary, one indicating the location of the testing points and their estimated threshold values, the other providing the information necessary for the evaluation of scotomas location and shape. It is therefore quite rational to superimpose both maps on the same graphic representation. The readability of this new representation was greatly improved by the use of several colors and by outlining the seperation between areas of different sensitivity. The resulting graph offers the familiar aspect of the isopter representation used in manual perimetry and is well accepted by most ophthalmologists (Figure 4).

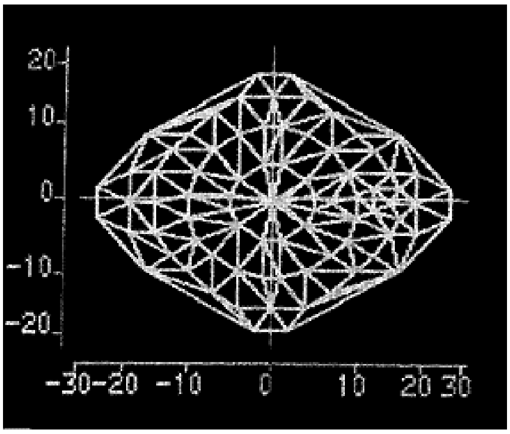

Figure 5. Dissection of the visual field into triangles.

Another problem is the determination of the interpolated map. In most methods, the surface is defined from a set of data regularly located over the domain to be represented. This is clearly not acceptable for visual field maps where some areas yield significantly more information than others. A suitable method should be capable of handling non equispaced data and also of representing with an acceptable accuracy the magnitudes and gradients of sensitivity. Polynomial methods were rejected for they can produce anomalies and require lengthy calculations. Weighing methods were found improper as the effect of a local change in threshold extends in an isotropic way upon a large area of the visual field. For instance, they produce undesirable anomalies in the neighbourhood of steep, elongated scotomas. A method initially proposed by Bengtsson and Nordbeck [1] was finally selected. The explored domain is dissected into triangles, using the measuring points as vertices (Figure 5). The intermediate values used in the half tone display and the contours are calculated by linear interpolation between the 3 vertices of each triangle. Real time constraints lead to the selection of a local iterative interpolation method [11].

This method presents several interesting features. First of all, the information brought by measuring points affects only the triangles which share these points as a summits. Second, its effects can easily be understood without an extended background in mathematics, hence by most ophthalmologists.

This map is diplayed in one of three modes, which ever is found the most suitable for the interpretation of the acquired data:

- the sensitivity mode (Figure 4) is found to be most informative with large deficits, when the remaining areas of sensitivity are best emphasised;
- the deficit mode (Figure 6) is obtained by substracting measured values from 'normal' ones obtained from a reference map built into the computer memory. It is ideal for small deficits as it eliminates the masking effect over small deficits of the sensitivity gradient with excentricity;

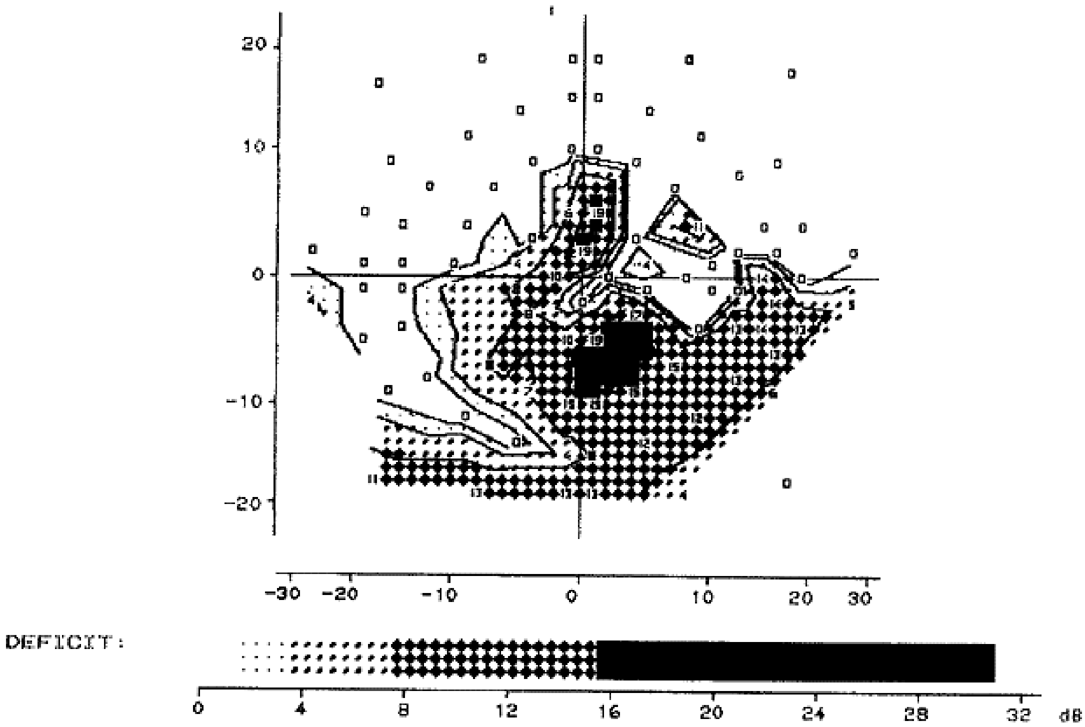

Figure 6. New representation of the visual field deficits.

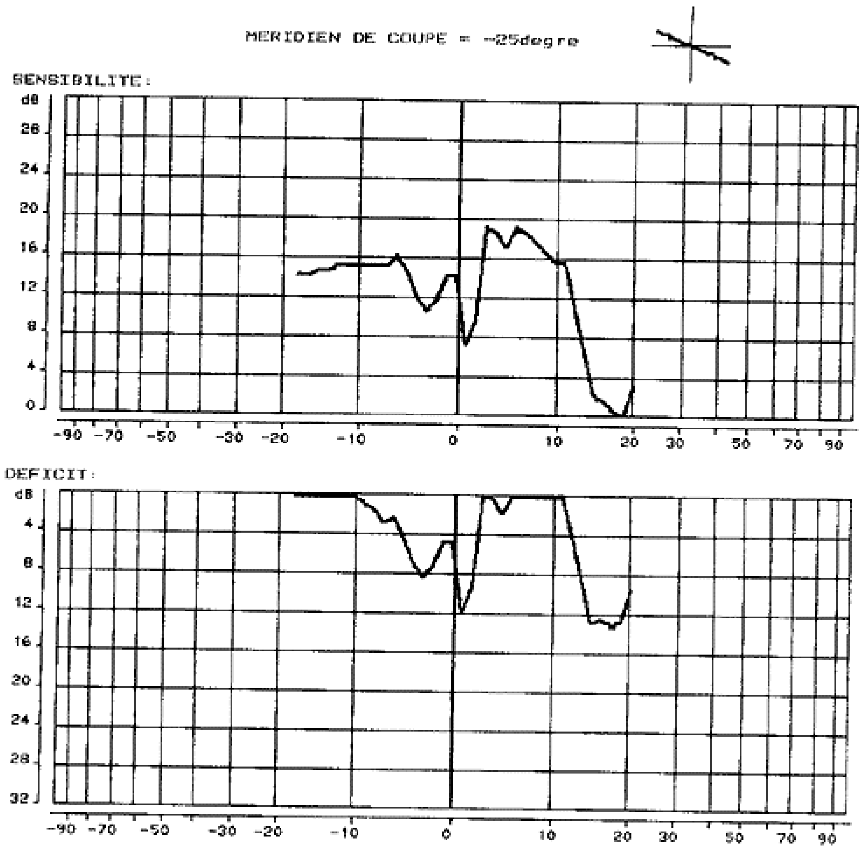

Figure 7. New representation of the visual field profile.

- the profile mode (Figure 7) allows a more precise, quantitative evaluation of sensitivity or deficit values along a given meridian.

Dynamic representation of the visual field

It is important to understand that the information visualised at any time during the examination, or even after its completion, is not the true patient's map of sensitivity. It is an estimated map which is more or less accurate, depending upon many parameters such as the threshold evaluation strategy, the patient's cooperation, etc. Therefore, what is relevant for clinical purpose is not only the topography of the visual field but also the amount of confidence given to its determination. The dynamic representation is derived from the static one. Additional color marks characterise the reliability of the threshold evaluation in each testing point. At the beginning of an examination, the best, a priori, estimation of the visual field is displayed with reliability indicators at their minimum value. The initial threshold values are selected from the 'normal' visual field if the patient's own visual field is unknown, or from a prior visual field if one is available. The visual display is updated after each measurement, with a local correction of the interpolated and isopter maps as well as of the corresponding reliability indicators.

Conclusion

The present method has been tested for several months in four different medical centers in Lille, Paris, Reims and Tours. More than 4000 visual fields have been completed. The dynamic representation is rapidly accepted by most ophthalmologists and technicians. The major reason is the improved understanding of the examination protocol as well as of the final results. The availability of a dynamic visual field representation throughout the examination is one step toward the implementation of semi-automated examination strategies. For instance, the examination protocol can be stopped at any time and changed for a new protocol more adapted to the patient's fatigue or sudden lack of cooperation.

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