AUTOMATED STATIC CAMPIMETRY WITH LOCALLY ENHANCED SPATIAL RESOLUTION

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Abstract

The diagnostic power of perimetry and campimetry can be considerably improved by the local concentration of targets within a perimetric grid. This procedure renders a higher spatial resolution in the corresponding retinal area, thus enhancing efficiency of the method. Two methods are introduced which individually tailor local stimulus concentration based on morphological changes or previous psychophysical results.

1. Regions of interest can be defined on individual, digitized fundus images, which are used as morphological landmarks for tailoring localized high resolution campimetry/fundus-oriented perimetry (FOP). With the help of this technique, even minimal physiological visual field defects such as angioscotomas are detectable in normal individuals. FOP is especially useful in patients with circumscribed morphological changes of the retina (chorioretinal scars) or optic disc (glaucoma, drusen). The method is able to detect scotomas in patients rated as normal with conventional 30-2 perimetry'. 2. Individual grids can also be constructed on the basis of the results of previous perimetric examinations. In representative cases with deficient ophthalmoscopy manifestation (e.g., Purtscher's traumatic angiopathy), grids with locally concentrated stimuli based on previous perimetric results markedly enhance the capabilities of visual field testing allowing an exact description and follow-up of circumscribed defects. This method may also be useful for detecting minute lesions of the posterior visual pathways.

Introduction

Nowadays threshold estimating procedures, which mostly use rectangular perimetric grids with 6° spacing, are generally accepted as a state-of-the-art assessment of visual field defects. However, this procedure is obviously not appropriate in cases of either very small or very large scotomas. This paper presents two solutions to this problem, i.e., fundus-oriented perimetry/campimetry (FOP), and local concentration of stimuli based on prior perimetric results. Of course, these two methods can be combined if necessary.

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Methods

Fundus-oriented perimetry/campimetry

This method has been described elsewhere in detail\textsuperscript{1-4}. Briefly, it correlates morphology with function by tailoring perimetric stimulus arrangements individually to characteristic fundus findings. This is realized by using two characteristic landmarks, \textit{i.e.}, the blind spot and the center of the visual field\textsuperscript{5}. In this way a digitized fundus image can be graphically displayed and processed by means of inversion along the horizontal and vertical axes. After superimposition, the center of the visual field is manually aligned horizontally or vertically with the foveola of the digitized fundus image. The blind spot, which has been initially defined by manual perimetry, is then superimposed onto the optic disc of the digitized fundus image. This activates rotatory and zoom functions for the fundus image mentioned above. Subsequently, a fundus-oriented arrangement of test points can be individually created on the screen of the control monitor (Figs. 1 and 4).

Local concentration of perimetric stimuli

Results of earlier perimetric examinations may serve as a basis for the construction of perimetric grids with localized stimulus concentration. In the case of extensive scotomas, complementary subsets of stimuli are merged. Basically, this procedure superimposes different subsets of test point arrangements, presented within subsequent perimetric sessions (Figs. 2a-c, left; Fig. 3, left). Each subset is constructed in such

\textit{Fig. 1.} Basic prerequisites for fundus-oriented perimetry/campimetry (FOP). Essential components are highlighted by gray background.
Fig. 2a-c. Left: complementary set of test points (TCC-A, TCC-B, TCC-C). Right: matching results in a patient with primary open-angle glaucoma (POAG). The scotoma changes its appearance remarkably, depending on the stimulus arrangement of each subset (TCC-A, -B, -C).
a way that its test points fall in between those of the other stimulus arrangements, thereby increasing the spatial resolution of the perimetric procedure. Some test point locations coincide in different subsets; these are taken as reference values in order to obtain information about systematic drifts from session to session. This procedure is especially suited for comparatively extensive scotomas with bizarre borders (and/or) without characteristic, circumscribed morphological lesions (e.g., advanced glaucoma, affections of the optic chiasm, postgeniculate lesions). Of course, this method can be combined with FOP.

Both methods are principally adaptable to all conventional perimeters or campimeters which allow generation of an individual stimulus arrangement and are capable of importing digital image data from a network, diskette, photo-CD, or other storage media (Fig. 1).

The examinations presented here were carried out with the Tübingen computer campimeter (TCC) using a high resolution true-color video display unit (Calibractor, Barco Inc., Kortrijk, Belgium). The monitor had been calibrated by means of a mobile luminance meter to ensure homogeneity of background luminance and stimuli over the entire surface of the display. Stimulus duration was 200 msec. A modified 4-2-1 strategy with four reversals was used in this study. Thresholds were assessed with the maximum likelihood method, based on a logistic regression model (‘logit analysis’).
Results: examples of application

Advanced glaucomatous visual field defect: subsequent superimposition of perimetric grids

Figures 2a-c and 3 illustrate the technique of subsequent, complementary stimulus concentration in the case of an advanced bizarre glaucomatous scotoma. The figures clearly show that the shape of the scotoma depends remarkably on the different subsets of stimulus arrangements.

Angioscotoma

Figure 4 demonstrates the basic principle of FOP in the case of angioscotoma detection: a line of narrow-spaced test points is constructed, which cross a retinal vessel nearly perpendicularly (Fig. 4, bottom). Additional stimuli are arranged within the entire central visual field in order to prevent the normal subject from a systematic shift of fixation or attention. The profile section of the differential luminance sensitivity (dls) curve shows a characteristic dip, which corresponds well with the location and extent of the causative retinal vessel (Fig. 4, top).

Purtscher’s traumatic retinal angiopathy

This disease is often characterized by only minute or even absent changes of the fundoscopic image in the post-acute stage. This is also the case in this patient: only slight irregularities within the macular wall reflex are visible (Fig. 5a). Therefore, FOP is not very helpful in this case. Local stimulus concentration in regions of known functional abnormalities is useful for detection and follow-up of circumscribed scotomas. Amsler chart findings are superimposed onto the campimetric result (Fig. 5b). Naturally, the Amsler grid can only detect scotomas within the central 10° visual field; additionally, it does not allow quantification of scotoma depth. Due to the comparatively coarse, rectangular standard 30-2 grid, the Humphrey Field Analyzer had difficulty in detecting some of the small, shallow visual field defects (Fig. 5c).

Early glaucomatous change: documentation with fundus-oriented perimetry/campimetry

This case was initially presented as ocular hypertension (Fig. 6a). However, within the follow-up period there was a considerable increase of optic disc cupping. Additionally, a small splinter hemorrhage occurred in the one o’clock position of the left optic nerve head (the image of the optic disc is mounted upside-down in order to enhance the morphological and functional interrelationship). While conventional perimetry using a 6° rectangular grid remains normal, local stimulus concentration within the affected retinal nerve fiber bundle region shows a corresponding slight regional depression of local dls (Fig. 6b).
Fig. 4. **Bottom:** Fundus image of a normal subject with superimposed perimetric grid. **Top:** Profile of differential light sensitivity (dls) along a line of test points (bright stimuli; size = 12') crossing a retinal vessel. The angioscotoma, *i.e.*, the dip in the dls profile is marked by a ‘+’. The arrow points to the scotoma position determined by manual kinetic perimetry, the circle and the cross hair show the location and diameter of the retinal vessel derived topographically from the fundus image with the Littman formula47.

Fig. 5a-c. Purtscher’s traumatic retinal angiopathy (left eye). **a.** Fundus photography: only minute changes are visible (arrow indicates irregularity of the macular wall reflex). **b.** Individual arrangement of stimuli with local concentration of test points according to earlier perimetric findings. Perimetric results with superimposed Amsler chart findings. **c.** Corresponding results of conventional perimetry with the Humphrey Field Analyzer (HFA 640; 4/-2dB strategy with two reversals).
Automated static campimetry with locally enhanced spatial resolution

Fig. 5a-c.
Discussion

The usual background luminance of 10 cd/m² in conventional perimetry is within the photopic luminance range and thus predominantly examines the cone system. This type of photoreceptor is characterized by a very inhomogeneous distribution over the retina, with excessive concentration in the foveal region. This privilege of the very central parts of the visual field continues along the entire primate visual system via the optic nerve, chiasm, optic tract, and optic radiation, and comes to its climax within the striate cortex; just 2° of the visual field are processed by approximately 50% of the calcarine region. Already, these purely neuroanatomical data clearly demonstrate that local resolution of the perimetric procedure has to be adapted to these circumstances in order to gain maximum information about visual system dysfunction. In many situations, a conventional rectangular, equidistant 6° perimetric grid is too coarse in the central and too dense in the more peripheral region of the visual field. Since the number of stimulus presentations possible in a single session is restricted to some hundreds, a general increase of stimulus density is neither appropriate nor effective.

Perimetric grids which consider the cone-distribution function and cortical magnification factor by way of a rigid centripetal stimulus concentration still may ‘waste’ targets in regions of minor diagnostic importance. Instead, creating grids of stimuli specifically ‘tailored’ to regions of interest according to the individual diagnostic needs seems to be the more advantageous procedure.

Morphology oriented perimetric techniques have been successfully applied for assessment of circumscribed choroidal/retinal structures or lesions. As well as FOP, which is described here, alternatively fundus-controlled methods can be used. With the help of a fundus camera or a scanning laser ophthalmoscope (SLO), direct inspection of the fundus and recording of fixation during the perimetric examination is possible. This is especially useful in patients with fixation instabilities, e.g., due to affections of the macular region. However, automated fundus tracking programs correcting such deviations ‘online’ before and during stimulus presentation are still in the developmental stage.

Examples of application for this method are the detection of minute, physiological visual field defects, such as angioscotomas, as well as circumscribed chorioretinal pathologies of the posterior pole or glaucomatous scotomas.

Langerhorst et al. have shown the positive influence of local test point concentration on the detection of glaucomatous scotomas.

Fundus-oriented perimetric procedures are not applicable in cases of postgeniculate lesions of the adult human visual system as they do not result in changes of the optic disc. Nevertheless, because of the remarkable cortical magnification factor, the strategy of local stimulus concentration may be useful, especially in cases of lesions affecting the occipital pole.

Conclusions

Local stimulus concentration, either oriented on circumscribed morphological lesions of the fundus image or based on prior perimetric results, may considerably improve perimetric and campimetric diagnostic power by enhancing spatial resolution in regions of interest.
Fig. 6a. Initial findings of a patient with ocular hypertension progressing into glaucomatous optic neuropathy (left eye). Top: Perimetric result of the Tübingen computer campimeter (TCC; 4-/2-/1dB strategy with three reversals) with subsequent superimposition of three stimulus subsets (TCC-A, -B, -C). Insert: Morphology of the optic disc (mounted upside-down). Bottom: Conventional perimetry with the Humphrey Field Analyzer (HFA 640; 4-/2dB strategy with two reversals; 30-2 grid).
Fig. 6b. Follow-up (approximately 12 months later). Top: Perimetric result of TCC using FOP with stimulus concentration in the lower retinal nerve fiber layer (RNFL) region, revealing a shallow visual field defect. Insert: Morphology of the optic disc (mounted upside-down) with a small intraretinal hemorrhage (within the box). Bottom: Conventional perimetry with the HFA as mentioned in Figure 6a cannot detect a clear visual defect in this area.
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References