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A comparison between Humphrey and frequency doubling perimetry for chiasmal visual field defects

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PURPOSE. *To evaluate and compare the diagnostic ability of frequency doubling technology perimetry (FDT) with standard automated perimetry (SAP) using Humphrey Field Analyser for the detection of visual field defects produced by chiasmal lesions.*
METHODS. *Fifteen patients with documented chiasmal disease and previously diagnosed of bitemporal hemianopia with Humphrey perimetry were prospectively evaluated. All of them underwent a new SAP (SITA 24-2) followed by FDT tests (C-20 threshold). Diagnostic criteria for hemianopia were established according to the total deviation plot and the threshold values of FDT. A patient was diagnosed with hemianopia if one or both criteria were met. Based on these criteria, FDT sensitivity was calculated. Testing time and global indexes for both perimetric strategies were compared.*
RESULTS. *The sensitivity of FDT was 75.0% (18 out of 24 eyes); the criterion based on threshold values was met more often (70.83%) than the criterion based on the total deviation plot (50.0%). Linear correlation was better for the external column than for the internal column of the visual field. Testing time with FDT was 122.16 seconds shorter than with SAP ($p<0.001$). The mean value for mean deviation (MD) was -13.62 dB (SD 6.88) for SAP and -8.83 dB (SD 5.94) for FDT ($p<0.001$).*
CONCLUSIONS. *Compared with standard automatic perimetry, FDT has a low sensitivity for detecting temporal hemianopias and also has more difficulty in defining the vertical limits of the defects. Therefore, it does not appear to be an adequate method for the detection of chiasmal visual field defects. (Eur J Ophthalmol 2005; 15: 739-45)*

KEY WORDS. *Frequency doubling technology perimetry, Temporal hemianopia, Chiasmal pathology, Neuro-ophthalmologic visual field defects*

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INTRODUCTION

Frequency doubling technology perimetry (FDT) relies on the principle that when a stimulus comprising light and dark bars of low spatial frequency (1 cycle per degree or less) undergoes counterphase flicker at a high temporal frequency (>15 Hz), it appears to the observer to have double the number of bars that are actually present (1). This stimulus preferentially stimulates cells of the magnocellular (M) layer of the lateral geniculate nucleus (2). These M cells are believed to be primarily involved in the detection of motion and rapid flicker (3).

FDT perimetry was developed for early detection of glaucomatous damage to the optic nerve (4). It has many advantages over classic perimetry: it is simple to use, there is no need to correct refraction, testing time is short, it is not expensive, and it has a portable weight (5).

Because of these advantages, its ability to detect and define neuro-ophthalmologic visual field defects has been previously studied (3, 6). However, none of these studies has focused on defects produced by chiasmal lesions.

The purpose of this study is to determine whether FDT perimetry can detect and lead to a correct classification of temporal hemianopias.

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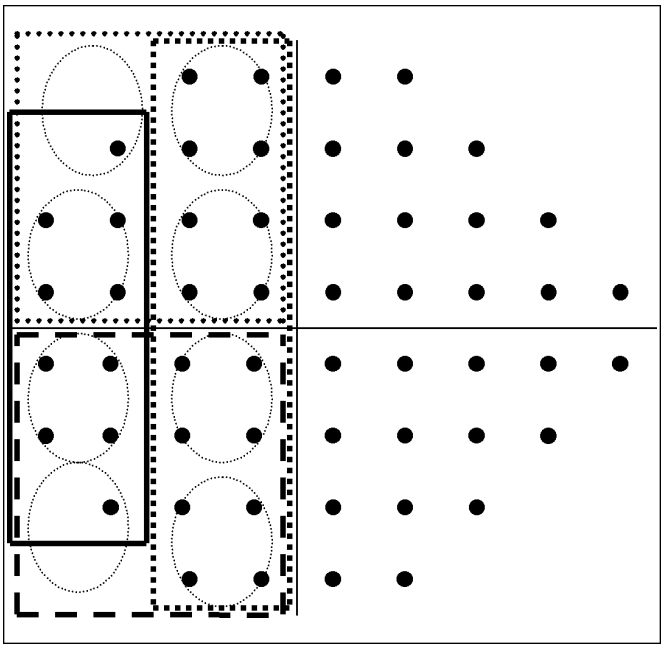

Fig. 1 - *Humphrey visual field divided into eight zones and grouped in columns and quadrants.*

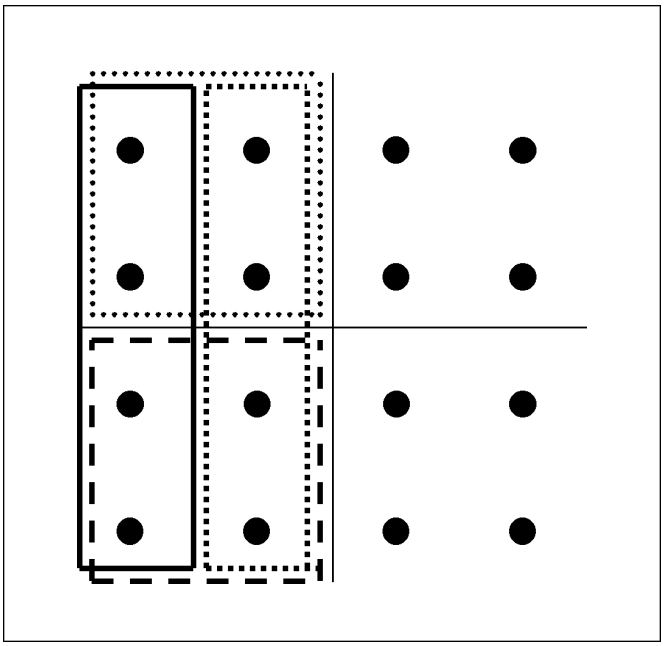

Fig. 2 - *Frequency doubling perimetry divided into eight zones and grouped in columns and quadrants.*

SUBJECTS AND METHODS

Fifteen patients with previous perimetric diagnosis of bitemporal hemianopia using the Humphrey perimeter were prospectively evaluated. All of them had been previously diagnosed by neurologic imaging and in several cases by histologic analysis of chiasmal lesions. Patients with other ocular diseases such as glaucoma, cataracts, or retinal pathology, which could have interfered with a correct perimetric exploration, were excluded from the study. Every patient was familiar with standard automated perimetry (SAP), since they had undergone a white-white automated perimetry on the Humphrey Field Analyser when they had been originally diagnosed.

All patients underwent a new session of standard automated perimetry (Humphrey Field Analyser 750, Zeiss/Humphrey Systems, Dublin, CA) 24-2 test, SITA strategy (Swedish interactive threshold algorithm). In the same visit, FDT testing was performed (Welch Allyn Inc., Skaneateles Falls, NY; Humphrey Instruments, San Leandro, CA). Considering the previously reported learning effect using FDT, 20-1 screening program was performed in patients with no previous experience with FDT (7, 8). Afterwards the C-20 threshold test was performed. In patients with refractive errors greater than 6 diopters, optic correction was used (8). Only the threshold test was used for statistical analysis. For SAP, visual fields were considered reliable when fixation losses, false negative and positive errors were less than 25%. FDT visual fields were considered reliable when fixation losses were less

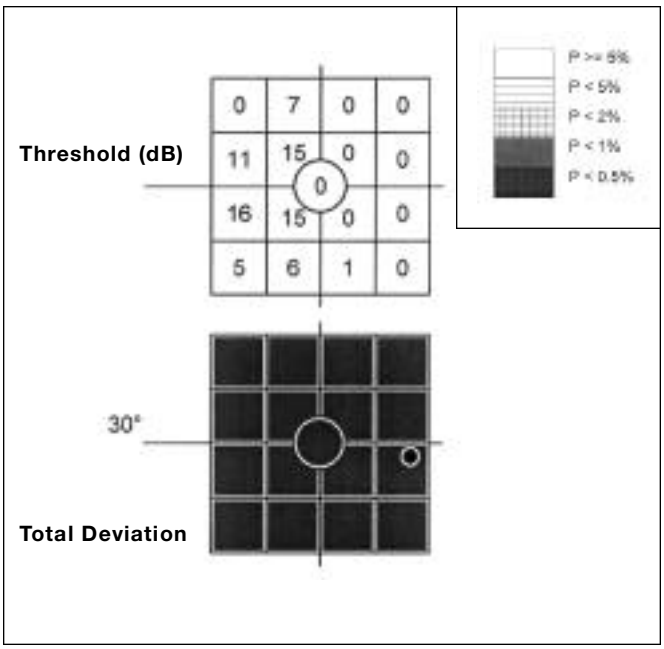

Fig. 3 - *The sensitivity and specificity of frequency doubling perimetry increases when taking into account threshold values instead of total deviation plot (Case 10).*

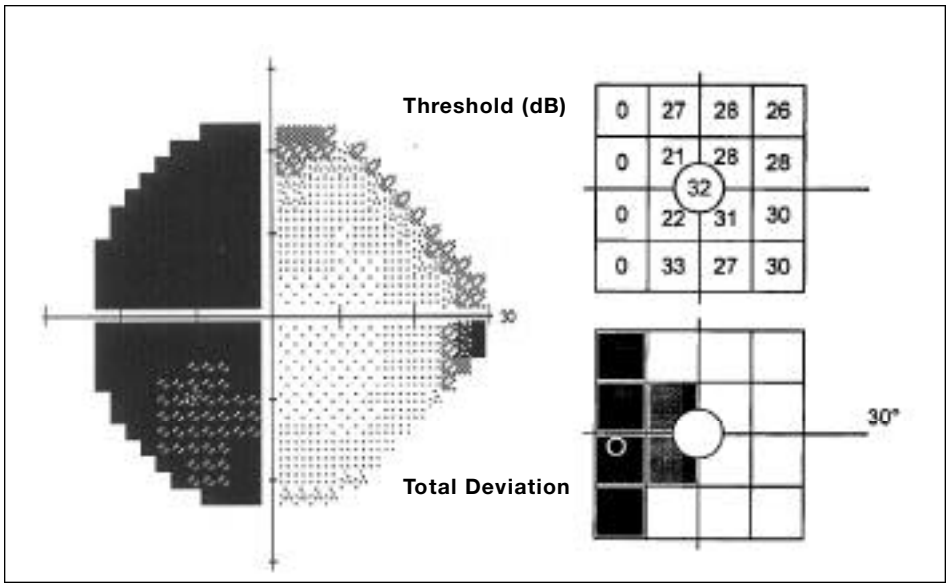

Fig. 4 - *An example of how the internal column appears less affected in frequency doubling perimetry than in standard automated perimetry (Case 5).*

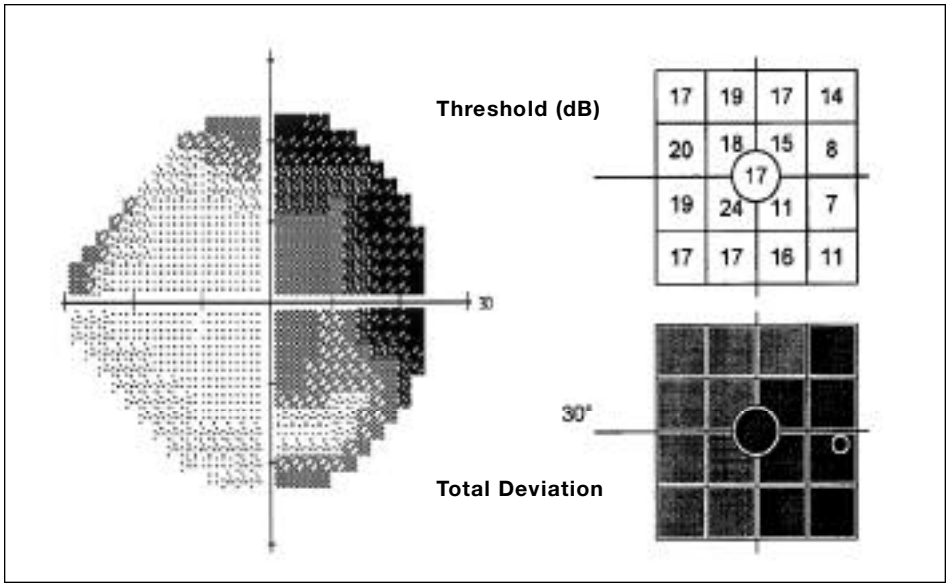

Fig. 5 - *Frequency doubling perimetry can sometimes show a defect much more extensive than standard automated perimetry, masking the hemianopic character of the lesion (Case 13).*

than or equal to 2 out of 6, and false positive and negative errors less than or equal to 1 out of 3 (5, 9).

Precise automated perimetric definitions for typical neurologic field defects are not readily available. Thomas et al set the following criteria: quadrantanopia was diagnosed if one of the two following criteria was fulfilled: the threshold values showed depression of three or more contiguous points by 5 dB or more along the vertical meridian as compared with their mirror image points; depression of other points in the affected quadrant was invariably present. Alternatively, the diagnosis was made if three points of the pattern deviation probability plot were depressed to 1% or lower probability level, again along the vertical meridian and as compared with their mirror image points. A hemianopia was diagnosed when diagnostic criteria for quadrantanopia were applicable to both the quadrants comprising the vertical field (10).

Because chiasmal lesions are predominantly tumoral lesions that compromise optic nerve fibers gradually as they expand, the visual field defects they produce initially are often partial vertical defects which become hemianopias as the tumor grows (11). We therefore considered as complete hemianopia those visual fields that fulfilled completely Thomas et al's criteria for hemianopia, and as

incomplete hemianopia those fields that had a quadrantanopia according to Thomas et al's criteria and depressed threshold values in the other quadrant of the same hemifield.

In order to compare both perimetric strategies, the 24-2 SITA test plot was divided into eight zones, which loosely correspond to the FDT test areas (Fig. 1). Mean threshold values for each of these areas were calculated and a linear regression analysis was used to compare these areas with the corresponding ones in FDT (Fig. 2).

We could not find precise criteria for hemianopia or quadrantanopia diagnosis with FDT. Therefore, following loosely the criteria set by Cerio-Ramsden et al (6), we decided to propose our own criteria according to the total deviation plot and according to the threshold values, since these are the data that a standard FDT instrument provides. In the total deviation plot, if three or more contiguous points were depressed to 1% or lower probability level along the vertical meridian as compared to their mirror image points, a hemianopia was diagnosed. When we analyzed the threshold values, if two or more contiguous points were depressed by 10 dB or more along the vertical meridian, as compared with their mirror image points, with depression of other points in the affected quadrant, a hemianopia was diagnosed. A patient was diagnosed with hemianopia if one or both criteria were met.

Additionally, we compared the testing time, mean deviation (MD), and pattern standard deviation (PSD) on both perimetric strategies with a Student t test.

To study macular involvement, we considered there was macular sparing in SAP if none of the four central test locations was depressed and in FDT when the central test point was normal. Then we compared both strategies with Pearson's chi square test.

RESULTS

The demographic data are shown in Table I. Mean age was 55.27 years (SD 14.77). Sixty percent of the patients were men. A pituitary macroadenoma was the most common diagnosis (60%). Five of the 15 patients had one blind eye (Tab. I).

Following the criteria described above, after analyzing the SAP tests for the remaining 25 eyes, 16 fulfilled criteria for complete hemianopia, 8 had incomplete hemianopia, and 1 had only a diffuse sensibility depression in the temporal hemifield.

For the purpose of analyzing sensitivity, results were grouped into hemianopias or not hemianopias; 24 eyes fulfilled criteria for hemianopia. The diagnosis obtained with FDT when our proposed criteria are applied is shown in Table II. The overall sensibility of FDT was 75.0 % (18 out of 24 eyes); however, the criterion based on threshold values was met more often (70.83 % [17 out of 24 eyes]) than the criterion based on the total deviation plot (12 out of 24 eyes [50.0%]).

A linear regression model was used to determine the correlation between the mean of the threshold values of different zones of the SAP field tests as compared to equivalent zones in the FDT.

Pearson correlation coefficient for the whole temporal hemifield was 0.778 ($p<0.001$). When the hemifield was divided into an external and an internal column, the R value was higher for the external column (0.844 [$p<0.001$]) than for the internal column (0.598 [$p=0.002$]). If the hemifield was divided into a superior and an inferior quadrant, the R values were of 0.729 ($p<0.001$) and 0.764 ($p<0.001$) respectively.

Testing time was significantly shorter for FDT as compared with SAP: 277.72 (SD 23.75) vs 399.88 (SD 57.97) seconds ($p<0.001$).

The mean MD was -13.62 dB (SD 6.88) for SAP and -8.83 dB (SD 5.94) for FDT ($p<0.001$). PSD values were 9.87 (SD 3.24) and 8.00 (SD 3.42) for SAP and FDT, respectively ($p<0.001$).

SAP showed macular sparing in 24% of the eyes (6/25), while FDT showed it in 40% (10/25) ($p=0.175$).

DISCUSSION

Since FDT has advantages over SAP such as its short testing time, portable weight, and the fact that it is not usually necessary to correct refraction, attempts have been made to determine its usefulness in detecting neuro-ophthalmologic visual field defects (6). Up-to-date evidence is controversial: some studies show that it may fail to demonstrate complete hemianopic and quadrantanopic defects (3). Because each neuro-ophthalmologic disease involves a different part of the visual pathway, we decided to analyze just visual defects caused by chiasmal disorders to avoid confounding factors. Another problem is the fact that clear automated perimetry definitions for typical neuro-ophthalmologic visual field defects have not been established.

We therefore defined hemianopia criteria for SAP tests, taking into account that chiasmal lesions produce defects that initially may be subtle and incomplete (12). Since we have not found any previous definition for FDT tests, we propose diagnostic criteria for hemianopias in order to standardize diagnostic procedures.

If a procedure is to be useful as a screening method for a given pathology, it must have high sensitivity. The sensitivity of FDT following the criteria described above was 75.0%, too low to be adequate as a screening method, as it means that one out of every four fields that fulfilled SAP criteria for hemianopia would not have been labeled as

TABLE I - DEMOGRAPHIC DATA AND DIAGNOSIS OF STUDY PATIENTS

Patient	Age, yr	Sex	Diagnosis	Visual acuity	
				R	L
1	61	Female	Meningioma	NLP	0.7
2	42	Female	Craniopharyngioma	0.8	0.9
3	44	Female	Craniopharyngioma	0.7	0.4
4	43	Male	Pituitary macroadenoma	0.9	1.2
5	53	Female	Meningioma	NLP	0.8
6	66	Male	Pituitary macroadenoma	0.8	NLP
7	72	Male	Craniopharyngioma	0.3	0.4
8	30	Male	Pituitary macroadenoma	0.9	1
9	69	Male	Pituitary macroadenoma	0.4	NLP
10	71	Male	Pituitary macroadenoma	FC	0.8
11	72	Female	Pituitary macroadenoma	0.4	FC
12	57	Male	Pituitary macroadenoma	NLP	1
13	71	Male	Pituitary macroadenoma	0.7	FC
14	35	Male	Pituitary macroadenoma	1	1
15	43	Female	Meningioma	0.2	0.6

NLP = No light perception; FC = Finger counting

TABLE II -DIAGNOSIS BY THOMAS' CRITERIA FOR STANDARD AUTOMATED PERIMETRY AND BY THE AUTHORS' PROPOSED CRITERIA FOR FREQUENCY DOUBLING TECHNOLOGY PERIMETRY (FDT)

Patient	24-2 VF defect		FDT defect following pattern deviation criteria		FDT defect following threshold value criteria	
	R	L	R	L	R	L
1	Blind	Incomplete	Blind	No	Blind	No
2	Incomplete	Complete	No	Yes	Yes	Yes
3	Complete	Complete	Yes	Yes	Yes	Yes
4	No criteria	Incomplete	-	Yes	-	No
5	Blind	Complete	Blind	Yes	Blind	Yes
6	Incomplete	Blind	No	Blind	No	Blind
7	Complete	Complete	Yes	No	Yes	No
8	Complete	Complete	Yes	Yes	Yes	Yes
9	Complete	Blind	Yes	Blind	Yes	Blind
10	Complete	Complete	No	Yes	Yes	Yes
11	Complete	Complete	Yes	No	Yes	Yes
12	Blind	Incomplete	Blind	Yes	Blind	Yes
13	Complete	Complete	No	No	Yes	Yes
14	Incomplete	Incomplete	No	No	No	No
15	Complete	Incomplete	No	No	Yes	No

Complete = Complete hemianopia; Incomplete = Incomplete hemianopia; Blind = Blind eye; No criteria = No hemianopia according to Thomas' criteria; Yes = Hemianopia following criteria for FDT; No = No hemianopia following criteria for FDT

such if just FDT had been performed. It is interesting to note that the criterion based on threshold values is more sensitive than the criterion based on the total deviation probability plot. Therefore, special attention should be paid to FDT threshold values when a hemianopia is suspected.

In order to study SAP and FDT's ability to characterize perimetric defects, we compared various parameters using the Student t test. MD for SAP was significantly lower than for FDT; this argues for the fact that SAP can more precisely determine the depth of visual defects. FDT also appears to have more difficulties in outlining the pattern of the defects, as is shown by the PSD value, significantly higher in SAP, and by the presence of macular sparing that showed a nonsignificant tendency to be more often present after FDT testing. We also compared the mean threshold values of SAP and FDT using a linear regression model as an indirect method for analyzing the relationship between the depth and extension of defects in both strategies. The correlation between FDT and SAP was significantly high when the whole hemifield was compared (0.778). It is interesting to note that this correlation was different when the external and internal columns were studied: it increased for the external column (0.844) and decreased for the internal column (0.598). Similar data have been reported with FDT in homonymous hemianopias (6). The most likely explanation for this difference is that the large flickering stimuli used by FDT extend across the vertical axis: scattered light is seen by the edge of the functioning visual field of the patient (13). In this way, FDT fails to accurately define the vertical limits of the defect, and the internal column appears to be less affected that it actually is (Fig. 4). Data supporting this evidence have been provided by Woodward and Wall (14, 15), who have demonstrated that the sensitivity for detecting hemianopias with FDT improves by offsetting the stimulus along the vertical meridian by 3º. This agrees with our clinical experience: when we study FDT visual fields, it is more difficult to detect hemianopias because the defect does not clearly correspond to a hemifield. In fact the defects in FDT are highly variable, ranging between defects confined to the external column as described above, to a depression of the whole hemifield (Fig. 5). This extensive and diffuse affectation appears to be due to the presence of scattered abnormal test locations that obscure the hemianopic character of the defect. Although this problem can also occur in SAP, because there are at least 52 test locations, the effect of a few scattered abnormal test locations is much less problematic. One possible explanation for this phenomenon could be the presence of fixation errors. In FDT full threshold tests fixation is checked only six times. Fixation is more difficult in FDT because of the lack of a chin rest. Neuro-ophthalmologic patients, because of their pathology and their demographic characteristics, may have even greater difficulty in maintaining fixation.

In our study, every patient was experienced in SAP, reducing the artifact produced by learning effects. In order to avoid this same artifact in FDT, all patients with no previous FDT experience underwent first an FDT C-20 screening test, which was not included in the final test results analysis. Matsuo et al (16) in their study of learning effects in FDT also performed a screening test prior to the first threshold test. When a second threshold test was performed, they found an improvement in MD value of 0.6–0.8 dB. This means that the FDT experience in our patients could be insufficient, and our results inaccurate. However, this further learning effect would only have slightly increased the difference in depth detected between both methods.

In summary, FDT is not sufficiently precise and valid to be used as a screening method in patients with lesions producing chiasmal syndromes, since far too many defects could go undetected. Because FDT underestimates the damage to the internal column, if confronted with a vertical affectation of the external column we should suspect a more extensive defect, such as a hemianopia.

FDT has a shorter testing time and is more easily transportable, so it could be initially employed to help decide which patients need further testing on the gold standard (10).

The new FDT Matrix model has a testing point distribution more similar to SAP and it appears to have better results (17). In fact, a recent study has shown that stimulus detection in the involved hemifield along the vertical meridian in homonymous hemianopia is less prominent than with FDT (18).

No author has any commercial or proprietary interest in any product or company cited in the article.

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