Correlation of the Multifocal Visual Evoked Potential and Standard Automated Perimetry in Compressive Optic Neuropathies

Helen V. Danesh-Meyer, Stuart C. Carroll, Brent J. Gaskin, Angela Gao, and Greg D. Gamble

PURPOSE. To evaluate the relationship between abnormalities detected by the multifocal visual-evoked potential (mfVEP) compared with those detected by static achromatic automated perimetry in patients with compressive optic neuropathy.

METHODS. Fifteen patients of mean age 50.8 years, with known compressive optic neuropathy from chiasmal lesions, underwent monocular mfVEP and 24-2 SITA-standard Humphrey visual field (HVF; Carl Zeiss Meditec, Dublin, CA) testing in each eye. Visual field spatial agreement and extent of involvement were analyzed by assigning a severity score to each quadrant, based on pattern deviation and amplitude deviation probability plots.

RESULTS. HVF mean deviation (MD) was $-6.54 \pm 7.43$ dB (mean), and the mfVEP mean AccuMap Severity Index (ASI; Objectivision Pty. Ltd., Sydney, Australia) score was 81 $\pm 74$. MD and ASI correlated significantly ($r = -0.55, P = 0.024$). Although both mfVEP and HVF reported approximately the same proportion of visual fields as abnormal (70%, 21/30, and 87%, 26/30, respectively), 19% (5/26) with abnormal HVF were labeled normal or borderline by mfVEP. The agreement for field quadrants between instruments was 69% ($\kappa = 0.35$). mfVEP severity scores for quadrants and hemifields were higher than scores for HVF in the same eyes. The superotemporal quadrant showed the strongest correlation between techniques ($r = 0.73, P = 0.002$).

CONCLUSIONS. In the first study to compare mfVEP to HVF in patients with compressive optic neuropathy, there was good qualitative and quantitative agreement between tests, though findings were in only modest agreement in some areas. The injury caused by compressive optic neuropathy may be usefully identified by mfVEP. Improved methods of analysis may increase the diagnostic utility of the method. (Invest Ophthalmol Vis Sci. 2006;47:1458–1463 DOI:10.1167/iovs.05-1146)

The conventional pattern visual evoked potential (VEP) is considered to be useful in assessing visual pathway lesions such as optic neuritis and other optic neuropathies, because it provides an objective measurement of optic nerve function. Patients with optic neuropathies may demonstrate increased signal latency and/or reduced amplitude.1,2 Reducions in pattern VEP amplitudes have been documented to occur in the corresponding visual fields of cortical lesions that affect the visual pathway.3,4 However, conventional pattern VEP has its limitations. Approximately 65% of the cortical response generated is produced by stimulating the central 2° of the visual field.4 Furthermore, the information provided by conventional pattern VEPs poorly describes the spatial detail and the extent of peripheral field involvement in chiasmal lesions. The VEP is also subject to wide intersubject variability.5 Hence, the conventional pattern VEP is limited in its ability to localize and monitor visual field defects.

With the advent of the multifocal (mf)VEP, the integrity of the visual pathway through to the visual cortex can be objectively assessed in the form of a topographic visual field map of up to 32° eccentricity from fixation.5,6 The mfVEP produces an objective map of the visual field by using multiple recording channels to detect signals from all areas of the visual field. This technology has recently become available to clinicians with the development of the AccuMap multifocal objective perimeter (Objectivision Pty. Ltd., Sydney, Australia). Numerous studies have demonstrated that mfVEP can detect glaucomatous change. The mfVEP has also shown good correlation with visual field defects in glaucomatous optic neuropathy and optic neuritis.7–12 The advantages of an objective perimetry test are both practical and theoretical. mfVEP eliminates the subjectivity and patient learning process required by the static automated perimeter.

To date, few published reports have described the use and response of mfVEP in nonglaucomatous optic neuropathies in comparison to conventional testing. Hood et al.12 clearly demonstrated that the mfVEP can be used to track local optic nerve damage after optic neuritis and that it was superior to Humphrey Visual Field (HVF; Carl Zeiss Meditec, Dublin, CA) in identifying areas of abnormality. Recently, mfVEP findings in patients with central visual pathway lesions have shown good agreement with HVF results.13 Two of these patients had compressive chiasmal lesions and showed corresponding visual field defects with both the mfVEP and the HVF. There are no data specifically comparing mfVEP and HVF in compressive optic neuropathy, though studies involving traditional full-field and hemifield pattern reversal VEP in chiasmal compression have yielded mixed results. Some reports suggest detectable preperimeter change, and others suggest that only moderate defects are detected reliably.14–16 The purpose of this study was to examine the results of mfVEP in subjects with known chiasmal compression and compare the visual field map to standard automated perimetry performed with the Humphrey Visual Field Analyzer.

METHODS

Subjects

Consecutive patients with pituitary tumors causing chiasmal compression were identified and recruited from Auckland City Hospital’s Department of Ophthalmology, University of Auckland, Auckland, New Zealand.

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neuro-ophthalmic clinic over a 3-month period beginning August 2003. The diagnosis of a compressive pituitary tumor was confirmed by MRI neuroimaging. Patients with diabetes mellitus, glaucoma, a family history of glaucoma, intraocular pressure greater than 21 mm Hg on any visit, or other ocular disorders affecting the optic nerve or macula were excluded from the study. All patients had visual acuity of better than 20/40 and were required to have two stable, reliable visual field test results (described later) within 3 months of mfVEP acquisition. All patients were at least 6 months from either surgery or radiotherapy.

Procedures adhered to the tenets of the Declaration of Helsinki, and the protocol was approved by the Auckland Ethics Committee. Informed consent was obtained from all patients. Patients then underwent a full ophthalmic examination of both eyes, including slit-lamp biomicroscopy, HVF, and mfVEP perimetry.

**Visual Field Testing**

Static achromatic automated perimetry was performed with the Swedish Interactive Threshold Algorithm (SITA)-Standard 24-2 program of the HVF Analyzer according to the manufacturer's recommendations, using a 4-mm² Goldmann size II stimulus (0.45°) on a 31.5-apostibl background. The differential light sensitivity threshold was determined at each test location. Patients whose visual field reliability indices fell outside these parameters were excluded: fixation losses <15%, false-positive responses <25%, and false-negative responses <25%. To reduce the learning curve effect, all patients had experience with automated perimetry before the fields used in this analysis. Each eye had to have two reliable visual field test results, with no evidence of deterioration, within 3 months of the study examination.

**mfVEP Acquisition**

The mfVEP was recorded using the AccuMap system running the latest iteration of available software (Opera ver. 2; ObjectiVision). The AccuMap simultaneously stimulates multiple sites within the visual field, and extracts corresponding VEP signals from those sites by using a spread-spectrum technique with families of binary sequences to drive the visual stimulus. The system collects tracings from 58 visual field areas, with a pseudorandom alternating checkerboard-pattern stimulus displayed on a high-resolution computer monitor. Each stimulation site is modulated in time according to a different sequence. The technique permits computation of the resultant signal by cross-correlation of the response evoked by the sequence stimulation with the sequence itself.

The visual stimulus is displayed as 58 packed segments in a dartboard configuration (Fig. 1). The segments are cortically scaled with eccentricity to stimulate approximately equal areas of cortical surface (V1 striate visual cortex) to produce a signal of similar amplitude from each stimulated segment. Each segment contains a checkerboard pattern (16 checks) with the size of individual checks proportional to the size of the segment, which is dependent on eccentricity. The central 1° is used as a fixation monitor and therefore is not stimulated. Fixation is maintained by asking the patient to indicate when a randomly generated checkerboard is seen. An electrode is placed just below the midline of the eye. Each run duration is 55 seconds, and comprises a fixed number of pseudorandom elements presented in a different sequence each time. A proprietary trace improvement algorithm determines when the required number of runs have been attained to provide an optimum tracing and the examination is then concluded by the operator. Amplifier settings for the AccuMap system are set at 100,000 times gain, with a 1 to 20 Hz band-pass filter that is digitally filtered to 1 to 5 Hz. Advanced software analysis produces a printout showing the visual field in a similar layout to conventional automated perimeters. Raw trace data are analyzed using the ObjectiVision Opera 2 system software. Peak-to-trough amplitudes for each wave within the interval of 60 to 220 ms are determined and compared among channels for every stimulated segment of the visual field. Amplitude and latency for each field sector of the mfVEP is determined. 9 Signal amplitude, latency, and interocular asymmetry for each sector in the combined trace array are compared with an internal normal database, and probability plots of abnormal sectors are constructed. The report generated by the AccuMap also displays an AccuMap Severity Index (ASI) score based on the total number of abnormal zones, relative severity and asymmetry. The software then classifies the ASI, by comparing to a built-in normative database of 100 patients, as normal (within 95% confidence interval [CI]; ASI, 0–11), borderline (95%–99% CI, ASI, 11–19), or outside normal limits (outside 99% CI, ASI, >19).

**Analysis of Data**

The mfVEP records were analyzed separately with the investigator masked to the clinical data and HVF results. The AccuMap software ranking of within normal limits/normal, borderline or outside normal limits/abnormal was compared with the HVF MD probability, an age-adjusted indicator of global field involve-
ment. For the purposes of comparison, borderline mfVEP reports were grouped with abnormal mfVEP reports, and for HVF, \( P < 2\% \) or less defined the field as globally abnormal. HVF with \( P < 5\% \) or greater were defined as normal fields. The Glaucoma Hemifield Test (Carl Zeiss Meditec) could not be used for classification as normal or abnormal, as the patients did not have glaucoma.

To investigate the spatial agreement of mfVEP and HVF, a modified cluster criterion as suggested by Goldberg et al.\(^7\) was used. This criterion allowed the definition of whether a quadrant of the probability plot was abnormal both for the HVF and the mfVEP. The cutoff criteria for an abnormal quadrant classification was defined as three points with \( P > 5\% \) or two points with \( P < 2\% \). The vertical and horizontal meridian was used as the demarcation line to determine the quadrants. To make direct comparison of the local damage identified on the mfVEP and HVF plots, the HVF pattern deviation clusters were defined in the same way, except that a cluster could contain no more than one point from the outer ring of the 24-2 HVF points.

Severity of field involvement, both as quadrants and the temporal and nasal hemifields, were also analyzed using the probability plots displayed on the perimeters’ reports. Humphrey visual field data was analyzed using the pattern deviation probability plots. Each probability point was assigned a numerical value (\( P > 5\% = 0 \), \( P < 5\% = 1 \), \( P < 2\% \) or \( P < 1\% = 2 \) and \( P < 0.5\% = 3 \)). The numerical values were then averaged over each quadrant. This gave a total severity score for each quadrant ranging from 0 to 3 (normal; 3, all points represent \( P < 0.5\% \)). Quadrants were mathematically combined to form temporal and nasal hemifield data, with a corresponding severity score of 0 to 6. The mean deviation (MD), pattern SD (PSD), and their respective normative probabilities were recorded for each field.

The mfVEP report displays a similar probability plot for amplitude deviation, and these points were assigned numerical values and averaged for each quadrant, again giving a severity score for each quadrant ranging from 0 to 3 (\( P > 5\% = 0 \), \( P < 5\% = 1 \), \( P < 2\% = 2 \), \( P < 1\% = 3 \)).

All data were analyzed by computer (SAS ver. 9.2; SAS Institute, Cary, NC). Data were normally distributed, as demonstrated by the D’Agostino and Pearson omnibus normality test. Agreement between abnormality classification between mfVEP and HVF, for global fields, quadrants and hemifields, was summarized as the percentage of agreement and as the chance-adjusted \( x \) statistic (with 95% CI and a 0.54 proportion of chance agreement). For all calculations of agreement, data from both eyes were used. Correlation coefficients were calculated for global indices of field severity (HVF MD and AccuMap ASI), and sectoral measures of involvement (severity score) with Pearson’s method for right eyes only. A comparable statistic was modeled using general estimating equations (GEE; with the GENMOD procedure of SAS), to take into account the correlation between eyes in the same subject.\(^7\) Because all comparisons were preplanned, no adjustment to the overall significance level was required or used. All tests were two-tailed, and a 5% significance level was maintained throughout the analyses.

**RESULTS**

A total of 15 patients were included for final analysis. The mean age was 50.8 ± 21.7 years, and there were seven men and eight women. Figure 2 shows a sample report from the AccuMap (ObjectVision Pty. Ltd.) and corresponding HVF perimetry in a patient with compressive optic neuropathy.

**Global Parameter Comparisons**

The mean MD from the Humphrey fields was \(-6.54 \pm 7.43\) dB (\( n = 30 \), range \(-0.56 \) to \(-28.31\)), and the mean PSD was \(4.37 \pm 5.16\) dB (\( n = 30 \), range 1.22–11.76). The mean ASI was 81 ± 74 (\( n = 30 \); range, 0–246). A Pearson’s correlation coefficient comparing MD to ASI yielded \( r = -0.55 \), \( P = 0.023\) for right eyes (\( n = 15 \)). No significant relationship was seen between PSD and ASI. The mfVEP reported 21 (70%) of 30 eyes as having abnormal results, 2 (7%) of 30 as borderline, and the remaining 7 (23%) of 30 as being normal. Nine patients had abnormal results bilaterally. Two patients had normal reports bilaterally. The remaining four patients had a mixture of normal, borderline, and abnormal results.

Where an MD \( P < 5\% \) or worse is used to classify a field as abnormal, the HVF reported 87% (26/30 eyes) as abnormal. Of these abnormal visual fields, 12% (3/26 eyes) were labeled as normal, and 8% (2/26 eyes) as borderline by mfVEP. Using the same criterion, in eyes with normal HVF results, the mfVEP classified none as abnormal or borderline. Conversely, where mfVEP gave a clear abnormal or borderline ranking (23/30 eyes), all eyes had an HVF MD \( P < 5\% \) or worse (i.e., an abnormal HVF result). However where mfVEP gave a normal ranking, 43% of eyes had an abnormal HVF result. A summary of the data is displayed in Table 1.

The mean ASI for a normal mfVEP was 3.71 ± 2.98 (\( n = 7 \)). The corresponding MD for this group of patients was \(-2.12 \pm 1.63\) dB, with a mean PSD of 2.97 ± 2.27 dB (\( n = 7 \)). In

![Figure 2](image-url)
Correlation of mVEP and SAP in Compressive Optic Neuropathy 1461

Table 1. Global Classification of All Eyes

<table>
<thead>
<tr>
<th>AccuMap Classification</th>
<th>HVF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abnormal</td>
</tr>
<tr>
<td>Abnormal</td>
<td>21</td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

HVF classification is based on mean deviation probability (P < 5% or worse represents abnormal) and the corresponding classification determined by the AccuMap software.

For comparison purposes of quadrants and hemifields, similar contingency tables were constructed, showing the percentage agreement and $\kappa$ values (Table 3). The percentage agreement varied from 70% to 77%, with $\kappa$ values again indicating fair to moderate levels of agreement (0.31–0.52).

Relationship between Extents of Loss

Each quadrant received a severity score between zero and three. A score of three represents a probability plot where all data points lie on the line of best fit. Temporal and nasal hemifields had a corresponding severity score of 0 to 6. Table 4 shows the individual scores for right eyes in each quadrant of the hemifields.

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superotemporal</td>
<td>73% (54–58)</td>
</tr>
<tr>
<td>Inferotemporal</td>
<td>70% (51–85)</td>
</tr>
<tr>
<td>Superonasal</td>
<td>77% (58–90)</td>
</tr>
<tr>
<td>Inferonasal</td>
<td>70% (51–85)</td>
</tr>
<tr>
<td>Hemifield</td>
<td></td>
</tr>
<tr>
<td>Temporal</td>
<td>73% (54–88)</td>
</tr>
<tr>
<td>Nasal</td>
<td>75% (58–88)</td>
</tr>
</tbody>
</table>

$\kappa$ statistic and agreement: ($\kappa$ >0.2 = fair, >0.4 = moderate, >0.6 good). 95% Confidence intervals shown in parentheses.


discussion

One criterion for the predictive power of a diagnostic method is to compare it to another technique that is considered the gold standard. In this study, we performed objective (mVEP) and subjective (HVF) perimetry on eyes of persons with tumors affecting the optic chiasm. The simplest level, one can label a test result as globally normal or abnormal. In these terms, 87% had abnormal HVF by virtue of having an MD index $P < 5%$ or less. The mVEP test, using the classification given by the AccuMap, designated 88% of these eyes as abnormal. Four eyes that were normal by HVF were also called normal by mVEP. Although the number of eyes in our study is small, one could therefore calculate that the sensitivity of mVEP for abnormal HVF is 88% at a specificity of 100%. If different mVEP criteria for abnormality were used, for example the quadrant severity scores in Table 2, sensitivity remained as high as 86%, though specificity fell to 52%. This may be because the AccuMap criteria established for identifying a visual field as normal or abnormal have been designed to separate glaucomatous eyes from normal.

A more detailed comparison between mVEP and HVF was provided by quadrants of each field, since the findings in chiasmal syndromes would be expected to affect the temporal field more than the nasal, particularly the superotemporal field, due to the typical expansion of pituitary lesions from below the chiasm. Spatial agreement between mVEP and HVF quadrants was 70% to 77%, similar to agreements seen in eyes affected by glaucoma. Despite the different distribution of injury in compressive syndromes, the agreement by quadrant was similarly accurate. Agreement in the nasal hemifields was better than temporally. This may be explained by the fact that these areas were more spared by the disease, thus producing a comparison of normal to normal in the two instruments.

Table 2. Agreement of Quadrants Based on Cluster Criterion/Severity Score in All Eyes

<table>
<thead>
<tr>
<th>mVEP</th>
<th>Abnormal</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal</td>
<td>62</td>
<td>10</td>
</tr>
<tr>
<td>Normal</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>35</td>
</tr>
</tbody>
</table>

Percentage agreement, 73% (64–80), $\kappa = 0.40$ (0.23–0.57).

Table 4. Severity Scores for Right Eyes

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>mVEP</th>
<th>HVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supero temporal</td>
<td>1.53</td>
<td>0.85</td>
</tr>
<tr>
<td>Infero temporal</td>
<td>1.02</td>
<td>0.75</td>
</tr>
<tr>
<td>Superonasal</td>
<td>0.79</td>
<td>0.52</td>
</tr>
<tr>
<td>Inferonasal</td>
<td>0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>Hemifield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal</td>
<td>2.55</td>
<td>1.58</td>
</tr>
<tr>
<td>Nasal</td>
<td>1.40</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Range 0–3 for quadrants, 0–6 for hemifields.
further demonstrates the high specificity of mfVEP seen in the global data.

In our study population, it was also noted that the mfVEP did not always clearly respect the vertical midline. This may be because, similar to the frequency-doubling perimeter, the stimulus of the mfVEP extends right up to the midline, whereas with HVF, the test points are 3° on either side. Hence, subtle fixation shifts may result in the appearance on the mfVEP that the visual field defect slightly spills over across the vertical midline.

A complication of assessing new technology is that the older technique is used as the gold standard. This has the value that a known benchmark is set, but it means that the newer technique can never be shown to be “better,” by definition. The higher severity scores in our study could be simply due to an overly sensitive scaling of damage; or, the mfVEP could have actually identified damage earlier than HVF. Longitudinal evaluations of patients with compressive optic neuropathy are needed, to determine which of these possibilities is true. Such longitudinal studies may be more expeditious than similar studies in glaucoma, because of a more rapid natural history of field involvement and deterioration in compressive chiasmal disease compared with that of chronic glaucoma.

The majority of research with the mfVEP has been in glaucomatous optic neuropathy. Results have varied, some suggesting that the mfVEP has a 97% sensitivity in detecting visual field loss in glaucoma with the ability to identify pre-perimetric change in 59% of fellow eyes,7,20 to others claiming that mfVEP may overestimate the number of abnormal field points in eyes with mild loss, generating an unacceptably high number of false-positive results.10 Artifactual cross-contamination of normal field sectors in the mfVEP could be implicated as being responsible, though it has been demonstrated that this does not occur in one normal subject.15

Previous investigators have identified disparities between the number of points falling beyond the 95% percentile of normality between the mfVEP and HVF with no consistent pattern to the discrepancy.9,21,22 The underlying basis of these disparities is unknown, though the differences cannot be explained by random variability alone.23 The discrepancies may be partly explained by the different sources of variability of the two modalities. Variability with HVF may be due to the eccentricity of the tested point, the extent of disease process, fatigue, concentration, and the response bias of the patient. These are measured by prolonged test times or increased error rates. There is also a learning curve associated with HVF that complicates interpretation. Several fields may be needed before a reliable result is achieved. In contrast, there is no learning curve for multifocal objective perimetry. Divided patient attention does not seem to affect the mfVEP.24 The mfVEP, however, is limited by operator experience with the technology. Background noise interpreted as a true signal may also contribute to the lack of correspondence between mfVEP and HVF. One of the problems previously recognized with mfVEP recordings was the high intersubject variability in VEP amplitudes. Alternatively, the signal may be small because of poor conductivity at electrode contact sites. Some of this variability has been addressed and overcome in the AccuMap system by the use of a scaling algorithm based on underlying electroencephalographic signal activity.25

Furthermore, there are limitations to directly comparing mfVEP to HVF, as the two modalities are different types of measurements. First, the HVF is a threshold test whereas the mfVEP is a suprathreshold or summed-input test. The mfVEP is a measure of the amplitude of a gross electrical response, whereas HVF is a behaviorally determined threshold measure.26 The assumption that mfVEP and HVF should correlate exactly assumes that the mfVEP signal is proportional to the HVF loss, that the same relationship exists between both tests and ganglion cell loss, and that both tests have contributions from the exact same proportion of the various ganglion cell types. The only direct measures of the relationship between local field sensitivity loss and local loss of human ganglion cells are the postmortem ganglion cell counts by Quigley et al. and others27–29 which suggest that although the relationship is not simple, it is not far from being linear. However, Hood et al.26 suggested that the amplitude of the signal portion of the mfVEP is related to the loss of ganglion cells and hence in turn, linearly related to HVF loss. Because noise affects the amplitude of the mfVEP, it limits the extent to which the mfVEP amplitude can be reduced by disease. If the limitation of the mfVEP in terms of the signal-to-noise ratio is taken into consideration, the relationship between mfVEP and HVF is better understood.

Consideration should also be given to the possibility that nonglaucomatous optic neuropathies involve different subsets of ganglion cells in various stages of disease severity. Clinically, nonglaucomatous optic neuropathies manifest loss of central visual acuity and color vision earlier in the disease course than is observed in glaucomatous optic neuropathy. Patients with nonglaucomatous damage to the optic nerve or damage to the chiasm also demonstrate very different visual field defect morphology than do patients with glaucoma, parallelizing differences in topographic sites of injury. Furthermore, unlike glaucoma, those with compressive optic neuropathy may have reversible visual field defects, suggesting impaired ganglion cell function, rather than ganglion cell death. Therefore, if mfVEP and HVF are each sensitive at detecting defects in different subsets of ganglion cells, both may be equally accurate but measuring different aspects of optic nerve damage.

The technique used by current mfVEP systems, such as the AccuMap, has undergone numerous revisions and enhancements to reach its current state. However, the mfVEP perimeter shares some limitations with its subjective counterparts—refractive error must be corrected, fixation must be maintained, lids may interfere with superior portions of the visual field and cataracts may affect the amplitude.30 It is particularly welcome to have a technique that can identify defects with minimal patient input. Poor HVF takers, on the basis of reliability indices, have been shown to yield reliable mfVEP recordings, and in these instances, mfVEP may prove a viable alternative.31

In conclusion, this is the first study to specifically evaluate mfVEP in compressive optic neuropathies. There was strong qualitative and quantitative agreement between regions of decreased mfVEP amplitude and regions showing HVF defects. Further, longitudinal studies are required to determine whether mfVEP can identify functional loss earlier than HVF in chiasmal syndromes. Additional research addressing its value in the wider sphere of optic nerve disorders is necessary and will require new techniques for data acquisition and analysis. For example, we constructed severity scores that made an inherent presumption of linearity across the probability differences.

### Table 5. Pearson’s Correlation Coefficients for Right Eyes: mfVEP and HVF Severity Scores

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Right Eye</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal</td>
<td>0.71</td>
<td>0.0032</td>
</tr>
<tr>
<td>Nasal</td>
<td>0.40</td>
<td>0.1377</td>
</tr>
<tr>
<td>Superotemporal</td>
<td>0.73</td>
<td>0.0021</td>
</tr>
<tr>
<td>Inferotemporal</td>
<td>0.54</td>
<td>0.0384</td>
</tr>
<tr>
<td>Superonasal</td>
<td>0.36</td>
<td>0.1812</td>
</tr>
<tr>
<td>Inferonasal</td>
<td>0.52</td>
<td>0.0462</td>
</tr>
<tr>
<td>Hemifield</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
from normal (i.e., that the difference between a score of 1 and 2 is equal in value to that between 2 and 3). It may be more useful to retain the percentile values in analysis. The future use of machine classifiers may improve on the assessment, as has been shown in analysis of HVF and laser imaging techniques. Using specific features of the disease under study, to exploit asymmetries or local manifestations that distinguish the disease from normal (just as the Glaucoma Hemifield Test uses comparison across the horizontal meridian to increase specificity of identification of glaucoma), may also increase predictive power in mfVEP. Even with the present criteria, the ability of mfVEP to distinguish eyes with abnormal fields from those with compressive disease was substantial.

Acknowledgments

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References