

The AccuMap

Using multichannel, multifocal, visual evoked potential to objectively assess visual fields.

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The ability to detect glaucoma objectively has been the subject of much research in electrophysiology during recent years. Investigators have reported changes in various components of the electroretinogram (ERG), the pattern ERG, and the visual evoked potential (VEP) in glaucoma, and their studies have shown differing results and variable levels of sensitivity.¹ Recent analyses of the multifocal ERG have suggested that it probably does not reflect localized glaucomatous damage.^{2,3} Some of the subcomponents of multifocal ERG, such as the optic nerve head component, may yet yield ganglion cell-derived signals that would be beneficial for glaucoma detection, particularly for primate studies, if they could be accurately quantified.

By contrast, the multifocal VEP (MVEP) is a rapidly evolving technique for assessing visual function and detecting visual field defects.⁴⁻¹³ This technology has been adapted for use in the AccuMap (ObjectiVision Pty Ltd, Sydney, Australia; distributed in the US by Heidelberg Engineering GmbH, Dossenheim, Germany) to provide an objective means of assessing the visual field (Figure 1).^{14,15}

MVEP TECHNIQUE

Baseler et al¹⁶ first reported the recording of an MVEP. They used the VERIS system (Electro-Diagnostic Imaging, San Mateo, CA), which employs pseudo-randomly presented multifocal stimulation together with cortical scaling of the size of the stimulated patches. The subject viewed a screen displaying a rapidly alternating checkerboard pattern with multiple zones, each changing according to a different sequence in time. Single-channel recordings were made via scalp electrodes. Individual VEPs from each zone were extracted from the noise in the form of binary kernels by means of applied mathematics, specifically, a Fast Walsh Transform. The investigators concluded that the MVEP could not be applied clinically due to the high variability of responses between individuals.

We modified the technique.⁷ We positioned a bipolar electrode 2 cm above and 2 cm below the inion (the bony

protuberance on the occipital skull) and recorded MVEPs from 60 areas of the visual field up to 26° of eccentricity in normal subjects. The electrode configuration was then further enhanced to a four-channel system employing an occipital cross-electrode holder. The plastic cross provided a curved, flexible support for four gold-cup electrodes attached to a headband. When centered over the inion, the recording positions were 2 cm above, 6 cm below, and 4 cm to either side. The electrodes could be linked to provide vertical, horizontal, and two oblique bipolar recording channels. This setup provided better signals from many zones (particularly along the horizontal meridian) that were missed if only a vertically oriented channel were used. The cross helped reduce variability between subjects and standardized the electrode positions to improve reproducibility.⁹ The stimulus check size and cortical scaling were confirmed as optimal for signal detection across the field.¹⁷

Because the test's application was still limited by interindividual variability, a means of compensation was required. During the recording, we applied a scaling algorithm based on underlying electroencephalogram



Figure 1. The AccuMap V2.0 Objective Perimeter.

(EEG) amplitudes, which reflect the characteristic signal conduction for each individual.¹⁸ This approach was based on the assumption that the principal factors governing the variability of signal amplitude between individuals were (1) the conductivity of the skull, subcutaneous tissues, and scalp and (2) such conductivity's proportional effect on the EEG, which is a much larger signal. Once alpha rhythm spikes (further information presented later) and electrocardiogram contamination are identified and removed on Fourier analysis, a scaling factor is applied to the MVEP data based on normative data. With this technique, interindividual variability dramatically decreased, thus enabling the creation and use of a normals database for the identification of localized field loss.

An alternative method employed by Hood et al¹⁹ involved examining the signal-to-noise ratio (SNR) rather than amplitudes. Although a reasonable option, it is more affected by background alpha rhythm, because the frequency of alpha rhythm lies in the 8- to 12-Hz range, where the majority of the MVEP signal occurs. Alpha rhythm increases when a subject loses visual concentration, but this finding can be normal in some individuals, even when they are alert. We have found that the use of an interactive fixation target (such as is used in the AccuMap) reduces alpha rhythm levels in normal subjects.²⁰ The other important factor is that, with the EEG scaling method, examiners can identify the alpha rhythm and other contaminants such as electrocardiogram signal (ECG) on the Fourier spectrum; they can then remove contaminants prior to determining the scaling factor to be applied for each individual. This ability provides a distinct advantage over the SNR technique, because the presence of contaminants reduces the final SNR determined, without any compensation for the overall size of the signal.

The AccuMap provides a Fourier analysis of frequencies after each run, and it allows operators to view compressed data so that they can exclude noisy runs. Cumulative runs are added until the signal is stable, and the software alerts the technician when sufficient runs have been collected. In contrast, when using VERIS, the entire 7- or 15-minute run must be completed before

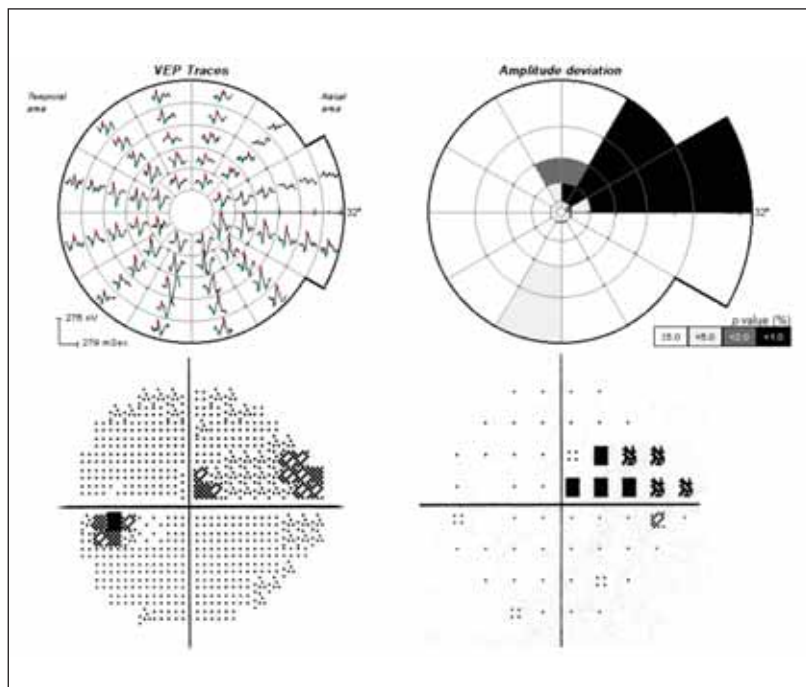


Figure 2. This MVEP recorded with the AccuMap system shows a superior field defect in the eye of a patient with glaucoma. VEP signals from all 58 zones (central rings expanded for presentation) is shown (top, left). An amplitude deviation probability plot based on significant differences from the normals database (100 subjects) is shown (top, right). The lower figures show the corresponding Humphrey visual field grey scale and pattern deviation plot.

any data are available for analysis. The AccuMap provides alerts to the technician for high- or low-frequency noise and alpha rhythm. The new V2.1 of the device will provide a noise index as a guide.

SENSITIVITY IN GLAUCOMA

In a study using the AccuMap V1.3, Goldberg et al¹⁴ reported greater than 95% sensitivity in glaucoma patients (sample of 100 eyes of 100 subjects, the visual field mean deviation for the glaucoma group was -6.5 dB). Many fellow eyes with normal visual fields had MVEP defects. In a further study of 436 consecutive patients, investigators reported similar sensitivity of 92% in early glaucoma and of 100% in moderate glaucoma (mean deviation > 6 dB).²¹ More importantly, the MVEP was extremely helpful in assessing patients with unreliable or variable subjective fields and for cases in which the degree of field loss was out of proportion to the disc changes. Using AccuMap V1.3, Fortune et al¹⁵ found that, with a specificity of 90%, the test's sensitivity was between 78% and 97%, depending on the criteria used for abnormality. Similar sensitivity levels have been reported using a multichannel MVEP on the VERIS system

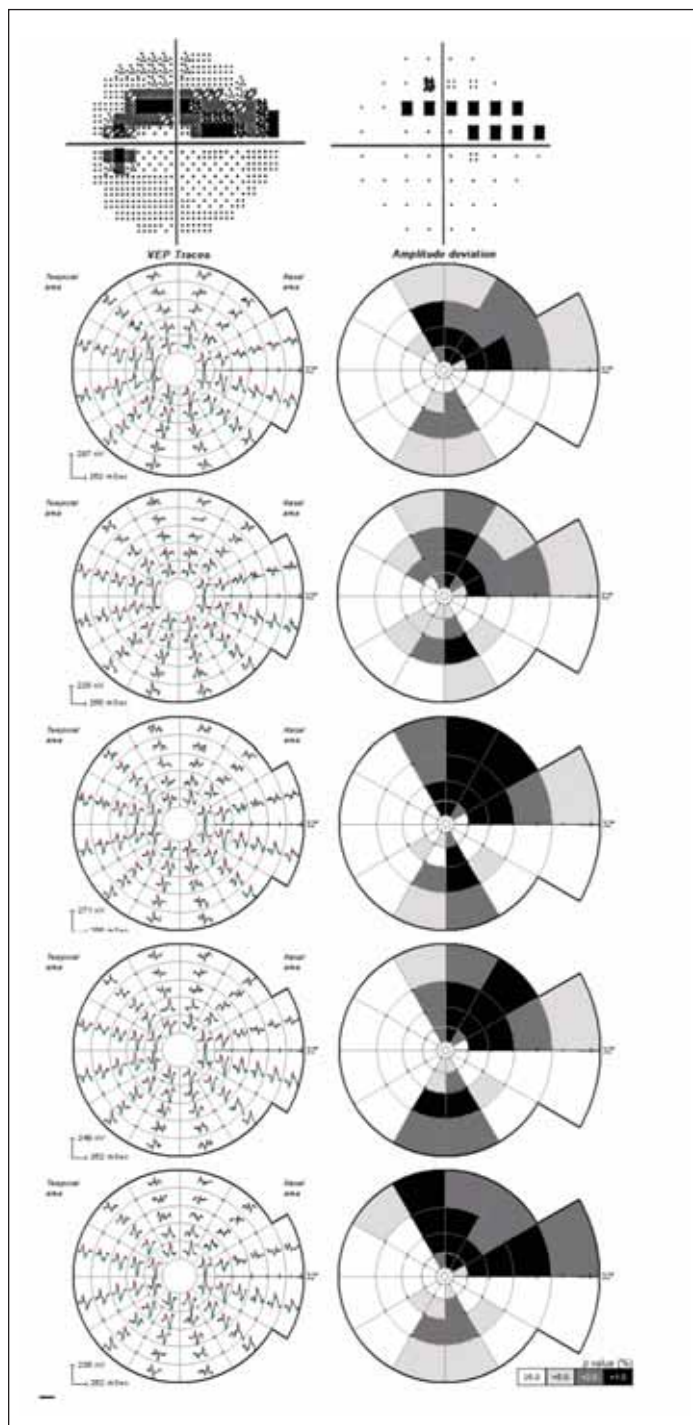


Figure 3. This example demonstrates the reproducibility of multifocal VEP recording in a glaucoma patient with a superior field defect on Humphrey testing (upper row). The AccuMap identifies the defect but also shows an early inferior arcuate defect. This patient underwent testing five times on different days 1 week apart. Despite some variability in the probability levels of the scotoma between visits, the distribution of field loss is consistent.

to look at unilateral hemifield defects.²²

Figure 2 shows an example of an MVEP recording and the corresponding subjective visual field result. The area of the scotoma corresponds well between the subjective Humphrey visual field (Carl Zeiss Meditec Inc., Dublin, CA) and the AccuMap probability plot. Figure 3 shows a different patient who underwent the test five times on 5 different days, each 1 week apart, and whose scotomas were consistently identified on the AccuMap. Between-test variability of the MVEP signal on the AccuMap V1.3 is approximately 15%,¹⁴ but recently conducted studies using the AccuMap V2.0 in 50 subjects tested twice demonstrated a mean point variability of 12% (Graham and Klistorner, unpublished data). Chen et al²³ found that the test/retest reliability of the MVEP was superior to that of subjective perimetry when a logarithmic scale was used.

Comparing VEP waveforms and the amplitude of the signals between the two eyes of the same individual is another useful technique for detecting early abnormality.^{6,10} Although different parts of the retina are being stimulated in the two eyes, the information from similar parts of the visual field of both eyes projects to identical areas of the visual cortex, and the resulting VEP waveforms are virtually identical. This technique has limited value in more advanced disease, because scotomas may appear in the same area of the visual field in the two eyes (eg, bilateral superior arcuates). In these cases, it is necessary to rely on the monocular deviation plot.

CORRELATION WITH STRUCTURAL CHANGES

Objective perimetry has demonstrated a good correlation with structural changes as detected by the scanning laser ophthalmoscope (HRT2; Heidelberg Engineering GmbH), both in patients with glaucoma (n=125) and in glaucoma suspects (n=126).²⁴ The agreement between the tests was 81%. Using the AccuMap's severity index and the Moorfields classification on the HRT, all glaucoma subjects were identified by either one or both types of objective tests. MVEP signals are affected by media opacity in the central two rings of the test zones, because the check sizes are very small in these areas. A study by Whitehouse²⁵ of 15 cataract patients tested pre- and postoperatively demonstrated

an improvement in the signal from the central rings, but the peripheral zones did not change significantly.

The MVEP can also be employed in neuro-ophthalmic disorders such as optic neuropathy, cortical lesions, and functional loss.²⁶⁻²⁹ Additionally, it is also useful in the assessment of children, in whom it is best restricted to short sequences of stimulus presentation.³⁰

CONCLUSION

The MVEP is now a well-characterized electrophysiological response to demonstrate localized visual field loss in the clinical setting. The technique is not specific to ganglion cells, because it reflects damage anywhere along the visual pathway. It can, however, be adapted with multichannel recording and appropriate EEG-based scaling to identify focal losses and to reliably detect glaucoma. The objective nature of this type of test has distinct clinical advantages over subjective methods of assessing glaucoma; of particular value are the facts that it does not involve a learning curve for the patient and it eliminates indecision on the part of the test subject. Patients also report that they find objective perimetry much less stressful to perform than white-on-white or blue-yellow perimetry. Its noninvasive nature has led to excellent acceptance among our patients. Technicians do require training but do not require a background in electrophysiology in order to perform the test. The scalp electrodes need cleaning between uses, as is the case for standard VEP recording.

Full test time with the AccuMap, including set-up, is approximately 30 minutes per patient. The device can provide an objective assessment of the patient's visual field, and it is particularly useful in subjects who have difficulty with conventional field testing. Studies currently being initiated will determine the technology's role in early detection in preperimetric cases. □

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