VEP Technology for the Detection of Glaucomatous Visual Field Loss

New testing strategies could help physicians identify structural changes before they affect patients' vision.

BY JAMES C. TSAI, MD

Standard automated perimetry (SAP) is the current gold standard for assessing visual function in glaucoma patients. Studies have shown, however, that patients can lose up to 40% of their retinal ganglion cells (RGCs) before they develop visual field defects that can be detected by SAP.[1] Ophthalmologists are therefore always looking for new technologies that will help them reliably and accurately identify early glaucomatous visual field loss.

Research suggests that certain subpopulations of RGCs are preferentially damaged in early glaucoma.[2] This article describes visual evoked potential (VEP), a new technology that targets these special cells, and discusses how ophthalmologists are using this perimetric method to detect early glaucomatous changes in the retina.

ASSESSING RETINAL FUNCTION

Recent research has elucidated functional differences between the retina's magnocellular and parvocellular pathways.[2] The magnocellular pathway is thought to convey primarily low spatial and high temporal frequency information from the retina to the lateral geniculate nucleus. In contrast, the parvocellular pathway is sensitive to visual signals of high spatial but low temporal frequency. Moreover, the magnocellular pathway is sensitive to low levels of luminance contrast, and the parvocellular pathway is more responsive to chromatic signals. Both pathways have separate "on" and "off" divisions that govern the distinct perception of brightness and darkness.

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Newer functional technologies developed to measure the selective loss of RGCs in early glaucoma include frequency doubling technology (FDT) and short-wavelength automated perimetry (SWAP). FDT perimetry uses low spatial/high temporal frequency stimuli to evaluate the function of the magnocellular pathway.[3] The latest version of this technology is the Humphrey Matrix screening algorithm (24-2-5) (Carl Zeiss Meditec, Inc., Dublin, CA), which utilizes 54 test locations arranged in a grid pattern with 6º spacing along the horizontal and vertical meridians of the visual field.[4] SWAP technology (Carl Zeiss Meditec, Inc.), also known as blue-on-yellow perimetry, presumably elicits responses from the retina's koniocellular pathway. The cells in this pathway are reportedly sensitive to blue light and, like those in the magnocellular pathway, are thought to be more sensitive to damage in early glaucoma.[5]

Another novel functional test that may detect early glaucomatous damage is the pattern electroretinogram (PERG). The testing time is shorter with PERG than with

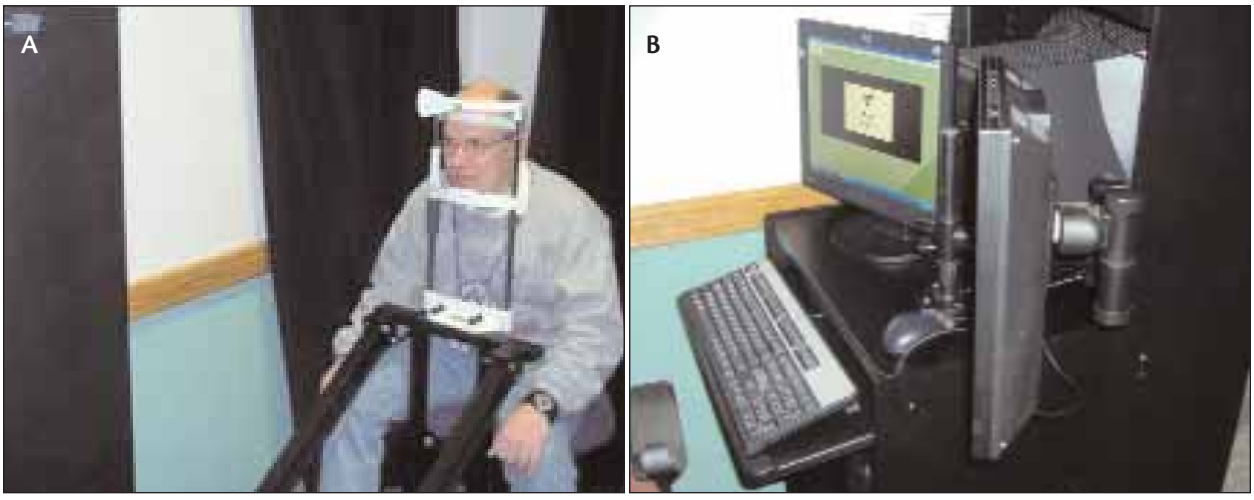

Figure 1. A patient prepares to undergo isolated-check visual evoked potential (icVEP) testing (A) with the investigational device (B).

FDT and SWAP, but PERG does not elicit the topographic information provided by the last two technologies.[6]

ELECTROPHYSIOLOGICAL PERIMETRY

Multifocal Visual Evoked Potential

Multifocal visual evoked potential (mfVEP) is an objective electrophysiological visual field test that shows promise for detecting glaucomatous functional abnormalities that occur in the early stages of the disease.[7] Although mfVEP testing is more time consuming than conventional achromatic automated perimetry, it may detect visual functional abnormalities in patients with early-to-mild glaucomatous damage and normal visual fields. The converse has also been observed.[8,9] In some cases, SAP may detect visual field defects that are not apparent with mfVEP in patients with early-to-mild glaucoma. Finally, mfVEP may be an objective test for assessing the extent of visual field loss in patients who have unreliable results with SAP.

Isolated-Check Visual Evoked Potential

VeriSci Corporation (Raritan, NJ) is developing a new electrophysiological device to evaluate retinal function in glaucoma patients. Isolated-check visual evoked potential (icVEP) technology elicits cortical activity and preferentially tests both the "on" and "off" subdivisions of the magnocellular pathway.[10,11]

In preparation for icVEP, a technician applies electrodes to the subject's scalp with a water-soluble paste (Figure 1).

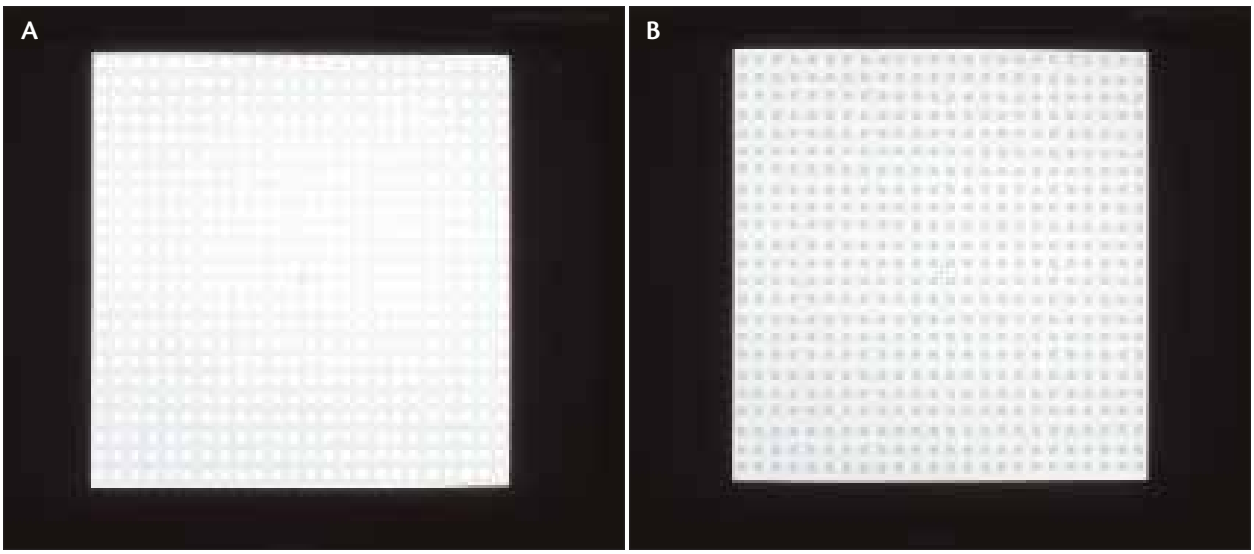

Figure 2. During icVEP testing, the computer displays a low-contrast bright check pattern (A) and a low-contrast dark check pattern (B) on a monitor. These patterns respectively stimulate the "on" and "off" subdivisions of the magnocellular pathway.

The patient is instructed to listen for an auditory cue and to fixate on a cross in the center of a computer monitor while the program displays a specific visual pattern. The electrodes record the subject's cortical response to the pattern and present the data as an electroencephalogram (EEG). In total, it takes 2 seconds to record the data (1 second each for EEG testing and recording). To calculate the fundamental frequency component of the icVEP, the device performs a Fourier transform on the EEG. The program uses eight separate runs to calculate the mean fundamental frequency component and determine the radius of a 95% confidence circle.

The reliability of icVEP is indicated by the signal-to-noise ratio (defined as the ratio of the mean amplitude of fundamental frequency component to the radius of the 95% confidence circle). A signal-to-noise ratio less than or equal to 1.0 is considered a failure. The device uses a 15% positive-contrast (bright) condition and a 10% negative-contrast (dark) condition pattern to differentiate between glaucoma patients and healthy control subjects (Figure 2). The total testing time with this algorithm for each eye is approximately 2 minutes, starting with the application of electrodes to the patient's scalp.[11]

A recently published study evaluated a small group of patients with glaucoma (n = 18, Snellen visual acuity of 20/30 or better) and control subjects (n = 16) with the low-contrast bright or low-contrast dark isolated-check patterns.[11] All of the patients were tested with both patterns. Analysis showed that testing with the 15% bright condition yielded a sensitivity of 78%, a specificity of 100%, and an accuracy of 94% for differentiating between patients with normal vision and those with moderate glaucomatous visual field loss. The dark 10% condition gave a sensitivity of 83%, a specificity of 86%, and an accuracy of 91% for detecting glaucomatous visual defects.[11] These results suggest that icVEP can rapidly and effectively assess abnormalities in both the "on" and "off" subdivisions of the magnocellular pathway in patients with glaucoma.

An advantage of icVEP compared with other perimetric tests is its ability to measure physiological activity directly. SAP, FDT, and SWAP all rely on behavioral responses to measure visual fields. Although icVEP does not assess peripheral visual function, which is thought to be affected preferentially in the mild-to-moderate stages of glaucoma, the high accuracy with which it identified glaucomatous central vision abnormalities in our study suggests that this area is also affected in early glaucoma. Isolated-check VEP also differs from mfVEP, because, unlike the latter, it does not provide desirable topographic information. It has a shorter testing duration than mfVEP, however, and allows the selective assessment of central visual function.

CONCLUSION

The advent of novel perimetric technologies is expanding clinicians' ability to test selectively the function of specific subpopulations of RGCs in glaucoma patients. The methods of VEP include those that preferentially test peripheral visual function (mfVEP) and central visual function (icVEP). It is to be hoped that future refinements and improvements in these electrophysiological techniques will provide clinicians with additional tools with which to identify patients who develop and experience progressive glaucomatous visual field loss. ❑

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