Perimeter Technology for Early Glaucoma Detection

Selective perimetry combined with standard automated perimetry is proving reliable for assessing glaucomatous damage.

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Primary open-angle glaucoma is currently incurable, but glaucoma subspecialists agree that early diagnosis and treatment are essential to controlling the disease and reducing vision loss. The diagnosis of glaucoma requires a multifaceted analysis of patients’ history and clinical findings, including assessments of visual function and imaging studies. The glaucoma community does not agree on what constitutes the first signs of glaucomatous damage, and patients with contradictory functional and structural results can pose a clinical challenge. For these reasons, selective perimetry—once considered a supplemental evaluation—may eventually become integral to everyday practice.

CONFLICTING VISUAL FIELD RESULTS

The current clinical standard for visual function testing is standard automated perimetry (SAP), an essential component of glaucoma diagnosis and monitoring. Qualitative and quantitative structural analyses have shown that significant deficits in the optic nerve head and the retinal nerve fiber layer can be present before detectable changes on SAP (Figure 1).1 Explanations for the disparities between visual field findings and optic nerve head/retinal nerve fiber layer evaluations are complex and have been attributed to factors such as redundancy within the visual system, scaling of the measurement range, and the signal-to-noise ratio of the measurement, particularly close to threshold. Regardless, SAP can underestimate visual field loss in the early stages of the disease.2 When a patient presents with clinical indications consistent with early glaucoma but normal SAP visual fields, confirming damage with a more sensitive perimetric test may be beneficial.

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The detection of visual field progression relies on the precision and repeatability of threshold estimations from individual visual field locations. Areas with the most visual loss on conventional SAP testing have been found to have the highest variability.3 The most clinically important regions, therefore, are ones in which the determination of change is the most difficult. The magnitude of such variability is large enough that it is advisable not to make clinical decisions about disease progression without the results of at least six SAP visual field tests.4 With advancing visual field deficits, patients’ perceptions in the area of damage require a brighter stimulus of the same size or a larger stimulus of the same luminance. Due to the spatial summation properties of the retina, larger, dimmer stimuli are more repeatable with defect depth than with equivalent smaller and brighter stimuli. The most commonly used SAP size III stimulus significantly increases variability and reduces reliability at threshold values below 16 dB, which indicates moderate to advanced vision loss.4 Once the damage is moderate
or severe, it is important that glaucoma physicians be confident about visual field change.

The limitations of SAP led researchers to investigate ways to decrease the variability and improve the reliability of visual field measures. Several studies have shown a reduction in variability associated with an increase in the SAP stimulus size in patients with vision loss. Strategies that obtain thresholds by changing the size rather than the luminance of the stimulus are more reliable for detecting visual field change in patients with moderate to severe field loss.

**EARLY DETECTION**

Based on the aforementioned observations, the Heidelberg Edge Perimeter (HEP; Heidelberg Engineering) was developed in an effort to detect early visual field deficits not found with SAP using selective perimetry while also providing the option of SAP testing as a tool to monitor progression from early to moderate and severe functional loss. The full range of perimetric assessment is thus possible in patients with glaucoma as well as other diseases of the retina, optic nerve, and visual pathway. An adaptive staircase threshold algorithm makes testing times comparable to those with other threshold estimation algorithms.

The HEP employs flicker-defined form (FDF), whereby a high-temporal-frequency stimulus undergoes a counterphase flicker, leading to a phantom contour illusion (Figure 2). This temporally driven illusion includes arrays of randomly positioned black-and-white dots that flicker at high temporal frequency and generate the stimulus by flickering in opposite phase between the dots within the stimulus and the dots of the background. The dots reverse polarity without changing their position, which means that white dots are replaced with black dots, and black dots are replaced with white dots. At high temporal frequency, subjects perceive an illusory circular pop-up stimulus, which appears as a gray or pale patch against the background. Although the exact mechanism underlying the FDF stimulus has not yet been entirely elucidated, evidence suggests that FDF perimetry could be more sensitive for detecting early functional loss than SAP and other types of perimetry, including frequency doubling technology. Other perimetric tests have also been introduced with the goal of detecting early visual field loss, but in a recent comparative study, FDF was more sensitive and bore a stronger correlation to structural measurements.

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Figure 1. Serial optic disc photographs (top), SAP results (middle), and Spectralis results (bottom) for the right eye. The optic disc photographs indicate progressive inferotemporal neuroretinal rim thinning over time with an associated optic disc hemorrhage. The most current spectral domain optical coherence tomography examination also indicates inferotemporal retinal nerve fiber layer thinning. SAP global indices remained within normal limits throughout the follow-up period.

(Courtesy of Amir Marvasti.)
Figure 2. Rapid flickering between phase 1 and phase 2 creates an “edge illusion” stimulus. This unique stimulus of the HEP has been shown to be sensitive in detecting early glaucomatous damage.

Figure 3. A combination report, including a structure and function map (bottom left and bottom right), provides visual field results and the corresponding retinal nerve fiber thickness analysis. The inner ring of the structure and function map represents the structural measurement of the Spectralis, and the outer ring represents the visual field result of the HEP.
“The combined structure and function reports ... can assist practitioners in making clinical decisions based on the relationship between structural and functional measurements.”

**STANDARD AUTOMATED PERIMETRY**

The HEP provided the first full-range SAP testing on a monitor-based perimeter for the detection and monitoring of glaucomatos progression, neurologic deficits, and diseases associated with progressive visual field deficits. SAP testing with the HEP has been shown to have similar diagnostic sensitivity and test-retest characteristics to SAP testing performed with the Humphrey Field Analyzer (HFA; Carl Zeiss Meditec).11 SAP testing with the HEP, however, reduces the limitation of increased variability with greater visual function loss by automatically increasing the SAP stimulus size as the sensitivity decreases. This has been shown to significantly decrease the test-retest variability for visual field sensitivity below 16 dB.6 The HEP SAP III equivalent stimulus size incrementally increases beyond this sensitivity value, which translates into better test-retest characteristics for HEP SAP than HFA SAP testing for glaucoma patients who present with moderate to severe visual field loss.11

The HEP can also combine visual field test results with structural measurements from the Spectralis spectral-domain optical coherence tomographer (Heidelberg Engineering; Figure 3). The combined structure and function reports of the HEP with the Spectralis can assist practitioners in making clinical decisions based on the relationship between structural and functional measurements.

**THE FUTURE OF GLAUCOMA TESTING**

The HEP assists clinicians with the early diagnosis of glaucoma and its progression. The technology combines full-range SAP and a unique FDF stimulus to permit the full range of perimetric assessment in patients with impaired visual function, including that specific to glaucoma. Although the FDF stimulus was designed to detect early glaucoma-related changes in the visual field, the enhanced SAP function allows clinicians to detect and monitor disease progression with improved repeatability compared with traditional SAP testing. The HEP can be used separately as a perimeter or in combination with the Spectralis for complete assessment of structure and function in glaucoma.