



Will Perimetry Be Performed to Monitor Glaucoma in 2025?

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Visual field testing has played an essential role in the diagnosis and management of glaucoma for more than a century. Methods to examine the visual field have been refined from early kinetic perimetry to current standard automated perimetry (SAP). Clinicians now use SAP for the diagnosis and management of glaucoma throughout the world. Various testing paradigms and analytic methods have been developed to simplify the diagnosis of glaucoma and the interpretation of progression. Moreover, strategies have been implemented to improve patient experience with visual field testing and to increase reliability. Objective functional tests, such as electroretinography, provide an alternative to subjective visual field testing but are not yet ready for widespread adoption. Standard automated perimetry is being adapted and improved constantly. New devices may allow patients to complete visual field tests at home, which could relieve patients and clinicians from in-office testing and allow for more frequent examinations. Glaucoma detection and progression analysis also are incorporating progressively more information and will be improved as deep learning strategies are applied. Finally, perimetric and structural testing likely will become more closely intertwined as testing platforms and progression analysis incorporate both of these measures. Visual field testing will continue to have an important role in the diagnosis and management of glaucoma. *Ophthalmology* 2017;124:S71-S75 © 2017 by the American Academy of Ophthalmology

To address the future of perimetry, the past, present, and future of visual field testing should be considered. Visual field testing has long had an important role in the understanding and management of glaucoma. Although glaucoma has been described in terms of both optic nerve head excavation and visual field constriction since the late 19th century, clinical management largely has been predicated on visual field changes.¹ Continuous improvements in visual field testing have provided a progressively deeper understanding of the functional damage caused by glaucoma. In 1886, Bjerrum quantified visual field loss through kinetic testing of the central 30° of vision. Subsequently, Traquair² further emphasized the importance of mapping visual field defects. His description of the “island of vision” remains an important foundational concept of visual field testing. Traquair’s work influenced Goldmann’s standardization of kinetic perimetry, a test that led to a new era of visual field mapping.³

Kinetic perimetry provided considerable new information, but was labor intensive and also required skilled examiners. The limitations of manual kinetic perimetry led to the development of semiautomated static perimetry in the 1960s. Research using semiautomated static perimetry devices revolutionized the understanding of glaucoma by demonstrating that the presence of glaucomatous field loss was not strictly dependent on elevated intraocular pressure.⁴ Advances in computing gave rise to standard automated perimetry (SAP) in the following decade. Standard automated perimetry removed some subjective variability by automating the visual field examination. It soon became the dominant form of perimetry because of its ease of use,

wide availability, and standardization of testing platforms. Moreover, SAP often detected visual field defects earlier than kinetic perimetry did.⁵ These developments led to achromatic SAP becoming the most commonly used functional test in the management of glaucoma.

The Present

Today, SAP is a cornerstone in the diagnosis and management of glaucoma. The Humphrey Field Analyzer (Carl Zeiss Meditec, Dublin, CA) and Octopus perimeter (Haag-Streit, Koeniz, Switzerland) are 2 examples of widely used automated perimeters. The Humphrey Field Analyzer presents white light stimuli varying from 0 to 51 dB of intensity, with 0 dB being the maximum brightness presentable by an individual instrument and 51 dB being 5.1 log units less than the maximum intensity.⁶ Because the stimulus intensity is machine dependent, there can be moderate variability among similar visual field machines from the same manufacturer. Stimulus size ranging from Goldmann size I through V and field extents of 10°, 24°, and 30° are standardized among machines.⁶ A 24° field with stimulus size III is the most commonly used field and stimulus size in both clinical and research settings. Several testing and interpretation algorithms have improved SAP for both patients and clinicians. The Swedish interactive thresholding algorithm testing strategies have decreased the time needed to complete

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SAP effectively, leading to improved patient acceptability.⁷ Novel analytic methods have enhanced interpretation of the test results. Age-related declines in visual field results are addressed by comparing threshold sensitivities with those of age-matched controls. Generalized depression or elevation can be corrected to evaluate visual fields in the presence of media opacity.

A number of strategies have been developed to assist the clinician in identifying visual field changes suggestive of glaucoma or consistent with progression. They simplify the analysis of complex visual field variability and provide a degree of objectivity. The glaucoma hemifield test detects asymmetric loss along the horizontal meridian that is suggestive of glaucomatous damage. The glaucoma hemifield test may help to identify glaucomatous changes that are not otherwise immediately apparent.⁸ Guided progression analysis is an event-based analysis that defines progression as pattern deviation in 3 or more locations on 3 consecutive tests. Guided progression analysis standardizes otherwise subjective measures of progression and has fair agreement with glaucoma experts.⁹ Global indices compare visual function to age-matched controls and can be used in trend-based analyses of progression to improve detection of glaucomatous change.¹⁰ Pointwise linear regression also can be used to analyze visual field progression and may detect progression earlier than other methods.¹¹

Despite the widespread use of SAP to monitor visual field loss, there are significant limitations. Both patients and physicians often complain, sometimes vehemently, about the tedious testing paradigm. Patients dislike the length and frequency of the tests, performance pressure, and difficulty understanding testing instructions.¹² Clinicians dislike the perceived lack of objectivity in SAP. Visual field tests are inherently subjective, so there can be significant variability on repeated testing, even in stable patients.¹³ Standard automated perimetry, as used in most clinical practices, also can be insensitive to detecting optic nerve injury. A substantial number of retinal ganglion cells may be lost before visual field loss is detected.¹⁴ Similarly, patients may have significant thinning of the retinal nerve fiber layer before a measurable visual field defect is present.¹⁵ Thus, there can be considerable permanent structural loss before any functional changes are detected with standard perimetric testing. This structural loss does not map well to functional changes, in part because of the nature of the SAP testing parameters. Standard automated perimetry stimulus intensities are scaled by logarithmic transformation, so visual field changes are minimized at high decibel levels and amplified at low decibel levels. Thus in early disease, significant loss of retinal ganglion cells translates into relatively small decreases in visual field function.¹⁶

Variations of SAP have been developed to address some of these limitations. Short-wavelength automated perimetry and frequency doubling technology are the most well studied alternatives to achromatic SAP. Short-wavelength automated perimetry presents blue stimuli on a yellow background to detect early koniocellular loss. This strategy initially was developed because koniocells were thought to be lost early in glaucoma, although this has been questioned

subsequently.¹⁷ Although short-wavelength automated perimetry seems to detect early glaucomatous loss, the test is limited by long test duration, between-individual variability, short- and long-term fluctuation, and media opacity.¹⁸ Frequency doubling technology uses the so-called frequency-doubling illusion to examine contrast sensitivity and decrease examination time.¹⁹ Second-generation frequency doubling technology testing may be superior to SAP for detecting early glaucoma, but is limited by the lack of progression analysis.²⁰ Given these limitations, neither short-wavelength automated perimetry nor frequency doubling technology are used routinely to monitor glaucoma patients in clinical practice.²¹ However, the development of these varied testing parameters demonstrates the potential of selective perimetry, particularly when used in conjunction with other diagnostic testing.²²

The above functional tests all depend on subjective patient responses. Subjectivity is the bane of disease management because the clinician must be reassured that testing progression is a true reflection of disease progression. Objective functional tests attempt to address this inherent variability. Pattern electroretinography measures the electrical activity generated by a pattern stimulus delivered to the macula.²³ Pattern electroretinography effectively detects preperimetric glaucoma patients, but requires a relatively skilled examiner and can be influenced by media opacity.²⁴ Photopic negative response is elicited by a full-field stimulus and performs similarly to pattern electroretinography in detecting early glaucoma.²⁵ However, photopic negative response has an advantage over pattern electroretinography in that it does not depend on clear media. Multifocal electroretinography, another functional test, records large numbers of local retinal responses and can differentiate central and peripheral retina responses. Early results were disappointing, but more recently the N2 component has been studied in greater detail and may be useful in detecting glaucomatous change.²⁶ Automated pupillography measures and analyzes pupil responses to various light stimuli. This test can predict both structural and functional changes in glaucomatous eyes, but likely can be influenced by nonglaucomatous structural factors.²⁷ Although these objective functional tests have potential, they still have not supplanted standard visual field testing with regard to ease of use, reliability, and ability to differentiate true functional progression.

Looking Forward

The evolution of SAP likely will include modifications to enhance functional testing and make it more rapid, convenient, and patient friendly. It is important that new testing paradigms be backward compatible with established protocols. Home testing is of particular interest and could save valuable office time and space. Several possibilities for home perimetry are under investigation or in development. For example, a motion displacement test presents a screening visual field on a standard laptop that is readily available to most patients.²⁸ Alternatively, portable head-mounted perimetry systems are being developed and could

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