REVIEW ARTICLE

Selecting visual field tests and assessing visual field deterioration in glaucoma

Kouros Nouri-Mahdavi, MD, MSc

ABSTRACT • RÉSUMÉ

Testing the peripheral field of vision is the mainstay for detection of glaucoma deterioration. Various methods and algorithms are currently available for detection of early glaucoma or establishing disease progression. Alternative testing strategies such as frequency doubling technology perimetry or short-wavelength automated perimetry have been extensively explored over the last 2 decades. The former has been found most promising for detection of earliest evidence of functional glaucoma damage when the standard achromatic perimetry results are still within the normal range. However, standard achromatic perimetry remains the standard technique for establishing deterioration of the disease. Both trend and event analyses are used for establishing change within series of visual fields. Trend analyses provide the clinician with rates of progression, putting the speed of glaucoma progression in the context of patient longevity, whereas event analyses demonstrate a "step" change regardless of the length of time it took for this amount of change to occur. The two techniques are complementary and should be used concurrently.

La mesure du champ périphérique de la vision est la base de la détection de la détérioration du glaucome. Diverses méthodes et divers algorithmes sont actuellement disponibles pour déceler un début de glaucome ou établir la progression de la maladie. Diverses stratégies de dépistage, telles que la périmétrie par doublage de la fréquence (FDP), ou celle de la périmétrie automatisée à courte longueur d'onde (SWAP), ont été explorées grandement au courant des deux dernières décennies. La première a été prometteuse pour la détection de la première évidence du dommage fonctionnel du glaucome lorsque le résultat de la périmétrie standard achromatique (PSA) était toujours normal. Toutefois, le PSA demeure la technique standard d'établissement de la détérioration de la maladie. Les deux analyses, des tendances et des évènements, servent à établir les changements dans les séries de champs visuels. Celles des tendances fournissent aux cliniciens des taux de progression plaçant la vitesse de progression du glaucome dans le contexte de longévité du patient; alors que celles des évènements démontrent un changement d'« étape », quelle que soit la longueur du temps requis pour ce changement. Les deux techniques se complètent et devraient être utilisées simultanément.

Examining the peripheral field of vision is one of the oldest techniques used for evaluation of the visual sensory system. Automation of perimetry in the early to mid-1970s led to its widespread use in patients with glaucoma. Despite the many advances in imaging technologies, clinicians rely heavily on perimetry to detect presence of glaucoma or its worsening. The field of perimetry is still evolving, and new techniques are actively being developed or evaluated for measuring the human visual system's functional performance. Innovative methods are also being explored for analyzing data from currently available perimetry techniques. The goal of this review article is to provide clinicians with an update and practical recommendations regarding the choice of visual field test in patients with suspected or definite glaucoma and to review currently available methods for detection of visual field deterioration in patients with glaucoma.

Selecting the Appropriate Test for Examining the Peripheral Field of Vision

The main goal at the time of an initial visual field test is to establish presence and severity of visual field loss in a patient with suspected or definite glaucoma. Oftentimes, in patients with early glaucoma or glaucoma suspects, the results of the first visual field examination can be inconclusive. In these cases, repeat testing or testing with an alternative testing strategy can be useful. Standard achromatic perimetry (SAP) remains the most frequently used test for measuring the peripheral visual field in glaucoma. It has a long history of use in patients with glaucoma, and most clinicians are familiar with interpretation of the test. Many of the strategies developed for detection of the earliest signs of glaucoma were originally developed for SAP or are only available with SAP.

In essence, SAP measures the eye's ability to detect, at a given test location, an incremental change in the brightness of a target or stimulus (differential light sensitivity). From a physiological point of view, the main determinants of this response, in normal eyes, are the background illumination, the magnitude of change in illumination, and the size of the stimulus. In SAP, both the background illumination and the stimulus are achromatic, that is, white. At the time automated perimetry was developed, because of limitations in changing the size of the stimulus in real time with static perimetry, a single-size stimulus

From the Glaucoma Division, Stein Eye Institute, David Geffen School of Medicine, University of California, Los Angeles, Calif.

Presented in part at the Glaucoma Management Review Course, 53rd Annual Walter Wright Day, Toronto, Ont., Dec. 6-7th, 2013.

Originally received Jul. 19, 2014. Final revision Sep. 30, 2014. Accepted Oct. 1, 2014

Correspondence to Kouros Nouri-Mahdavi, MD, Stein Eye Institute, David Geffen School of Medicine, University of California, 100 Stein Plaza, Los Angeles, CA 90095; nouri-mahdavi@jsei.ucla.edu

Can J Ophthalmol 2014;49:497–505
0008-4182/14/$-see front matter
http://dx.doi.org/10.1016/j.jcjo.2014.10.002

had to be used throughout each test, and the Goldmann size III target became the standard for automated static perimetry as the best compromise between sensitivity for detection of field defects and variability of threshold sensitivity. However, other stimulus sizes are available and can be used, with the most frequently used one being size V Goldmann. It is well established that structural damage in early glaucoma may not lead to glaucomatous field loss before a substantial number of retinal ganglion cells (RGCs) and axons are lost.[1] This has been attributed to a significant redundancy in the human visual system components in charge of perceiving achromatic stimuli.[2] It has been hypothesized that varying redundancy in different RGC pathways can be potentially used to detect initial visual field loss sooner if alternative methods tailored to specific RGC pathways are used to measure peripheral field of vision. Hence various types of stimuli have been explored to evaluate functional performance of the visual system. Two types of alternative perimetry techniques that have found significant interest and become widely available are short-wavelength automated perimetry (SWAP) and frequency doubling technology perimetry (FDT).

Testing Alternatives in Patients with Early or Suspected Glaucoma

Eyes with early glaucoma where structural changes are visible at the level of the optic nerve head or retinal nerve fibre layer may not demonstrate changes on SAP visual fields.[3,4] Many studies have shown that alternative testing algorithms may demonstrate early visual field loss in such patients.[5] However, in some of the studies, subjects were included only if they had a normal SAP visual field, thus biasing the results toward a better performance by alternative perimetry techniques. Some patients may also have small, localized defects in the central field that fall between the 6-degree testing grid of the 24-2 pattern and are hence sometimes missed.[6] The central field is significantly undersampled given the much larger number of RGCs and receptive fields in the macular area.[7] Therefore, in cases with normal 24-2 SAP where confirmation of glaucomatous damage is desirable, using FDT or SWAP, or taking a 10-2 field focusing on detecting smaller regions of central field loss are potentially useful strategies.

The newer version of FDT perimeter, the Matrix FDT (or FDT2), measures the human eye's sensitivity to perceive frequency doubling illusion at 54 test locations across the central 24 degrees mimicking the 24-2 test pattern used for SAP. The stimulus size measures 5 × 5 degrees (compared with 0.43 degree for SAP). FDT was originally considered to isolate magnocellular RGCs (about 10% of total RGCs), although this has been questioned more recently.[8–10] The test is fairly short (4–5 minutes) and better liked by patients compared with SAP. Both the original version of FDT (FDT1) and the newer version (FDT2 or Matrix) have been shown to be able to detect evidence of early glaucoma sooner than SAP in some patients.[11–13] Figure 1 shows the right eye of a patient with glaucoma with normal SAP where the Matrix FDT demonstrates a typical superior arcuate defect. In a study by Leeprechanon et al.,[13] the investigators found that field defects tended to be wider and deeper with FDT2 compared with SAP. In contrast, Liu et al.[14] found a similar performance for FDT versus SAP, whereas FDT clearly performed better than Swedish Interactive Thresholding Algorithm (SITA) SWAP. In a longitudinal study of glaucoma suspect eyes by Liu et al.,[14] 8% of eyes developed visual field defects on FDT perimetry, as opposed to 6% on SAP, and 4% on both. The rates of change in pattern standard deviation (PSD) were faster for FDT perimetry, although the rates of change or their SD may not be directly comparable between the FDT and SAP.[15] It has been demonstrated that FDT abnormalities predict future SAP field loss.[16,17] The original N-30 version of FDT detected visual field loss in 61% of fellow eyes of glaucoma patients with normal SAP. Of these, 50% developed visual field loss on SAP after 4 to 27 months.[17] Studies of structure–function relations have shown similar strength of relations for FDT compared with SAP,[18] although Lamparter et al.[19] found a better correlation with the superior sectorial thickness measurements from Heidelberg Retina Tomograph with FDT compared with SAP.

One of the advantages of FDT is that its variability is independent of severity of glaucoma and is more uniform than SAP over its dynamic range; that is, measurement variability does not increase as a function of worsening sensitivity.[20,21] The potential clinical use of this feature is yet to be demonstrated. This is consistent with lower intersession and intrasession variability of FDT compared with SAP.[22] Rates of PSD change for FDT were recently shown to predict a faster change in SAP PSD.[23] Another study by Liu et al.[24] showed a higher proportion of test locations demonstrating significant progression over time with FDT as compared with SAP in a group of patients with glaucoma (average mean deviation, MD = −9.2 dB). However, in a recent longitudinal study, FDT matrix failed to show any benefit for detection of glaucoma deterioration in patients with early to moderately advanced glaucoma (average MD = −4.0 dB).[25] Clearly, more convincing data are needed to prove use of FDT for detecting disease worsening in established glaucoma.

SWAP is widely available on a variety of perimetry devices. The blue on yellow stimulus is projected through bistratified RGCs and the koniocellular pathways to the brain.[26] The test uses a blue Goldmann size V stimulus on a yellow background. The original full-threshold SWAP test was very lengthy and, therefore, tiring for the patient. The more recent versions of the test, such as SITA SWAP on the Humphrey Field Analyzer (HFA), are more patient-friendly and shorter, taking 4 to 5 minutes to perform.[27] The main limitations of the SWAP are potential absorption of the blue light by cataractous lenses in the elderly and the