**LEARNING OBJECTIVES**

- **Special Focus**
  A comprehensive overview on optimal testing, taking into account traditional and recent technologies to detect glaucoma damage and progression such as changes in optic disc and SAP, use of OCT, electrophysiology PERG/VEP and others.

- **What’s New**
  A review of where we are going with the newest approaches such as OCT, PERG, VEP in the light of the newest clinical data.

- **Clinical Issues**
  Insight into an optimal approach to testing: What tests and strategies are to be used for whom and when?

- **Practical Tips**
  A practical approach to use of current test methods: Minimizing artifacts and avoiding pitfalls in interpretation.

**TARGET AUDIENCE**

This educational program is aimed at general ophthalmologists, ophthalmology residents and glaucoma specialists.

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Special Focus:
Optimal testing, technologies to detect glaucoma damage and progression

Linda Zangwill MD, Christopher Bowd, PhD
Hamilton Glaucoma Center and the Shiley Eye Institute, University of California San Diego, California USA

1) Technologies to Detect Glaucomatous Visual Field Damage

There are several ways to identify glaucomatous defects from standard automated perimetry (SAP) print outs (Figure 1). Firstly, inspect sensitivity thresholds at each test point. Sensitivity thresholds are not particularly useful to identify defects, because these values are not age-corrected.

In older patients, low thresholds could be attributable entirely to age. More meaningful information is available in the total deviation (TD) and pattern deviation (PD) probability plots (Figure 2). The TD probability plot shows the point-by-point probability of abnormality (in grey scale) compared with an age corrected normative database. The PD probability plot provides similar information adjusted for both age and generalized depression that could be caused by other pathologies (e.g. cataract).

So in the PD plot, localized defects most likely from glaucoma are highlighted. Localized patterns of abnormality, identified on the PD probability plot, can be assessed to determine if they are what is considered characteristic for glaucoma (e.g. nasal step, superior or inferior arcuate patterns of defect). Odd-looking patterns might result from a test-taking artifact or patient inattention.
Three global indices of visual field sensitivity are available. Mean deviation (MD) is the weighted average of the point-by-point decibel deviations from normal that are shown in the TD plot. Pattern standard deviation (PSD) represents the relative point-by-point decibel deviations from normal across the visual field. PSD increases as the point-by-point deviations from normal across the visual field become more variable. PSD increases in the presence of localized defects.

The Visual Field Index (VFI) is another summary parameter that is a modification of MD designed to be less affected by cataract and more sensitive to changes near the center of the visual field. The VFI is based on geographically weighted PD probability map values; it has been reported to represent the percentage of remaining useful vision. 3 Theoretically the VFI ranges from 100 in a healthy eye to zero in a seriously damaged eye. There is no suggested abnormality cut-off for this parameter. Although these global indices are not used for diagnosis, a PSD outside normal limits is likely to likely to detect local defects earlier. Once glaucoma has been diagnosed, MD, PSD and VFI provide a general idea of the severity of the disease although in advanced glaucoma PSD becomes less useful as it reverts to more normal values due to a generalized depression (i.e. relative reduction of local defects).

The Glaucoma Hemifield Test (GHT) 2 is a summary parameter that describes the relative difference in sensitivity in five zones of the superior hemifield compared with five corresponding zones in the inferior hemifield. Results are either “outside normal limits”, “borderline” or “within normal limits”. This parameter is particularly useful to detect early to moderate disease because glaucomatous visual field defects usually manifest asymmetrically across the visual field horizontal midline. Consider other important items to identify glaucomatous defects. Firstly, tests must be reliable, with few fixation losses and few false positive and false negative responses. This last reliability criterion is less important in individuals with advanced disease because a reported false negative may be a truly unseen test point that is the result of a severe defect. Secondly, observed abnormalities should be repeatable and consecutive abnormal tests should have the same general patterns of defect. In the Ocular Hypertension Treatment Study (OHTS), 86% of 702 initial abnormal SAP tests did not show a subsequent abnormal test. In fact, 66% of these eyes had all indices within normal limits on follow-up testing 5, thus the importance of repeatable abnormal results to identify true glaucomatous defects.

Finally, visual field results are quite variable and learning effects, artifact caused by drooping eyelids, small pupils and by inattention or „trigger happiness“ can result in different patterns of defects that are not disease related: hence the need to check for similar and recognizable patterns of defect in consecutive tests (Figure 3).

2) Technologies to Detect Glaucomatous Progression

Glaucoma management aims to preserve visual function for an individual’s lifetime. To this end, clinicians need to monitor closely the magnitude and rate of visual fields changes so that appropriate treatment can be initiated to preserve visual function. Information on the rate of visual field deterioration along with the severity of the disease at diagnosis and the patient’s age and general health status (i.e. likely longevity) should be used to estimate the likelihood of visual impairment. 4

Similar to detection of disease using SAP, disease progression also can be assessed subjectively based on information available in TD and PD probability plots. To do this, a longitudinal series of TD or PD plots can be compared for increases in scotoma size and/or depth or the development of new scotomas. Because of the large variability in SAP results, this information is not always meaningful. Two useful progression detection algorithms currently are available in the Humphrey Statpac software: Guided Progression Analysis (GPA) 5 and linear regression of Visual Field Index (VFI). 3 would be damaging to the optic nerve.

Guided Progression Analysis (GPA)

GPA is a PD plot-based event analysis calculation that relies on the comparison of change at each test location to the variability observed between two baseline tests at the same location (Figure 4). According to the Early Manifest Glaucoma Trial (EMGT) criteria 4, “Likely Progression” is assigned to a visual field if at least three test points are flagged as significantly progressing.

Figure 2 - shows the Total Deviation probability plots from an eye with advanced glaucoma (MD = -22.79 dB, VFI = 34) using the 24-2 scan pattern (top) and the 10-2 scan pattern (bottom).
assumes that change over time is linear; predicted rate of change over time using linear regression to suggest a
Like GPA, VFI is not perfect. For instance, progression and increases the likelihood
progression is a predictor for future
5). This is in part because faster
disease management than simply knowing if a patient has progressed or not (Figure
This is because adding more test points will result in a better (“tighter”) linear fit. Finally, linear regression of VFI is not a good indicator of progression in early disease because of a ceiling effect in early disease (VFI remains high as MD decreases) and in advanced disease (decrease in VFI can be highly variable after approximately -15 dB MD).10,11
Progressor
Another available progression detection technique uses ordinary least squares linear regression and is implemented using Progressor® software.12 Based on five or more consecutive tests, Progressor® software performs linear regression (like regression of VFI) of threshold sensitivity on a point-by-point basis using all test points in the 24-2 test pattern. Individual points are defined as progressed if the negative slope of the point-wise change in sensitivity meets or exceeds a user-selected cut-off. A global progression event can be assigned (similar to GPA) based on a user-defined global progression criterion (e.g. ≥ 3 of the same test points with a slope
≥ 1.0 dB/year for inner points and
≥ 2.0 dB for edge points, confirmed in three consecutive exams13). No matter the technique used for progression detection, as suggested by the 2011 World Glaucoma Association Consensus Group statements,14 frequency of follow-up testing should be dictated by the relative risk of significant progression (based on extent of damage, life expectancy and any other relevant clinical observations, such as structural change and IOP control14), with frequency increasing with increasing risk. Management needs to be individualized appropriately.

3) Optimal Testing
Several critical clinical questions must be answered to determine how best to “monitor closely” visual function in glaucoma patients, using any or all of the techniques described above. How many visual fields are really needed? How often should visual field tests be obtained?

Given the variability of visual field results, a sufficient number of visual field tests must be obtained in order confidently to identify changes that are greater than the variability in the measurements. More visual fields offer a better estimate of the rate of visual field progression. But how many visual field tests are needed over what period of time?

According to Chauhan et al,15 to detect relatively slow progression (-0.50 dB/ year) in 2 years, 7 visual fields are needed each year; clearly more than is practical. On the other hand, to detect fast progressing glaucoma (-2.0 dB/year), Chauhan et al 15 recommend that newly diagnosed patients complete visual field testing three times per year during the first two years after glaucoma diagnosis.15 These recommendations were adopted by The European Glaucoma Society in 2008.16
The 2011 World Glaucoma Association Consensus Group7 on Glaucomatous Progression developed similar guidelines on the optimal number of visual field tests required with newly diagnosed glaucoma patients.
Specifically, during the first two years after a diagnosis of glaucoma “at least two reliable visual fields is optimal in the first six months…and at least two further visual fields should be performed within the next 18 months. Where the lifetime risk of visual disability is high, such as those who already

![Figure 3 – shows the Total Deviation and Pattern Deviation probability plots from an eye with a small pupil. This pattern of defect generally is not characteristic of glaucoma](image)

at the same location over three consecutive tests (“Possible Progression” is assigned if the same three points have progressed over two consecutive tests). GPA is attractive because it is objective, but it relies on the variability between baseline tests. Because of this, its sensitivity to change can be variable depending on baseline variability. Also, it does not require the progressing points to be contiguous, so the observed change may not represent the predicted increase in scotoma size that is associated with disease progression.6 Once a GPA result of “Likely Progression” has been assigned, new baseline examinations should be obtained to allow identification of a subsequent progression event. As suggested by the 2011 World Glaucoma Association Consensus Group,7 new baseline examinations also should be obtained after any significant therapeutic intervention.

Visual Field Index (VFI)
Unlike the GPA, linear regression of the VFI can provide the rate of change over time (i.e. change in VFI value per year) and, because it is derived from PD and not MD, it likely is fairly resistant to the effects of developing/worsening cataracts. Knowing the rate of progression is more important for long-term disease management than simply knowing if a patient has progressed or not (Figure 5). This is in part because faster progression is a predictor for future progression and increases the likelihood of visual impairment in one’s lifetime.8 Like GPA, VFI is not perfect. For instance, using linear regression to suggest a predicted rate of change over time assumes that change over time is linear; this may not be true.9 It also assumes a stable treatment regimen and it does not consider intervening surgical procedures. Further, assuming change over time is linear, estimates of change of VFI over time (i.e. estimates of the negative slope of VFI) will be more accurate when more tests are included in the regression equation.

![Figure 3 – shows the Total Deviation and Pattern Deviation probability plots from an eye with a small pupil. This pattern of defect generally is not characteristic of glaucoma](image)
have advanced damage, three baseline visual fields may be necessary.”

Wu and colleagues recently showed that the time required to detect a significant decrease in MD slope decreased as the frequency of testing increased, although not proportionally. Based on their results, they suggested that obtaining two reliable visual fields at baseline followed by semi-annual testing, with confirmation of progression during follow-up, is a reasonable compromise for detecting glaucomatous progression while minimizing the burden on patients and clinicians associated with more frequent testing. After the initial two years following diagnosis of glaucoma, the frequency of visual field testing should be based on the risk of visual impairment during the patient’s lifetime.

The 2011 World Glaucoma Association Consensus Group recommends that, “In low and moderate risk patients, subsequent visual field frequency should be one visual field per year... and, as a rule, repeated sooner... if other clinical observations are suggestive of possible progression or increased risk of progression.” However, “In high risk patients, subsequent visual field frequency should be two visual fields per year and repeated sooner if possible progression is identified on the basis of an ‘event’ analysis, or if other clinical observations are suggestive of progression or increased risk of progression.”

Computer simulation has been used to determine the optimal spacing for the intervals between testing for detecting rapidly progressing glaucoma (rate of loss: -2.0 dB/year). Crabb and Garway-Heath suggest that compared with evenly-spaced follow-up every six months, visual field testing 2 or 3 times at baseline and at the end of a 2 year period identifies more patients with rapidly progressing visual fields with a lower false positive rate.

By aggregating the visual field testing earlier and later in the follow-up period, there is increased efficiency to reduce the false positive rate, and to estimate the rate of visual field loss. This “wait and see” approach, developed using “moderate” variability of the visual fields in the computer simulation to detect fast progression, is being tested in longitudinal studies.

The number of fields and intervals between them can also influence the methods used to measure the rate of change. For example, Medeiros et al. reported that a Bayesian-based slope estimate technique was more predictive of future impairment than ordinary least square regression, particularly in eyes with moderate to fast rates of change. Other statistical or machine learning based progression detection methods also have been proposed and compared to ordinary least square regression of VFI or MD with varying

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**Figure 4** - shows the first incidence of possible and likely progression, based on GPA analysis, in an eye with a developing inferior temporal visual field defect. Half-filled triangles represent test points progressed, relative to baseline variability, in two consecutive tests (possible progression). Filled triangles represent progression in three consecutive tests (likely progression).
degrees of success but none have been incorporated into HFA software. 20-24 Most patients can be monitored using the 6-degree by 6-degree grid spacing of 24-2 visual field test pattern. However, when central vision is compromised or threatened, it may be useful to obtain 10-2 visual fields that use 2-degree by 2-degree spacing to document better how glaucoma is affecting central vision. 25,26 Several studies 26,28 have reported evidence of visual field damage in the central visual field using 10-2 test pattern that is not detected in the peripheral field using 24-2 testing even in very early stages of the disease. Zhang et al. 25 documented that the 10-2 test pattern results are useful to make clinical management decisions; in about one third of visual fields considered to threaten fixation based on 30-2 or 24-2 test patterns, the threat, based on 10-2 testing was not imminent. In some patients, 10-2 testing can be important to determine the level of visual impairment expected from glaucomatous visual field loss in the central and peripheral visual field.

4) Recent Advances

Very recently two new test features have been introduced and will be incorporated into the Humphrey Visual Field Analyzer 3 (personal communication, Carl Zeiss Meditec Inc.). The first is a newfaster 24-2 test pattern called SITA Faster 24-2. 29 Results indicate that this algorithm requires a considerably shorter test time (half the time of SITA Standard 24-2) while providing very similar results compared with both SITA Fast 24-2 and SITA Standard 24-2 algorithms.

A new combined 24-2 and 10-2 test pattern also has been introduced. This pattern, the SITA Faster 24-2C, is composed of 10 points from the 10-2 pattern tested at the end of the SITA Fast 24-2. 30 Results indicate that this test pattern provides an improved sensitivity to detect visual field loss in the central 10 degrees over the SITA Fast 24-2 pattern, which tests only 4 points within this region. 31

References:


30 Monhart M, Lee G, Iwase A, Flanagan J. Selecting additional test locations to enhance the 24-2 pattern using a scoring system. World Glaucoma Congress 2017; Helsinki, FIN.

Core Concepts

- Standard automated perimetry has been the clinical standard of care in glaucoma for decades.
- It is limited by excessively high variability, a limited dynamic range, hampering both detection of early disease and the ability to monitor severe glaucoma, and poor patient acceptability.
- Objective functional testing can outperform perimetry in certain cases, and is useful when other results are ambiguous. However, no such techniques have yet been shown to consistently outperform perimetry, and so for now they remain supplementary rather than primary diagnostic tools.
- New test stimuli are being developed that aim to improve the signal-to-noise ratio. In particular, flickering stimuli and alternative stimulus sizes show promise.
- New testing algorithms aim to reduce test duration, and/or increase testing of the central region of the visual field where defects are commonly missed.
- Portable visual field testing instruments are under development, in particular using tablet computers or using head-mounted screens. These would allow more frequent testing to be conducted, since they can be used outside clinical settings.

What’s new:
Assessing function in Glaucoma
Stuart Gardiner MD, PhD
Devers Eye Institute, Legacy Research Institute, Portland, Oregon, USA

Variability

Sensitivities measured using SAP can vary markedly from one day to the next. Variability also worsens with glaucoma. When a location is significantly damaged, the 95% interval for retesting that location covers over half of the presumed dynamic range of the instrument (see Figure 1). Indeed below 15-19 dB, sensitivities from SAP are no longer even significantly correlated with the true sensitivity.¹

Dynamic Range

Due to this extremely high variability at low sensitivities, SAP cannot be relied upon to assess progression once sensitivity at a location has decreased below 15-19 dB.¹ Unfortunately, common structural measurements such as retinal nerve fiber layer thickness also reach their measurement floor at a similar level of damage. Therefore the unsatisfying conclusion is that for eyes with severe damage, the only way to assess progression at the moment is to look at the remaining areas of the visual field that have not yet reached this level of damage.

At the other end of the scale, SAP is also suboptimal. Clear structural defects are often detected prior to functional loss (although functional loss is detected first in almost as many cases, with any time lag being principally the result of SAP having slightly higher test-retest variability). In particular, defects near fixation are often missed, despite their importance to the patient’s visual performance and daily quality of life.²

Patient Acceptability

Patients commonly report disliking SAP, preferring structural imaging tests.³ Historically, test duration and accompanying fatigue were seen as leading causes of this dissatisfaction. The most commonly-used testing algorithms now take around 5 minutes per eye, although with the just-released SITA-Faster program, it takes half this time. It takes an additional 10-15 minutes to get the patient positioned and their eye sufficiently adapted to the background luminance to obtain reliable results, meaning that further reductions in test duration would have relatively little impact on the overall visit duration. Perhaps more importantly, patients report frustration at deciding whether they actually see a stimulus or not; this is unsurprising when sensitivity is usually defined as the stimulus that the patient will respond to any time lag being principally the result of SAP having slightly higher test-retest variability). In particular, defects near fixation are often missed, despite their importance to the patient’s visual performance and daily quality of life.²

1) Why do we need something new?
Clinicians and, often, patients are very familiar with standard automated perimetry (SAP), which has been the primary clinical standard of care for functional testing in glaucoma for many years. Even the testing algorithms that are most commonly used are now 20 years old. Why then, in the face of such stable technology, are advances in functional testing still needed? The answer, in part, is because SAP unfortunately continues to suffer from three major problems: variability, dynamic range, and patient acceptability.

2) How can it be improved?
Given these substantial problems with current testing, several avenues are being explored to improve functional
assessment. These can broadly be split into a four, often overlapping, areas of research.

**New Testing Paradigms**

SAP relies on the test subject responding to a visual stimulus by pressing a button. This can cause problems, especially in elderly patients who may have difficulty depressing the button sufficiently and reliably. Therefore objective functional testing is a natural avenue of research.

For multifocal visual evoked potential (mfVEP), the patient views a reversing checkerboard pattern while electrodes record the resultant activity in the visual cortex. Unfortunately the test is technically demanding to administer, and so to date it has remained a specialist test used in cases where other test results are not definitive, and/or to rule out non-visual sources of defects. Multifocal pupillographic objective perimetry (mfPOP) records pupillary changes in response to visual stimuli and appears to have similar performance to SAP, and so may have promise as an objective measure of function, but this has not yet reached the point of clinical adoption.

The pattern electroretinogram (PERG) records retinal ganglion cell function in response to stimuli. Since there are far more retinal ganglion cells centrally, PERG may perform better than SAP at detecting central functional loss, but less well in eyes with peripheral loss.

While each of these techniques can outperform SAP in certain cases, none can yet do so consistently in all cases. As such, they remain a supplementary tool in the clinician’s arsenal, rather than something that could replace SAP in the foreseeable future.

**New Test Stimuli**

The majority of functional testing at the moment uses a static Goldmann Size III stimulus, with diameter 0.43º. This represents more of a historic accident than anything else.

Researchers are examining the potential benefits of using larger Size V stimuli (diameter 1.72º), which is known to increase sensitivity and hence decrease variability, and so allow reliable measurements later into the disease process. However, there is ongoing debate about whether this hampers the ability to detect early defects. As it may be preferable for stimulus size to increase with eccentricity, and/or with damage, research in this area continues.

Meanwhile, alternative stimulus types may provide better signal-to-noise ratios than the static circular stimuli currently used in most commercial perimeters for SAP.

Previously, researchers tried using blue-on-yellow stimuli (Short Wavelength Automated Perimetry, SWAP) to target certain subtypes of ganglion cell, but this increased variability so much that it negated any benefits for earlier detection of damage. It was also adversely affected by nuclear sclerotic cataracts.

More recent work has focused instead on optimizing stimuli for detection by wider ranges of ganglion cell types. Gabor patches, sinusoidally-modulated stimuli presented in a Gaussian envelope to blur the edges, may have lower variability and consequently better signal-to-noise ratio. However, these cannot be presented using projection-based perimeters like the Octopus or the Humphrey Field Analyzer (HFA).

The most similar stimulus to have been implemented commercially is the Frequency-Doubling Technology (FDT) stimulus, which is a flickering sinusoidal stimulus, but with hard edges; while this is not optimal, it has still proven useful in particular for screening tests.

**New Testing Algorithms**

An algorithm that aims to measure sensitivity at around 50 visual field locations in just 5 minutes can only afford to present 4-6 stimuli at each location.

Within that limit, it has to determine sensitivity on a scale of 0-40 dB, ideally to within 1-2 dB. This severely limits the amount of information that can be obtained, and is probably the biggest cause of the high variability discussed above.

Current testing algorithms actually perform impressively given this constraint, but various techniques have been proposed to further improve the reliability and accuracy of the results. Information from neighboring locations can be used to reduce variability, although if taken too far this risks losing spatial information about small defects. Information from structural testing can also be used to inform the choice of stimulus contrasts to present.

Another approach is to stop testing locations that have progressed to the point where reliable sensitivities can no longer be measured, and instead spend the time on more accurate measurements elsewhere in the visual field.

Efficiency savings from new algorithms can be used to improve spatial information about defects. For example, targeting stimuli around the edge of defects has been shown to improve the ability to monitor disease progression. The closest of these approaches to reaching clinical care is the Swedish Interactive Threshold Algorithm (SITA) Faster 24-2C test for the HFA3, which reduces redundancies in the SITA Fast algorithm and spends those gains not...
just on further reducing test time (which as mentioned above is of limited benefit at this point), but on adding testing at additional central locations in order to detect early defects that can be missed using the current 24-2 test grid. This algorithm was presented by Carl-Zeiss Meditec at the 2018 ARVO meeting (Callan et al, E-Abstract #5111), and is becoming available as this article goes to print.

**New Test Equipment**

Current functional tests are performed using instruments that take up several cubic feet of space, without even including room for the test subject and operator. More portable options would allow for much easier testing. In particular, this would facilitate screening programs outside standard clinical settings; and/or allow patients to test themselves at home, whereby any loss of accuracy caused by non-standardization of test conditions would be compensated by the ability to test patients far more frequently.

Two main technologies are currently under development that may address this issue. Perimetry could be performed on a tablet computer, subject to two main constraints. The stimulus intensity needs to remain constant on repeated testing, which is not feasible with many commercial tablets; and/or it needs to be automatically calibrated prior to each test.

The Melbourne Rapid Fields (MRF) app for iPad has shown promise in this regard, and early results suggest similar performance to traditional perimeters. An alternative portable approach is taken by the “imo” head mounted perimeter. This requires more specialist equipment than just a tablet computer; but results in improved standardization of test conditions and hence of results. It remains to be seen which of these approaches will prove beneficial in more circumstances.

**4) Summary**

While the “gold standard” for functional testing has not changed for many years, new techniques are in development that address some or all of the problems with SAP.

Some, such as the upcoming SITA Faster 24-2C test, aim to refine SAP, and so have clear clinical utility. Other techniques such as objective testing are currently best seen as supplementary tests for use when SAP results are equivocal or unreliable, since none has yet proven to be sufficiently superior to SAP to justify switching completely.

**References:**


Clinical Issues: Optimizing Your Approach to Visual Field Testing

Brennan Eadie MD, PhD, FRCSC, Marcelo Nicolela MD, PhD, FRCSC
Department of Ophthalmology & Visual Sciences, Dalhousie University

Visual field testing is critical for accurate diagnosis of glaucoma and monitoring for disease progression. All patients with glaucoma or suspected of having glaucoma, if able, should have periodic visual field testing. The optimal visual field test, or combination of tests, depends on the individual patient. The gold standard visual field test for most patients with glaucoma, or suspected of having glaucoma, remains Standard Automated Perimetry (SAP). Integral to SAP are various test strategies (e.g., Swedish Interactive Thresholding Algorithm [SITA] Standard or SITA Fast, Humphrey Field Analyzer) and various grids of points (e.g., 24-2, 30-2 or 10-2 programs) that can be employed to map the visual field.

A new strategy (SITA-faster) is currently becoming available, with claims of improved performance and even shorter test times, however no peer-reviewed publications are yet available at this time.

The 24-2 testing program remains preferable for most patients with glaucoma as it is faster than the 30-2 test pattern, while maintaining similar performance for diagnosing and monitoring the disease. In general, using the same test pattern increases one’s chance of detecting progression. However, recent evidence suggests that a 24-2 test pattern may miss localized, paracentral visual field defects that can be detected with a 10-2 test pattern.

Thus, a 10-2 testing program should be considered even in early or suspected glaucoma because a 24-2 testing pattern may miss small paracentral visual field defects that can be detected with this test.

Frequency Doubling Technology (FDT) and Short Wave-length Auto mated Perimetry (SWAP) should not be used routinely instead of SAP.

A 10-2 testing program should be considered even in early or suspected glaucoma because a 24-2 testing pattern may miss small paracentral visual field defects that can be detected with this test.

The 24-2 testing program remains preferable for most patients with glaucoma as it is faster than the 30-2 test pattern, and appears comparable for diagnosis and monitoring of glaucoma.

The 10-2 testing program is important for patients with visual field loss approaching fixation.

Consider switching to a size V stimulus in cases of severe visual field damage, particularly with decreased visual acuity.

In general, more frequent testing is recommended when patients are first diagnosed, in order to assess the rate of change within the first few years and to identify fast progressors (suggested six visual field tests in the first two years).

Cluster-based trend analysis may be more sensitive to focal visual field progression while maintaining a similar sensitivity to analyzing global indices over time.

Choose thoughtfully the best visual field test, or combination of tests, and the frequency of testing, at every visit.
Figure 1 - Examples of cases with 24-2 and 10-2 visual fields: (A) left eye with a paracentral defect shown both on 24-2 and 10-2 tests, but more pronounced in the latter; (b) left eye with a small localized paracentral defect missed with 24-2 test but identified with 10-2 test.

Figure 2 - Comparison of Size III (A) vs Size V (B) testing stimulus in a patient with advanced visual field damage.
a 24-2 and 10-2 test pattern in the same eye at a single visit.

One disadvantage of the 10-2 test is that there is currently no dedicated statistical progression analysis. One should consider using a size V stimulus in cases of severe visual field damage, particularly with decreased visual acuity, to preserve an adequate dynamic range to observe progression in the remaining visual field. (Figure 2)

Other testing modalities, such as frequency doubling technology (FDT) and short-wavelength automated perimetry (SWAP) have been labeled as more sensitive than SAP for early defects; however, more recent evidence seems to suggest that this is not necessarily true, and these tests should not be routinely used at the expense of SAP.

There is considerable variation between individuals in their rates of progression. Performing more frequent visual field testing early after the initial diagnosis of glaucoma allows more timely detection of fast progressors, as these patients need to be treated aggressively.

After this initial period, the frequency of visual field testing can be reduced and depends on disease severity, age and general health, level of control of intraocular pressure, test tolerability and speed of change.

Progression is commonly assessed by either event based or trend analysis. An example of event based analysis is the glaucoma progression analysis of the HFA, where points of each follow-up visual field are compared with a pair of baseline tests, and those points changing by a larger amount than expected by test-retest variability are flagged. Trend based analysis is usually performed on global parameters (such as MD or VFI). Although pointwise trend analysis can also be performed, this approach can lead to more false positive results. Another good strategy, available on the Octopus perimeter, is cluster-based trend analysis, which may have the added benefit of being more sensitive to focal visual field progression while maintaining a similar sensitivity to global indices analysis over time.

In summary, SAP using a program such as SITA 24-2 is the most utilized method for diagnosis and monitoring patients with glaucoma, and the frequency of testing should be adjusted depending on many factors. Clinicians should consider other approaches to visual field testing in special circumstances.

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References


Practical Tips:
Minimizing artifacts and avoiding pitfalls in visual field interpretation
C. Gustavo De Moraes, MD, MPH
Columbia University Medical Center, New York, NY

Core Concepts

• Make sure the correct date of birth has been entered.
• Keep in mind the effects of pupil size and do not perform visual field tests under pharmacologic mydriasis.
• Watch for ptosis and rim artifacts.
• Ensure the optimal reliability indices for each individual patient and confirm consistency across their visual field sequences.
• When assessing progression, reset the baseline tests based upon most recent changes in the treatment regimen.
• Do not rely solely on summary statistics.
• Perform 10-2 visual fields in patients with or suspected glaucoma.

Standard automated perimetry (SAP) is a subjective, behavioral test. Its interpretation is therefore subject to patient-, disease-, and device-related sources of artifacts and variability. The following are some of the most relevant issues that need to be taken into account before, during, and after testing in all individuals undergoing SAP examinations.

1) Age

There is a physiologic age-related decay in retinal sensitivity which is estimated to be approximately 0.07 to 0.08 dB loss per year and varies with eccentricity and hemifields.2 The total deviation (TD) plot shows the differences of pointwise threshold sensitivities between the subject undergoing visual field testing and the corresponding average values of age-matched controls. The TD probabilities are based on the distribution of these normative values.

An incorrect year of birth, particularly by more than a decade, may result in misclassification. If the tested patient is compared with younger subjects, for instance, the TD probability plot may falsely show clusters of significant abnormalities; if compared with older subjects, one may miss an early localized defect. Implications may be even more significant when assessing progression: even small changes (improvement or decay) in pointwise or global (mean deviation, MD) sensitivities – even on a single visit from the entire sequence – can affect their respective slopes and p-values, also leading to misclassification.

2) Pupil size

Both mydriasis and miosis can lead to abnormal results on SAP. Miosis is more difficult to address before testing because it often results from the pharmacologic effects of intraocular pressure (IOP) lowering medications (pilocarpine) and their wash-out could be detrimental (e.g. from IOP elevation or angle closure). Mydriasis, on the other hand, is often induced pharmacologically during office visits for an enhanced fundus examination.

Visual field testing with mydriasis can decrease foveal threshold and MD by 2.0 and 1.2 dB on average, respectively.3 This effect can have clinically significant implications both for the detection of visual field defects and for monitoring progressive changes. Therefore, clinicians should avoid performing visual field tests after pupil dilation. If the patient is on pilocarpine, clinicians should keep track of changes in pupil size between visits and consider its effect on sensitivities when assessing the overall level of functional loss.

3) Edge-artifacts

Some arcuate defects in the superior hemifield can be the result of partial ptosis and an incorrect diagnosis of glaucomatous functional loss may ensue. Always check whether the upper lid is blocking – even partially – the visual axis. If so, consider elevating the eyelids (temporarily with tape or permanently).

Moreover, if the corrective lens used during visual field testing is decentered or set too far from the eye, the lens rim may project into the central field and lead to arcuate-like defects that resemble glaucomatous defects. If the lens correction exceeds 5 diopters, a soft contact lens correction should be considered to minimize trial lens rim artifacts.4

4) Reliability indices

Unreliable tests are common even among experienced patients. For some patients, visual field test results meeting the standard reliability criteria may never be achieved.
To address this issue, a recent study investigated evidence-based criteria for assessment of visual field reliability. Fixation losses (FL) had little impact on the MD variation and no level of FL produced more than 1 dB variation at any disease stage. False negatives had a minimal impact up to 20% abnormal catch trials. More importantly, false positives yielded more positive MD values even when less than 20%, with greater effect above this level. If a patient is unable to perform tests with satisfactory reliability indices, clinicians should consider the variation within these indices over time when assessing progression.

5) Baseline tests

Event- and trend-based progression analyses are performed using visual field tests performed within a time frame of interest. If progression is suspected or confirmed, treatment may be initiated or escalated. Clinicians should remember to re-set the baseline tests whenever a significant change in treatment occurs.

If this is not done, the progression algorithms will continue to flag that sequence as progressing (“possible” or “likely” in the case of event analysis, or “statistically significant slopes” in the case of trend analysis). Clinicians could then mistakenly assume the treatment change was not effective and subject the patient to unnecessary further interventions.

6) Summary statistics

To increase objectivity when interpreting visual field results, computerized statistical analyses provide summary indices that may help to define the presence of functional loss, its severity, as well as tracking longitudinal changes.

Most commonly used indices are the MD, pattern standard deviation (PSD), and glaucoma hemifield test (GHT). Based on how the patient’s test compares with the normative database, these indices can be flagged with probabilities (MD and PSD) or whether they are “outside normal limits” (GHT).

Based on how the patient’s test compares with the normative database, these indices can be flagged with probabilities (MD and PSD) or whether they are “outside normal limits” (GHT). However, these indices should be used only to facilitate the interpretation of the test results, not to diagnose glaucoma.

In particular, their results should be interpreted after a scrutinized evaluation of the TD and pattern deviation (PD) plots looking for patterns of loss that are typical of glaucoma (e.g. arcuate defects, nasal steps).

More importantly, visual field test results should never be interpreted in isolation: they should always be correlated with other clinical information and (ideally) the results of structural tests (disc photos and optical coherence tomography).

Figure 1 shows an example of an eye initially classified as “pre-perimetric” or “glaucoma suspect” because the 24-2 visual field was “within normal limits”.

However, note that a cluster of test locations reached statistical significance at the 5% and 2% levels which matched the location flagged as abnormal on the OCT.

7) 10-2 visual fields

In a recent study, Grillo et al. investigated evidence-based criteria for assessment of visual field reliability. Age-related changes of the normal visual field. Archives of ophthalmology (Chicago, Ill.: 1960). 1986;104(7):1021-1025.

References

1 Jaffe GJ, Alvarado JA, Juster RP. Age-related changes of the normal peripheral visual field. Archives of ophthalmology. 1986;104(7):1021-1025.


Figure 1 - Right panel: 24-2 visual field with summary indices (MD, PSD, and GHT) within normal limits. Note, however, that there are two points in the nasal area with P-values of 5 and 2%. Left panel: OCT report flipped to field view shows an arcuate-like defect in the nerve fiber layer (black arrow) that projects to the nasal area where the abnormal points are located (black shape).

Figure 2 - The importance of performing 10-2 visual fields. Top left: OCT scan of the macula, which includes 30% of the retinal ganglion cells (RGC). Below it, fundus photos with the test location of the central 10 degrees of the 24-2 (red crosses) and 10-2 (black circles) grids overlaid. Right panel, top: a normal 24-2 of with no abnormalities (red arrow) within the central 10 degrees (black square). Bottom: the 10-2 done on the same day shows an arcuate defect (red arrow). The red circles represent the 16 location of the 24-2 grid that fall within the central 10 degrees (macula).
In order to maximize the learning effect, participants have the opportunity to register at our website and to answer a number of multiple choice questions for each of the four sections covering the key points of each section. Shortly after test completion, participants receive electronic feedback on successful accomplishment or failure. In case of failure the participant is encouraged to review articles and retake the test. A successful test will earn the participant valuable CME credits needed for their continuous medical education efforts.

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STATEMENT OF NEED AND PROGRAM DESCRIPTION
Recent months and years have seen significant advances in our understanding of glaucoma. Much has been learned, not only about damage mechanisms and pathogenesis, but also about diagnosis and management. Treatment options – both medical and surgical – continue to expand. This program will review this new knowledge with an emphasis on incorporating recent insights into day-to-day practice.

Date of original release: October 2018
Approved for a period of 12 months.

This issue is accredited for Continuing Medical Education (CME) by the Physicians’ Chamber of Baden-Württemberg, Germany (Local Medical Responsible: Andreas Buchholz MD, PhD, ROPh).

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Participants have an implied responsibility to use newly acquired information to enhance patient outcomes and professional development. The information presented in this activity is not meant to serve as a guideline for patient care. Any procedures, medications, or other courses of diagnosis or treatment discussed or suggested in this activity should not be used by clinicians without evaluation of their patient’s conditions and possible contraindications or dangers in use, applicable manufacturer’s product information, and comparison with recommendations of other authorities.

Contributors
- Linda Zangwill, MD, PhD is Professor at Hamilton Glaucoma Center and the Shiley Eye Institute, University of California San Diego, California USA. She has received financial support from Heidelberg Engineering, Carl Zeiss Meditec, Topcon Medical Systems and Optovue Inc., in the form of research funding or research materials or services at no cost. She is an inventor/developer designated on the patent of Carl Zeiss Meditec.
- Christopher Bowd, MD, PhD is a researcher at Hamilton Glaucoma Center and the Shiley Eye Institute, University of California San Diego, California USA and a coworker of Linda Zangwill. He has no commercial relationships to disclose.
- Stuart Gardiner, MD, PhD is Professor at Devers Eye Institute, Legacy Research Institute, Portland, Oregon, USA. He has no commercial relationships to disclose.
- Marcelo Nicolela, MD, PhD, FRCSC is Professor at the Department of Ophthalmology & Visual Sciences, Dalhousie University, Halifax, Canada. He has no commercial relationships to disclose.
- Brennan Eadie MD, PhD, FRCSC, is a researcher at the Department of Ophthalmology & Visual Sciences, Dalhousie University, Canada and a coworker of Marcelo Nicolela. He has no commercial relationships to disclose.
- Gustavo de Moraes MD, PhD, is Associate Professor of Ophthalmic Sciences, Medical Director of Clinical Trials at Columbia University Medical Center, New York Presbyterian Hospital, Edward S. Harkness Eye Institute, New York, USA. Within the last 12 months he has received financial support from Carl Zeiss Meditec, Inc. and Topcon, Inc. in the form of research funding or research materials or services at no cost.

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