AMERICAN JOURNAL OF OPHTHALMOLOGY®

FRANK W. NEWELL, *Publisher and Editor-in-Chief*
Suite 1415, 435 North Michigan Ave., Chicago, Illinois 60611

Published monthly by the OPHTHALMIC PUBLISHING COMPANY
Suite 1415, 435 North Michigan Avenue, Chicago, Illinois 60611

PERSPECTIVES

Automated Perimetry in Glaucoma

Joseph Caprioli, M.D.

The realization that measurements of intraocular pressure have limited value to diagnose glaucoma has accentuated the importance of evaluating the structural and functional abnormalities caused by glaucoma. The contemporary care of patients with glaucoma requires careful, sequential recordings of the visual field and the appearance of the optic disk. Automated perimetry is a ready means to obtain standardized, quantitative measurements of the visual field, has prompted valuable clinical research, and has improved the care of patients with glaucoma.

Static threshold measurements are sensitive to shallow depressions of the visual field. This increases the detection rate of early glaucomatous defects compared to routine manual techniques.[1-5] Although static threshold measurements are not new to practitioners, the computerized format and the generation of a large amount of numeric data present new challenges. The increased sensitivity of the method has increased the "noise" of the measurements and demands careful attention to the many variables that may affect the measured threshold. Visual field measurements should never be interpreted in the absence of other clinical information. It is necessary to integrate intraocular pressure, appearance of the optic nerve, and other ocular, systemic, historical, and social factors when making decisions about diagnosis and therapy.

The mainstay of automated glaucoma testing has been the central 30-degree field programs. In patients with advanced visual loss, programs designed to test a small area of central field with high resolution are time-efficient since nonseeing areas are not tested and seeing areas are tested with high resolution. Measurements of the peripheral nasal field may detect early defects in glaucoma when none are present in the central 30 degrees, an event that occurs at the rate of 10% to 15%.[6,7] Computerized kinetic perimetry has recently been introduced and initial reports are encouraging, but its reliability and reproducibility have yet to be estab-

lished.[8,9] The most time-efficient way to test the peripheral field in glaucoma has yet to be determined.

The differential light sensitivity begins to decrease at an early age (20 years) and continues to decrease at a fairly constant rate throughout life.[10] The decline of sensitivity is location-dependent: the sensitivity of the peripheral field decreases more than that of the central field. The profile of visual sensitivity thus becomes steeper in the periphery with age. The variability of responses in normal individuals is greater in the periphery than in the center.[11] The difference between a measured value for the patient and a normal value must therefore be greater in the periphery than in the central field if the difference is to be considered significant. Variability may also increase with age, though this effect remains uncertain.[12,13]

Patient reliability is an important initial consideration when interpreting visual fields. This may be assessed by the rates of false-positive and false-negative answers; the operator's assessment of reliability; the fluctuation of repeated threshold measurements; the number of fixation losses; and the number of stimulus presentations required to complete a visual field examination. A simplified scheme to gauge patient reliability is presented in Table 1. The operator must adequately explain the testing procedure and encourage patient cooperation and alertness during the examination if reliable results are to be obtained.

Abnormalities of the visual field can be recognized in two ways: by point-by-point comparison with data from normal individuals of similar age, and by comparison with thresholds in adjacent areas of the visual field, in the opposite hemifield of the same eye, or in the visual field of the contralateral eye. Criteria for abnormality must remain pliable by other clinical considerations. Rigid criteria will lead to overdiagnosis of visual field defects in some and underdiagnosis in others. The criteria should depend on one's level of suspicion for glaucomatous optic nerve damage. If strict criteria are used, specificity for glaucomatous defects will be high but sensitivity will be low; if one uses liberal criteria, sensitivity will be high but specificity will be low. Examples of graded criteria are provided as a framework for interpretation (Table 2) but should not be used as an imperative set of rules. A repeat examination should be performed whenever possible to confirm the presence of a new or subtle defect, especially when the presence of such a defect may prompt a surgical decision.

TABLE 1
VISUAL FIELD RELIABILITY SCORE

CRITERIA	SCORE
1) Rate of false-negative catch trials	
(if < 8 trials, score = 0)	
≥ 10% and < 20%	1
≥ 20% and < 30%	2
≥ 30%	3
2) Rate of false-positive catch trials	
(if < 8 trials, score = 0)	
> 20% (≥ 8 trials)	1
3) Subjective grading of performance by perimetrist	
Good to excellent	0
Fair	1
Poor	2
Terrible	3
4) Short-term fluctuation	
> 4.0 dB	1
5) Fixation losses	
> 15% of trials	1
6) Total number of stimuli*	
> 550 (for standard 30-degree programs)	1
> 400 (for standard 24-degree programs)	1
The maximum total score is 10.	
Score = 0 — Reliable	
Score = 1–2 — Probably reliable	
Score = 3–5 — Results suspect	
Score > 5 — Interpret with great caution	

*Note that eyes with advanced abnormalities will require more stimuli to complete the examination than eyes with little or no defect.

The classic glaucomatous visual field defects are often preceded by widespread, shallow depressions throughout the visual field, though the concept of uniform diffuse depression in early glaucoma is debated.[14,15] Diffuse depression is not specific for glaucoma and is frequently caused by media opacity, inaccurate refraction, miosis, retinal disease, or poor test performance. Computer-assisted comparisons with normal data may help identify early glaucomatous defects. Probability maps that take regional variability into account are most helpful.[16,17] The visual field indices mean defect (or mean deviation), corrected loss variance (or corrected pattern standard deviation), and short-term fluctuation, originally introduced by Flammer and associates,[18] seem useful to evaluate sequential examinations[19] but may not be suited to detect the earliest glaucomatous defects.[20]

TABLE 2
EXAMPLES OF CRITERIA FOR ABNORMALITY (CENTRAL 30 DEGREES)

Strict
≥ 4 adjacent points of ≥ 5 dB loss* each
≥ 3 adjacent points of ≥ 10 dB loss* each
Difference of ≥ 10 dB across nasal horizontal meridian at ≥ 3 adjacent points
Exclusions: physiologic blind spot; superior and inferior rows
Moderate
≥ 3 adjacent points of ≥ 5 dB loss* each
≥ 2 adjacent points of ≥ 10 dB loss* each
Difference of ≥ 10 dB across nasal horizontal meridian at ≥ 2 adjacent points
Exclusions: physiologic blind spot; superior and inferior rows
Liberal
≥ 2 adjacent points of ≥ 5 dB loss* each
≥ 1 adjacent point of ≥ 10 dB loss* each
Difference of ≥ 5 dB across nasal horizontal meridian at ≥ 2 adjacent points

*Loss is relative to normal values or to values of surrounding points. For probability maps that compare measured thresholds to normal values one may substitute $P < .05$ for 5 dB loss, and $P < .01$ for 10 dB loss.

Careful comparison of sequential visual fields often appropriately directs glaucoma treatment. Knowledge of the conditions under which valid comparisons can be made is essential. It is best to avoid changes in treatment, whenever possible, based on the comparison of only two visual fields. A series of examinations may show the true course of the disease when only two examinations would be misleading. There are no generally accepted criteria for progression of defects, but some guidelines can be offered. A new, confirmed defect that meets reasonable criteria for abnormality can be considered progression. In areas of a previous defect, a further decrease in the threshold of greater than or equal to 5 dB would be suggestive, whereas a decrease of greater than or equal to 10 dB can usually be considered a significant change.

A number of confounding variables make the interpretation of visual fields difficult, particularly for progression. The differentiation of long-term fluctuation (test-retest variation) from true progression of visual field loss remains one of the important challenges in modern perimetry. Long-term fluctuation in glaucomatous eyes increases with the depth of the defect and with distance from fixation.[21-23] The comparison of sequential visual fields is enhanced if these factors are considered. Computer-assisted analyses have been developed to evaluate sequential visual field examinations for evidence of progression beyond that which might be explained, at a given level of probability, by long-term fluctuation. The practitioner must be cautioned, however, that statistical significance should not be equated with clinical significance.

Changes in pupil area by a factor of four or more can significantly affect the visual field, and may be exaggerated in the presence of even minor media opacities. Pupil size should be measured and recorded at every visual field examination; when it is less than 3.0 mm, patients' pupils should be dilated before testing whenever possible. When this is not possible, examinations should be repeated at the same pupil size.

Cataract can have a profound effect on measured visual thresholds, especially in the presence of a small pupil. A subjective evaluation of the media is useful, but such evaluations are rarely sensitive enough to detect small changes that can significantly affect visual field measurements. Quantitative measurements of light scattering by the crystalline lens may be helpful.[24] In difficult situations in which changes in media clarity have occurred, it helps to correlate apparent deterioration of the visual field with change in optic nerve appearance. Stereophotographs of the optic disk are indispensable in this regard.

Refractive errors of only one diopter can cause a significant decrease of measured central visual thresholds.[25,26] Aphakic eyes are best tested after placement of contact lenses, since aphakic spectacle correction induces significant peripheral artifact.

The results of psychophysical tests generally improve as subjects gain experience. This learning effect is small in most patients who have previous experience with manual perimetry, but some patients still show a dramatic improvement on their second automated test compared to their first. The variability of test results decreases significantly with experience.[27] Whenever possible, the patient's second visual field test should be used as a baseline for subsequent comparisons.

The weight given to perimetric findings in decision making depends on the reliability of the patient, the visibility and appearance of the optic nerve, the level and trend of intraocular pressure, and ocular, systemic, historical, and

social factors. Computerized static threshold perimetry has increased the validity of routinely performed visual field examinations. It has made comparisons of multiple examinations more meaningful, but also more problematic. Automated perimetry has properly shifted the emphasis away from intraocular pressure measurements and toward the visual field in the diagnosis and treatment of glaucoma. Perimetric results, when they are reliable, should play prominently in the minds of practitioners when making diagnostic and therapeutic decisions.

Future work to enhance the value of automated perimetry will undoubtedly include the development of summary indices with improved sensitivity and specificity for early glaucomatous defects; better strategies to differentiate true progression from long-term fluctuation; and time-saving testing algorithms with acceptable detection rates for early defects. Automated perimetry has, perhaps, provided more questions than answers about the early functional abnormalities in glaucoma. The sensitivity of the technique has made us more aware of the "noise" inherent in psychophysical testing; improved techniques to separate the "signal" from the "noise" must be developed.

From the Department of Ophthalmology and Visual Science, Glaucoma Service, Yale University School of Medicine, New Haven, Connecticut.

Reprint requests to Joseph Caprioli, M.D., Department of Ophthalmology and Visual Science, Yale University School of Medicine, 330 Cedar St., New Haven, CT 06510-8061.

References

1. Heijl, A.: Automatic perimetry in glaucoma visual field screening. A clinical study. Graefes Arch. Clin. Exp. Ophthalmol. 200:21, 1976.

2. Fankhauser, F., Spahr, J., and Bebie, H.: Some aspects of the automation of perimetry. Surv. Ophthalmol. 22:131, 1977.

3. Li, S. G., Spaeth, G. L., Scimeca, H. A., Schatz, N. J., and Savino, P. J.: Clinical experiences with the use of an automated perimeter (Octopus) in the diagnosis and management of patients with glaucoma and neurologic diseases. Ophthalmology 86:1302, 1979.

4. Dyster-Aas, K., Heijl, A., and Lundquist, L.: Computerized visual field screening in the management of patients with ocular hypertension. Acta Ophthalmol. 58:918, 1980.

5. Hotchkiss, M. L., Robin, A. L., Quigley, H. A., and Pollack, I. P.: A comparison of peritest automated perimetry and Goldmann perimetry. Arch. Ophthalmol. 103:397, 1985.

6. Caprioli, J., and Spaeth, G. L.: Static threshold examination of the peripheral nasal visual field in glaucoma. Arch. Ophthalmol. 103:1150, 1985.

7. Seamone, C., LeBlanc, R., Rubillowicz, M., Mann, C., and Orr, A.: The value of indices in the central and peripheral visual fields for the detection of glaucoma. Am. J. Ophthalmol. 106:180, 1988.

8. Stewart, W. C., Shields, M. B., and Ollie, A. R.: Peripheral visual field testing by automated kinetic perimetry in glaucoma. Arch. Ophthalmol. 106:202, 1988.

9. Miller, K. N., Shields, M. B., and Ollie, A. R.: Automated kinetic perimetry with two peripheral isopters in glaucoma. Arch. Ophthalmol. 107:1316, 1989.

10. Haas, A., Flammer, J., and Schneider, U.: Influence of age on the visual fields of normal subjects. Am. J. Ophthalmol. 101:199, 1986.

11. Heijl, A., Lindgren, G., and Olsson, J.: Normal variability of static perimetric threshold values across the central visual field. Arch. Ophthalmol. 105:1544, 1987.

12. Katz, J., and Sommer, A.: A longitudinal study of the age-adjusted variability of automated visual fields. Arch. Ophthalmol. 105:1083, 1987.

13. Heijl, A.: Perimetric threshold variability and age. Arch. Ophthalmol. 106:450, 1988.

14. ———: Lack of diffuse loss of differential light sensitivity in early glaucoma. Acta Ophthalmol. 67:353, 1989.

15. Langerhorst, C. T., van den Berg, T. J. T. P., and Greve, E. L.: Is there general reduction of sensitivity in glaucoma? Int. Ophthalmol. 13:31, 1989.

16. Heijl, A., Lindgren, G., Olsson, J., and Asman, P.: Visual field interpretation with empirical probability maps. Arch. Ophthalmol. 107:204, 1989.

17. Heijl, A., and Asman, P.: A clinical study of perimetry probability maps. Arch. Ophthalmol. 107:199, 1989.

18. Flammer, J., Drance, S. M., Augustiny, L., and Funkhouser, A.: Quantification of glaucomatous visual field defects with automated perimetry. Invest. Ophthalmol. Vis. Sci. 26:176, 1985.

19. Wu, D. C., Schwartz, B., and Nagin, P.: Trend analyses of automated visual fields. In Greve, E. L., and Heijl, A. (eds.): Documenta Ophthalmologica Proceedings Series 49, Seventh International Visual Field Symposium. Dordrecht, Dr. W. Junk Publishers, 1987, pp. 175–189.

20. Chauhan, B. C., Drance, S. M., and Douglas, G. R.: The use of visual field indices in detecting changes in the visual field in glaucoma. Invest. Ophthalmol. Vis. Sci. 31:512, 1990.

21. Flammer, J., Drance, S. M., and Zulauf, M.: Differential light threshold. Short- and long-term fluctuation in patients with glaucoma, normal controls, and patients with suspected glaucoma. Arch. Ophthalmol. 102:704, 1984.

22. Heijl, A., Lindgren, A., and Lindgren, G.: Test-

retest variability in glaucomatous visual fields. Am. J. Ophthalmol. 108:130, 1989.

23. Werner, E. B., Petrig, B., Krupin, T., and Bishop, K. I.: Variability of automated visual fields in clinically stable glaucoma patients. Invest. Ophthalmol. Vis. Sci. 30:1083, 1989.

24. Flammer, J., and Bebie, H.: Lens opacity meter. A new instrument to quantify lens opacity. Ophthalmologica 195:69, 1987.

25. Goldstick, B. J., and Weinreb, R. N.: The effect of refractive error on automated global analysis program G-1. Am. J. Ophthalmol. 104:229, 1987.

26. Heuer, D. K., Anderson, D. R., Feuer, W. J., and Gressel, M. G.: The influence of refraction accuracy on automated perimetric threshold measurements. Ophthalmology 94:1550, 1987.

27. Werner, E. B., Adelson, A., and Krupin, T.: Effect of patient experience on the results of automated perimetry in clinically stable glaucoma patients. Ophthalmology 95:764, 1988.