Automated Combined Kinetic and Static Perimetry

An Alternative to Standard Perimetry in Patients With Neuro-ophthalmic Disease and Glaucoma

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Objectives: To create a fully automated, combined perimetry program consisting of a static examination and a kinetic examination, and to compare the results of this test with standard static and kinetic visual fields (VFs).

Methods: Fifty-six patients (74 eyes) undergoing neuro-ophthalmic or glaucoma evaluation who had standard static or kinetic perimetry examinations underwent the combined perimetry test. This automated, combined test, performed on the Octopus 101 perimeter, consisted of a static tendency-oriented perimetry examination and a preprogrammed kinetic examination. Three masked physician reviewers independently classified all of the VFs. The VF pairs were considered a match if the consensus descriptions of the standard and combined VFs matched.

Results: Thirty-seven eyes underwent evaluation for neuro-ophthalmic disease (comparison standard test, 20 static and 17 kinetic) and 37 for glaucoma (comparison standard test, 17 static and 20 kinetic). The VP pairs matched in 32 eyes (86%) in the neuro-ophthalmic group and 28 (76%) in the glaucoma group. On inspection by a fourth reviewer, many of the nonmatching VF pairs were those for which a consensus was not reached, but still conveyed similar information. Two glaucomatous eyes demonstrated central scotomata not delineated by the combined examination findings. Two subtle nasal steps were detected solely by the combined examination. The combined test ranged in time from 6 to 12 minutes per eye.

Conclusions: The Octopus 101 perimeter can be used to create an automated test that combines the advantages of static and kinetic perimetry and produces equivalent results while not requiring examiner expertise.

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FORMAL PERIMETRY IS USED TO identify and follow up visual field (VF) defects. Currently, the 2 choices for formal VF testing are kinetic and static perimetry. The type of perimetry chosen is often based on availability and patient and disease characteristics. Goldmann kinetic perimetry, introduced in 1945,[1] is typically used for those patients with VF defects outside the central 30°, with severely decreased vision, or who benefit from interaction with the examiner. Limitations of manual kinetic perimetry include the need for a skilled perimetrist,[2] as well as the inherent examiner bias, lack of stringent reproducibility and standardization, and variability of the manual examination. Automated static perimeters were introduced in the 1970s and early 1980s. Two commonly used automated perimeters, the Octopus (Interzeag International, Bern-Koniz, Switzerland) and the Humphrey Field Analyzer (Zeiss Humphrey Systems, Dublin, Calif), were found to be superior to manual kinetic perimetry[3-7] in detecting VF loss in the central 30° earlier, with more standardization, and without the need for skilled perimetrists. Limitations of static perimetry included the need for greater patient concentration and initiative, decreased efficacy in delineating complex lesions that extend into the peripheral field, and localizing lesions within the occipital lobes.[8,9]

Recently, an addition to the Octopus 101 static perimeter, a computer-driven kinetic examination using test stimuli that correspond to traditional Goldmann perimetry, was introduced.[10] Unlike manual kinetic perimetry, where stimulus presentation occurs via movement of a mechanical arm by the examiner, the Octopus stimulus is computer driven, controlled by an examiner using a mouse or by a preprogrammed set of commands. Integrated software measures reaction time and the area encompassed by each isopter. This new tool allows for the combination of static with kinetic examinations and increases the standardization with which kinetic stimuli are shown during testing. Static examinations, including tendency-oriented perimetry (TOP) strategy testing (which is an effective strategy for patients with neuro-ophthalmic disease and glaucoma[11,12]), and kinetic examinations can be performed in the same sitting.

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We designed a test that could be administered by an unskilled examiner, combining TOP strategy central 30° static testing with a set of preprogrammed kinetic isopters. We compared the results of this automated, combined test with standard static and kinetic examinations to determine whether a fully automated, combined test could be used as an alternative and potentially complementary method of VF testing.

METHODS

PATIENTS

The institutional review board of the University of Pennsylvania, Philadelphia, approved the protocol for this study, and all subjects signed informed consent statements. Patients who were examined at regular appointments in neuro-ophthalmology or glaucoma clinics underwent prospective evaluation. No patients were called in specifically to participate in this study. Patient inclusion criteria consisted of being 18 years or older, having the cognitive and motor ability to perform the test, and having a standard VF test performed within the previous 6 months in which results demonstrated a stable VF defect on more than 2 occasions or a new VF defect, and the willingness to undergo a standard static or kinetic test and the combined test on the same day. Eyes were excluded if visual acuity was worse than 20/400.

VF TESTING

If the patient underwent both tests on the same day, the standard examination was completed first, followed by the combined test. Testing was performed on each eye if vision loss was present bilaterally. Age-corrected near refraction was used for central VF testing in all 3 testing methods. Seven eyes with normal results of standard VF testing also underwent the combined test.

Standard Static Examinations

All of the patients underwent testing on the Humphrey Field Analyzer, but static testing strategies were not uniform because many of the patients with chronic VF defects had their static examinations before the study began; however, this variability allowed the combined test to be compared with a variety of commonly used static strategies. Most of the patients underwent central 24-2 threshold testing, 4 eyes were examined with a 30-2 threshold test, and 2 eyes had a 10-2 threshold test. Six of the 24-2 examinations were performed with Swedish Interactive Thresholding Algorithm (SITA) Fast perimetry, whereas all of the other examinations used the SITA standard strategy. Calibration and bowl illumination were completed as directed.[13]

Standard Kinetic Examinations

All of the Goldmann VFs used for this study were performed by 1 of 2 skilled Goldmann perimetrists. When delineating peripheral isopters, the test object was moved at a speed of approximately 3° per second from nonseeing areas inward. To delineate scotomata and the blind spot, stimuli were moved from inside the scotoma outward.

Automated, Combined Examination

To create the automated kinetic portion of the examination, the Octopus 101 programmed kinetic perimetry software (Interzeag International/Haag-Streit) was programmed to test III4e and I4e vectors drawn at every 30° except at the nasal horizontal meridian, where vectors were drawn every 15°. Temporal vectors started 90° and nasal vectors started 60° from the midline. We drew 4 III4e reaction time vectors and 8 I4e vectors to test the blind spot in a compasslike configuration[14] (**Figure 1**).

The central 30° was evaluated first, using a TOP strategy 32-program examination. The TOP strategy, designed to approximate VF thresholds in a shorter period than standard Octopus testing, uses a mathematical algorithm to approximate individual position thresholds through consecutive approximations. The VF is divided into 4 intermingled grids, and each position within the grids is tested only once but is adjusted 3 more times on the basis of responses of neighboring test points in the other intermingled grids.[12]

After patients underwent the short TOP strategy examination, they rested for 2 minutes before starting the automated kinetic component. The III4e isopter was delineated, followed by the I4e isopter, and then both were corrected for the patient's individual reaction time as assessed by the reaction time vectors embedded within the program. If the patient did not respond to I4e stimuli, the examiner was instructed to trace the preprogrammed blind spot vectors with III4e stimuli. The TOP examination was then overlain on the kinetic representation of the VF.

RELIABILITY OF VFs

Standard static examination results were considered unreliable if fixation losses were greater than 50%, as suggested by others.[15] Goldmann VFs were considered unreliable if the examiner assessed patient fixation to be poor or if the blind spot could not be mapped. The combined examinations were considered unreliable if isopter crossing occurred at more than 1 point, if the blind spot could not be delineated, or if false-positive or false-negative findings on the static component exceeded 25%.

COMPARISON OF AUTOMATED, COMBINED VFs WITH STANDARD TESTS

Three physician reviewers (S.L.G., P.S.S., and K.S.S.) unfamiliar with the study reviewed and classified the VFs. Each reviewer was masked to patient identifiers and to the classification by the other reviewers. The VFs were distributed in a randomized fashion in which the standard and combined examinations were not grouped in any order, such that reviewers could not compare a patient's examinations. The data made available for the automated, combined examinations consisted of the combined kinetic-static printout and the standard static 7-in-1 printout. The reviewers were given a modified list of pattern configurations from the Ocular Hypertension Treatment Study[16] from which to choose (**Table 1**). We included the additional choices of generalized constriction and enlarged blind spot because of their unique appearance on standard kinetic perimetry. The reviewers were also asked to assess the severity (mild, moderate, or severe) and location of the defect.

The masked descriptions by each reviewer were compared for each VF, and a consensus description was formed if at least 2 of the 3 reviewers described the VF as having the exact same pattern configuration, severity, and location. The consensus description of the standard VF was then compared with that of the combined VF, and they were considered a match if the descriptions matched exactly. An attempt was made to categorize all of the VF pairs into 1 of 9 groups described in **Table 2** on the basis of their degree of agreement, similar to previous studies.[2,15] For those individual VFs for which a consensus description was not reached by the 3 reviewers, a fourth reviewer (N.J.V.) reassessed the VF pair in an unmasked fashion. These VF pairs could not be classified into 1 of the 9 groups because a consensus description of the individual VFs was not reached and so were categorized as NC (no consensus).

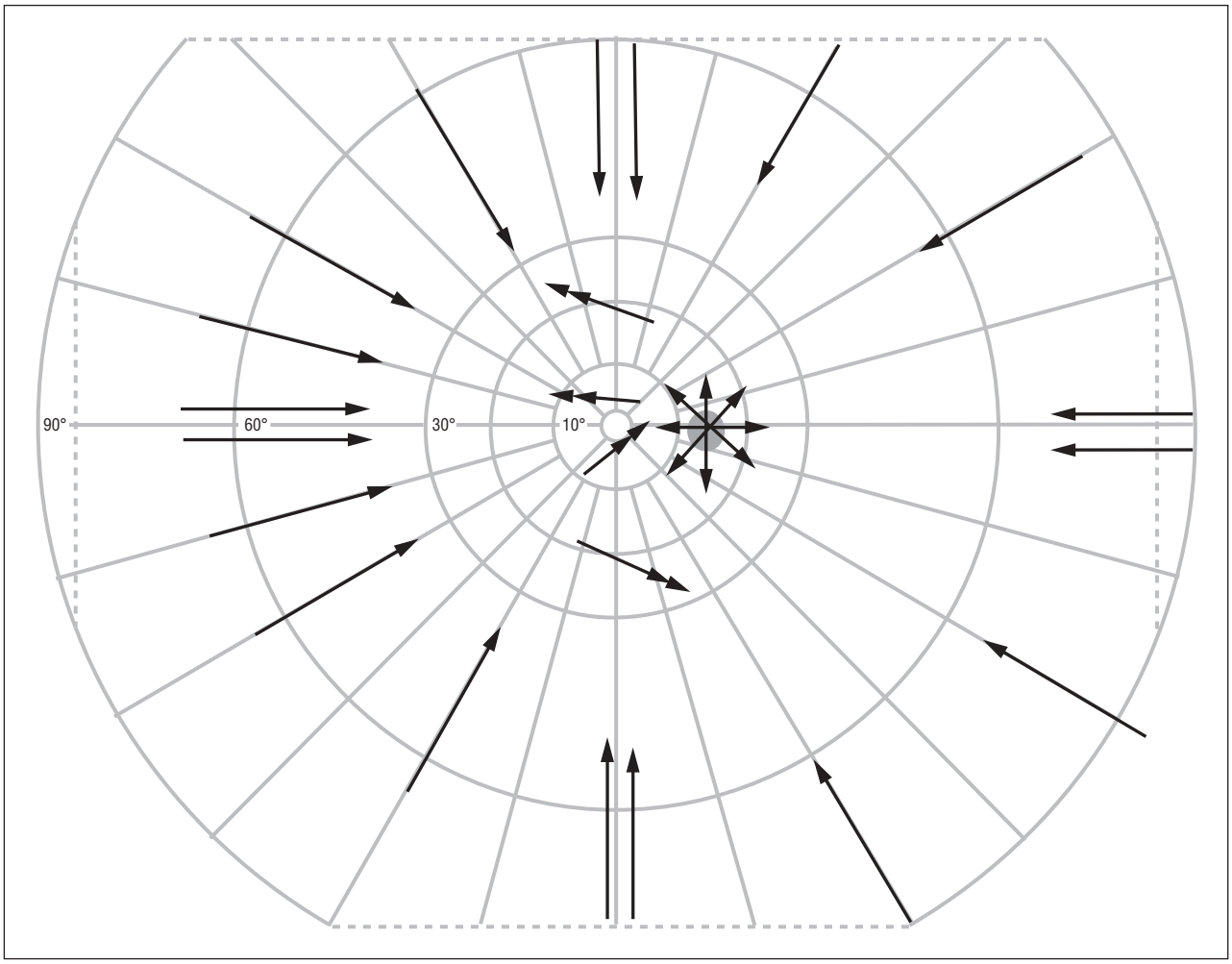

Figure 1. Stimulus trajectory in preprogrammed kinetic examination. The I4e and III4e stimuli were presented along each marked vector. The blind spot was mapped with an I4e stimulus except in those patients who did not respond to the I4e stimulus. Four reaction time vectors (double-headed arrows) were included in each examination.

PATIENT PREFERENCE

Patient preference was assessed using a written survey that questioned which test the patients would prefer to undergo at the next visit and a series of questions exploring the patients' reasoning.

RESULTS

PATIENTS

Fifty-six patients (with a total of 74 eyes undergoing examinations) were included in this study. Their ages ranged from 18 to 91 years, with a mean±SD age of 62.0±18.0 years. Twenty-two patients (37 eyes; comparison standard tests, 20 static and 17 kinetic) underwent neuro-ophthalmic examination (including 7 eyes with normal standard VF test results) and 34 (37 eyes; standard tests, 17 static and 20 kinetic) had glaucoma (including 1 eye with normal standard VF test results). The mean±SD age of the neuro-ophthalmic group (6 men and 16 women) was 50.5±17.0 years, whereas that of the glaucoma group (14 men and 20 women) was 69.0±16.0 years. The visual acuity of the patients ranged from 20/15 to 20/400. Clinical diagnoses for the neuro-ophthalmic group included temporal arteritis, cortical visual loss, optic atrophy, stroke, atrophic papilledema, retrobulbar optic neuritis, and ischemic optic neuropathy. Glaucoma diagnoses included suspected glaucoma, chronic open-angle glaucoma, traumatic glaucoma, and pseudoexfoliative glaucoma. The distribution of the principle VF defect pattern configuration based on the consensus description of the standard examination is shown in Table 1. All of the patients who attempted the examination were able to complete it.

COMPARISON OF COMBINED WITH STANDARD VFs

Sixty-five (88%) of the 74 VF pairs were classified into the categories described in Table 2, and their distribution is demonstrated graphically in **Figure 2**. Examples of matching VF pairs (group 1) with standard comparisons are shown in **Figure 3** and **Figure 4**. Nine VF pairs were reanalyzed by the fourth reviewer because they could not be classified into 1 of the 9 groups, owing to an NC rating by VF reviewers on the pattern configuration of either or both of the patient's VFs. For those eyes with static examinations, the discrepancy was attributed by the fourth reviewer

to nonspecific VF depression (**Figure 5**A) such as that seen in patients with cataracts. For those with kinetic examinations, it was considered due to a complex VF leading to differing descriptions among the reviewers (Figure 5B). These VF pairs were not included in the data analysis.

Eyes With Standard Static Examinations

The 2 VFs were similar (groups 1-4) in 31 (84%) of the 37 eyes undergoing standard static examination. This group included 5 normal static examination findings that were normal on the combined test as well. One eye (3%) with a normal static examination result was classified into group 5 because the automated, combined test delineated a nasal step not shown on standard testing (Figure 5C). One eye (3%) was classified into group 7, in which the standard static examination finding was considered unreliable owing to high fixation losses. Four eyes were classified as NC (Figure 5A).

Table 1. Distribution of Pattern Configurations of VF Pairs

Pattern Configuration	No. (%) of Eyes	
	Glaucoma Group (n = 37)	Neuro-ophthalmology Group (n = 36*)
Altitudinal	1 (3)	3 (8)
Arcuate	13 (35)	5 (14)
Central scotoma	3 (8)	2 (6)
Enlarged blind spot	1 (3)	0
Generalized constriction	5 (14)	3 (8)
Hemianopia	1 (3)	11 (31)
Inferior depression	0	0
Nasal step	3 (8)	2 (6)
Paracentral scotoma	1 (3)	1 (3)
Peripheral rim	0	0
Quadrant	0	0
Superior depression	0	0
Temporal wedge	2 (5)	0
Total loss	0	0
Vertical step	0	0
Complex pattern, unspecified	3 (8)	2 (6)
Nonspecific visual field depression	3 (8)	1 (3)
Normal VF	1 (3)	6 (17)

Abbreviation: VF, visual field.
*The VF of 1 eye is not included because its standard static examination result was considered unreliable.

Eyes With Standard Kinetic Examinations

The 2 VFs were similar (groups 1-4) in 29 eyes (78%) of the 37 eyes undergoing standard kinetic examination. One eye (3%) with a normal kinetic examination result was classified into group 5 (Figure 5D), and 2 (5%) were classified into group 6, in which the standard kinetic examination delineated central scotoma that was not delineated on the combined test result (Figure 5E). Five eyes were classified as NC (Figure 5B).

All Eyes

Overall, the VFs were found to be similar in 60 (81%) of the 65 eyes in which a consensus was reached (excluding the 9 NC VF pairs). The standard and combined examinations were each considered more sensitive in 3% of the eyes.

PATIENT PREFERENCE

Most of the patients (28 [76%]) who were asked to compare the combined test with the standard static test preferred the automated combined examination, whereas those who had previously undergone kinetic testing preferred traditional kinetic tests (27 [74%]).

COMMENT

Static and kinetic perimetry are both useful individually; however, they each have individual shortcomings, many of which are eliminated by combining the 2 meth-

Table 2. Agreement Between Combined and Standard Perimetry Tests

Group	Agreement Between Combined and Standard Tests	Standard Perimetry Type, No. (%) of Eyes*					
		Neuro-ophthalmologic Group			Glaucoma Group		
		Static	Kinetic	All	Static	Kinetic	All
1	Matching defects	11 (30)	15 (41)	**26** (70)	10 (27)	13 (35)	**23** (62)
2	Combined test more extensive	0	0	**0**	2 (5)	0	**2** (5)
3	Combined test less extensive	1 (3)	0	**1** (3)	2 (5)	1 (3)	**3** (8)
4	Both normal	5 (14)	0	**5** (14)	0	0	**0**
1-4	**Total Good Match**	**17** (46)	**15** (41)	**32** (86)	**14** (38)	**14** (38)	**28** (76)
5	Combined test had defect, standard test normal	1 (3)	0	**1** (3)	0	1 (3)	**1** (3)
6	Combined test normal, standard test had defect	0	0	**0**	0	2 (5)	**2** (5)
7	Combined test reliable, standard test unreliable	1	0	**1** (3)	0	0	**0**
8	Combined test unreliable, standard test reliable	0	0	**0**	0	0	**0**
9	Both tests unreliable	0	0	**0**	0	0	**0**
NC	No consensus	1 (3)	2 (5)	**3** (8)	3 (8)	3 (8)	**6** (16)
5-NC	**Total Poor Match**	**3**	**2**	**5**	**3**	**6**	**9**
Total		**20** (54)	**17** (46)	**37** (100)	**17** (46)	**20** (54)	**37** (100)

Abbreviation: NC, consensus description could not be reached.
*Percentages have been rounded and may not total 100.

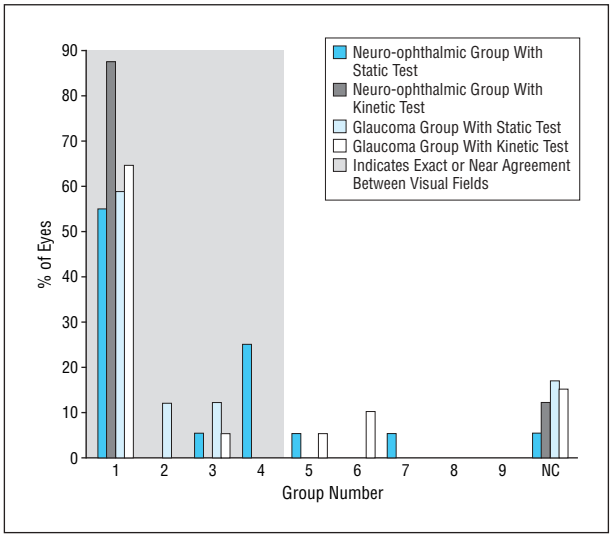

Figure 2. Distribution of visual field (VF) comparisons among patients with neuro-ophthalmic disease and glaucoma. Sixty VF pairs (81%) were classified as a good match (shaded area). Those VF pairs that included at least 1 VF for which a consensus description was not reached could not be classified and are depicted as no consensus (NC). Groups of VF pairs are described in Table 2.

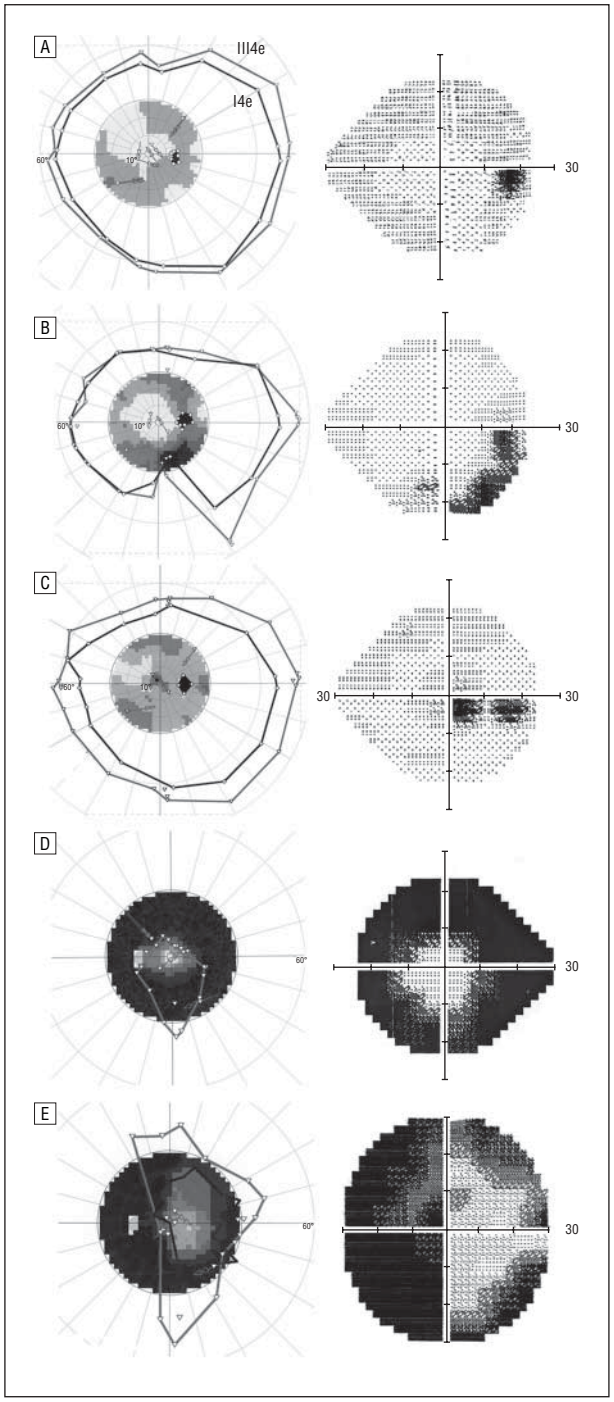

Figure 3. Representative visual field (VF) pairs with static comparisons from group 1 in which the descriptions for the eye's individual VFs matched. The left side shows automated, combined examination findings; the right side, the Humphrey VF grayscale printout. A, Findings within normal limits; B, mild inferotemporal arcuate; C, mild central scotoma; D, severe generalized constriction; and E, severe temporal hemianopia. Groups of VF pairs are described in Table 2.

ods. We set out to determine whether an automated, combined test could be completed without the need for a skilled perimetrist.

Although this study requires further investigation to define exact accuracy and reproducibility, it demonstrates that a carefully designed, automated, combined VF test can, in most cases, be used as an alternative to standard testing in patients with neuro-ophthalmic disease and glaucoma. Eighty-four percent of the standard static examinations and 78% of the standard kinetic examinations were reproduced by the combined test. These numbers may be even higher (92%) if one excludes the 9 VFs that were not categorized owing to lack of reviewer consensus on the patients' VF defect description.

In certain cases, one of the testing methods was found to be more sensitive. In 1 eye with a standard static test in the neuro-ophthalmic group and 1 eye with a standard kinetic test in the glaucoma group, the combined examination delineated defects that were not present on standard testing. In one of these cases (Figure 5D), our experienced perimetrist did not detect a subtle nasal step, which was associated with a recent change in the appearance of the patient's optic disc and increased intraocular pressures. This instance demonstrates that the combined examination is a possible alternative to standard methods and may be better in certain cases of subtle peripheral defects. The static component of the combined test missed 2 small central scotomata found on standard kinetic testing (Figure 5E). One explanation for this finding is fixation loss during the static test that was not present on manual kinetic testing. In addition, there were eyes in which small paracentral scotomata delineated by the combined test were classified into group 3 (3 of the 4 eyes in this category), in which SITA standard testing showed a slightly more extensive defect than did the TOP component of the automated, combined test. Morales et al[12] reported that the TOP examination may measure scotoma to be smaller and shallower than standard Octopus testing. Thus this discrepancy is likely due to the shorter and less accurate nature of the TOP test when compared with the SITA standard results of these 3 eyes. The number of VFs categorized into these groups in which 1 technique was found to be significantly more sensitive than the other is small (3% in

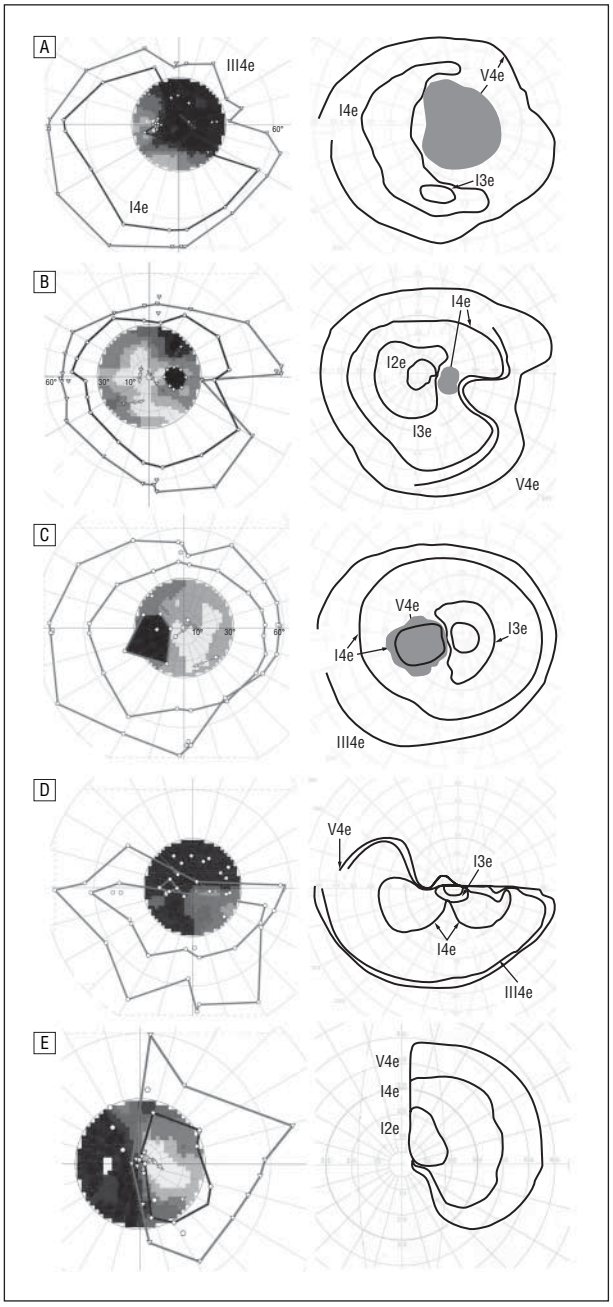

Figure 4. Representative visual field (VF) pairs from group 1 in which the descriptions for the eye's individual VFs matched. The left side shows automated, combined examination findings; the right side, Goldmann VFs. A, Severe central scotoma; B, severe temporal wedge; C, moderate enlarged blind spot; D, severe superior altitudinal defect; and E, severe nasal hemianopia. Groups of VF pairs are described in Table 2.

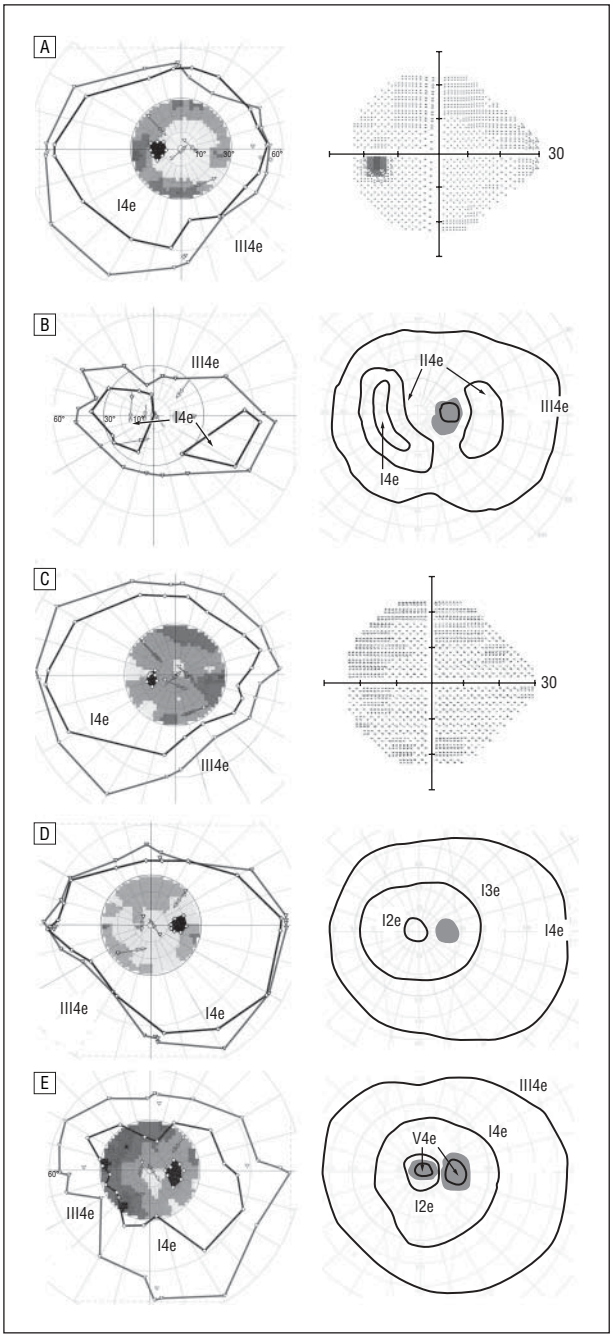

Figure 5. Visual field (VF) pairs that were not classified as a match. A, Representative examples of standard static comparison VF pair that did not fit into the categorization scheme. B, Representative example of a kinetic comparison VF pair that did not fit into the categorization scheme. C, Visual field pair belonging to group 5. The tendency-oriented perimetry strategy central examination delineated a nasal step not demonstrated by a 24-2 Humphrey visual field. D, Visual field pair belonging to group 5. The combined examination delineated a nasal step not demonstrated by Goldmann perimetry. E, Visual field pair belonging to group 6. The combined examination did not delineate a small central scotoma demonstrated on standard Goldmann perimetry out to V4e. Groups of VF pairs are described in Table 2.

groups 5 and 6) and likely represents typical perimetry variation, falling well within the estimates reported for test-retest reliability of static VFs.[17,18]

To our knowledge, this study is the first to assess the Octopus 101 with TOP strategy testing for automated combined examinations. Other studies reported combined examinations using the Humphrey Field Analyzer or the Fieldmaster 5000.[19-21] In those studies of patients with glaucoma, helpful information was obtained in approximately 27% of eyes, but the studies concluded that the additional information was not worth the increased test time of 21.5 minutes. However, using the Octopus 101, the time for a static field overlaid on 2 peripheral isopters ranged from 6 to 12 minutes. The use of the shorter TOP strategy, validated in several studies,[11,12] may alter the previous opinion that a combined examination is too time-consuming relative to the amount of information offered.

To our knowledge, the use of an automated, combined test has never been evaluated for neuro-ophthalmic disease. In this patient population, standard kinetic perimetry is often preferred for dense defects and for focused examination of those patients with neurological deficits in whom the concentration, coordination, and mental stamina needed to perform automated perimetry may not be present. Recently, SITA Fast perimetry, a strategy similar in testing duration and difficulty to the TOP strategy, was found to be an acceptable alternative for patients with low vision and/or severe neurological disease.[15]

In 9 cases in our series, a consensus could not be reached regarding the description of one or both of the individual VFs. All of these pairs were analyzed by a fourth reviewer who believed that they conveyed the same information but were not classified in the same category owing to the nonsimultaneous review process. This would not likely be an issue in clinical practice, where a physician with a clinical context and history would come to the same conclusion in all cases.

As has been found in many other studies, patients preferred standard Goldmann perimetry compared with the automated, combined test. This is likely owing to the longer duration of the automated, combined test. Although testing time was not officially compared, our skilled perimetrist typically completes kinetic tests within 7 minutes, whereas the automated, combined test duration was often 10 to 12 minutes. Also, patients typically do not like the static nature of standard static tests,[5,15] regardless of the fact that the TOP strategy test duration is less than 4 minutes. Conversely, when compared with traditional static testing, more patients preferred the automated, combined test, without significant correlation with previous testing strategy (SITA standard or SITA Fast). Some possible explanations for this preference are the examiner interaction, easier kinetic component, and larger bowl of the Octopus 101.

Although minimal perimetry skill is required on the part of the examiner, this test does require that the administrator be computer literate. Ideally, an examiner would understand kinetic perimetry enough to retest vectors during which patients lost fixation, or to add extra vectors to further delineate scotoma. An examiner who has a minimal understanding of kinetic testing might be able to perform these additions to the test without having to delineate any complex scotomata in the central field. Other additions to this protocol necessitating slightly more skill include changing stimulus size on the basis of patient response and changing vector trajectory or length on the basis of the defect. Our examiner did not perform these additions to the test, as we attempted to create a test that was uniform and required very little skill.

Shortcomings of our method include the increased time, given the large number of kinetic stimuli necessary to delineate defects if an unskilled examiner administers the test, the lack of patient approval compared with kinetic testing, and the possibility of missing very small defects in the central 30°. Further studies will be necessary with larger populations to further assess accuracy. It will also be important to study the reproducibility of this test and the use of this method by examiners of different skill levels. Finally, it may be necessary to compare this examination with a single, standardized strategy for static testing in large groups of patients.

Aside from not requiring a skilled perimetrist, this test has several other advantages. Notably, the integrated software can correct the peripheral isopters for individual patient reaction time. This feature is important for patients who are slow to respond to the kinetic stimulus and in whom manual kinetic VF tests might overestimate their defects. The software also calculates the area encompassed by each isopter, thereby creating hard data that may be compared from time to time to establish progression of disease. Finally, the use of computerized perimetry alleviates the bias and lack of standardization that are inherent to manual examinations.

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