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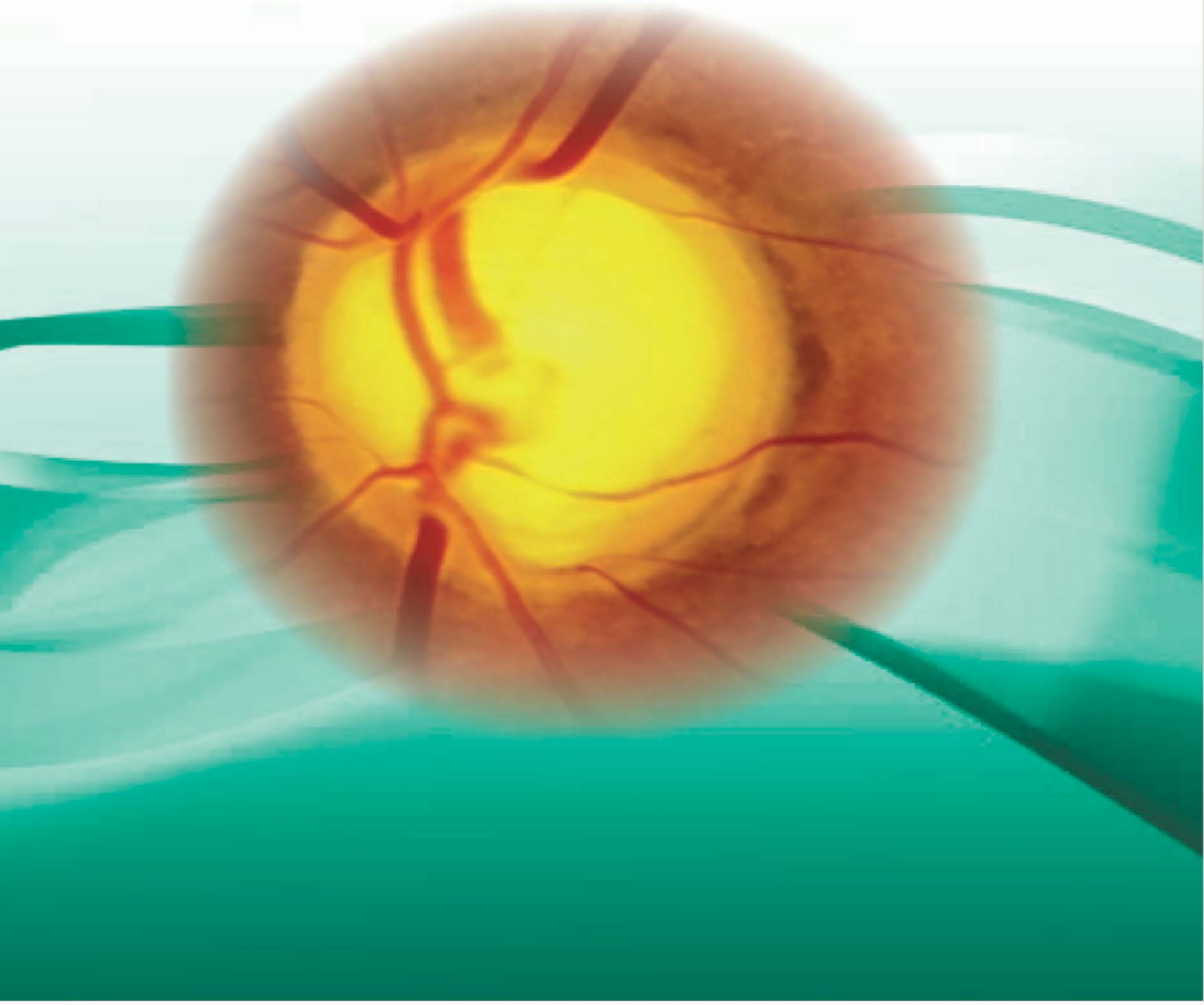

HV Nema
Nitin Nema

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CHAPTER 4

Perimetry in Glaucoma

Rangaraj NR

VISUAL FIELD

Perimerty is the evaluation of visual function at a given instance of time. Static and kinetic perimetry are different ways to plot the visual fields. The stimuli in static perimetry are at fixed locations and vary in intensity to plot the visual field. The kinetic perimetry has different sizes of stimulus moving from not seeing to seeing to plot the visual fields. This chapter discusses static perimetry, which is now widely used in clinical applications. The characteristic pattern of visual field loss makes many eye conditions like glaucoma, optic nerve diseases and neurological alter the visual function in a characteristic pattern, which makes computer-assisted perimetry a valuable tool for diagnosis and follow-up (Figs. 4.1 and 4.2). Visual field testing compliments other parameters like intraocular pressure and structure changes in the optic nerve head in decision making as in glaucoma to chart progression of the disease.

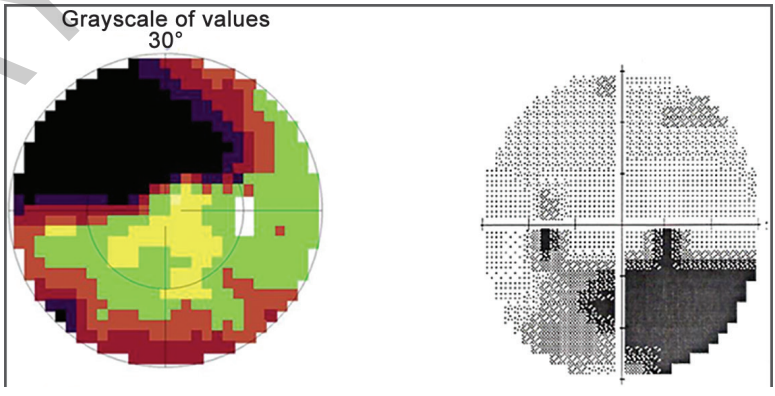

Fig. 4.1: Gray/color scale.

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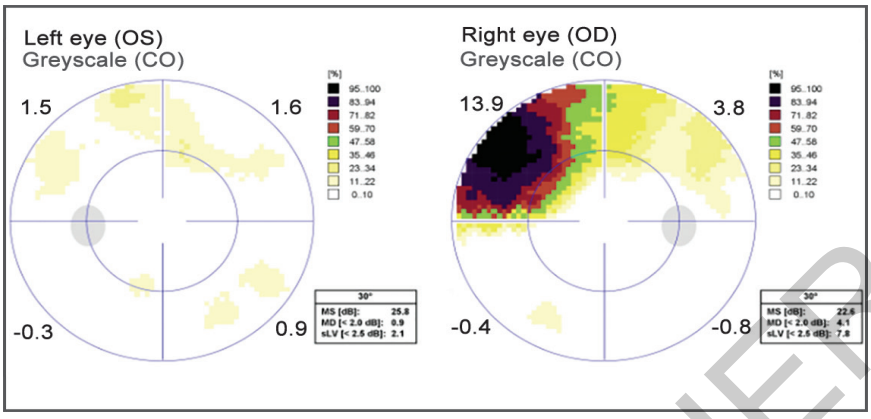

Fig. 4.2: Two on one representation with age matched color/gray scale.

The central 30 visual field examination using white on white automated static perimetry is currently the gold standard in evaluation, management and follow-up of glaucoma.

DEFINITION, TERMINOLOGIES AND PRINCIPLES IN VISUAL FIELD PERIMETRY

Visual field is the area seen when the eye is steadily fixated at a point at that instant. Hence the visual field could vary in a subtle area within the normality for the age matched population. Visual field is always measured with standard conditions of background illumination and color. The size of the stimulus varies in a kinetic perimetry from 1 to 5, with size 3 being fixed for routine static perimetry with age matched database.

Static perimetry tests the subject's ability to perceive the faintest light presented in a given location in the tested area of visual field. Differential light sensitivity is the perception of least difference between the stimulus light and the background illumination. Differential light sensitivity in effect measures the least difference between the stimuli and the background illumination.

Visual field when measured for diagnosis, follow-up and comparison is done under standard conditions of color, and background illumination that is fixed for a particular machine. Stimulus size may vary for normal estimations and for low vision conditions.

The patient's threshold is defined as the stimulus luminance, which is perceived for a given background illumination, with a probability of 50% chance of seeing or not seeing which is described by the frequency of seeing curve (FOSC) as function of stimulus luminance. Threshold is expressed in decibel (dB) scale in clinical practice. In reality, the threshold is not a fixed point; it fluctuates during the test when it is being conducted and over long periods of time at the same test points. The FOSC is very steep normally; this is due to the consistency of response to the projected light stimulus during

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visual field examination. This ability to perceive the 50% threshold illumination is very sharp in normal individual at all test points in the visual field, about 4 dB bandwidth (Fig. 4.3). The test points which are abnormal due to disease show inconsistency of response and the bandwidth of response becomes more than 4 dB, which makes the FOSC flat (Fig. 4.4). Generalized depression of the field causes the FOSC shift to the right but remains steep.

The standard testing conditions in perimetry data are obtained from one visit to the next. This consistent data obtained during each visit help in

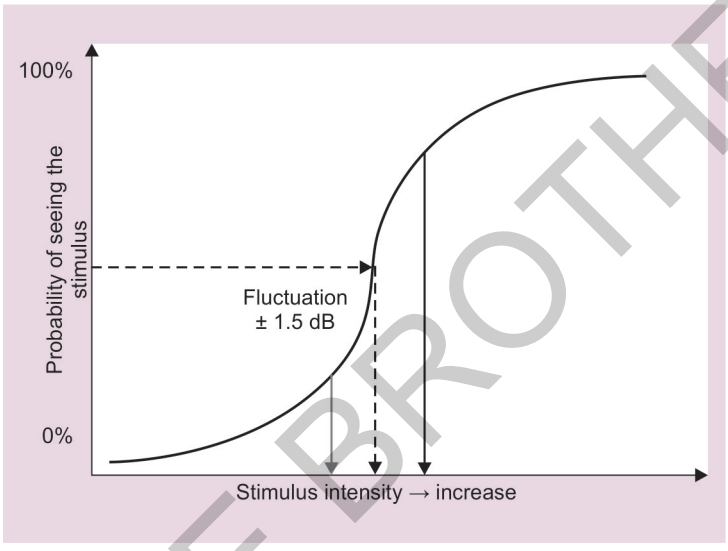

Fig. 4.3: Normal frequency of seeing curve..

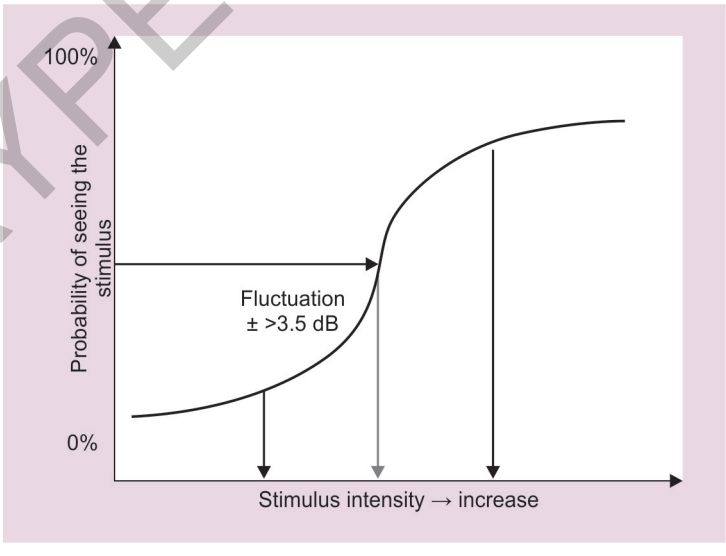

Fig. 4.4: Flat frequency of seeing curve.

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follow-up and comparison to be made with age related normals. These standard test conditions are adopted in the widely used Octopus and Humphrey perimeters. The clinically relevant test conditions are the background illumination, size and duration of stimulus.

Background illumination affects the shape of the hill of vision. Lower background illumination in static perimetry increases the dynamic range and highlights areas of depressed sensitivity better because of the flatter slope of the hill of vision (Fig. 4.5). The drawback of lower background illumination is longer period of adaptation for the patient before the test is started. The Goldmann kinetic perimetry uses a 31.4 asb as the background illumination. The direct projection perimeters like the Octopus 300 and 600 use background illumination of 31.5 asb, hence can be used in normal clinic lighting conditions with little influence on adaptation time.

The stimulus exposure time is 100 ms in the Octopus perimeter, which is time enough to reach temporal summation of the stimulus luminance. Any exposure longer than 200 ms will provoke fixation reflex and give erroneous results (Fig. 4.6). Setting the stimulus interval takes into consideration the

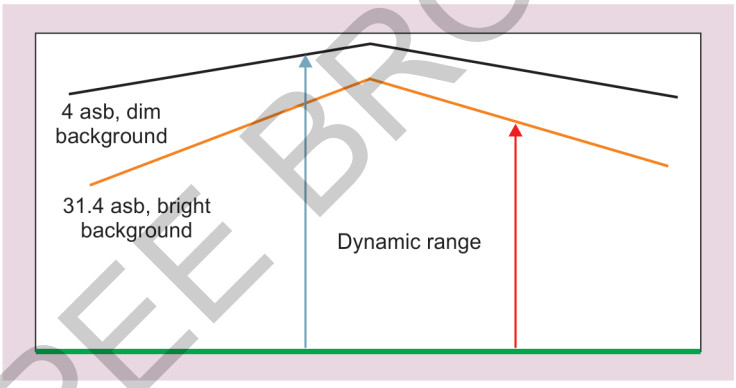

Fig. 4.5: Dynamic range with low and high background illumination.

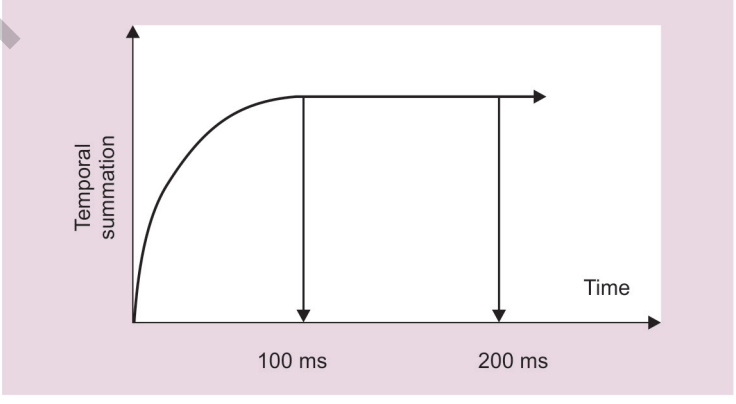

Fig. 4.6: Stimulus duration in ms and temporal summation.

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'no' answer and the next stimulus. The adaptive stimulus presentation keeps track of the average time of response and proceeds with the completion of the test either faster or slower. The normal stimulus interval is set between 1.5 and 4 seconds.

MEASUREMENT STRATEGIES

It is important to understand that the 'how' of testing is the strategy and the 'where' is the program or the set of test points being tested. The choice of test strategies is offered in the Octopus 300/900 series perimeter to meet the different clinical situations of diagnosis and follow-up. The two main testing procedures offered across all perimeters are the screening tests (qualitative) and the quantitative tests as offered by the full threshold tests in the 4-2-1 dB steps.

Traditional screening strategies give qualitative results in a yes or no format to save time to get a general idea of the visual field to help in looking for an expected pattern of visual field loss expected in the particular disease process. New strategies like tendency-oriented perimetry (TOP) and dynamic give quantitative results in the same time. The two-zone testing and screening strategies are of only academic value now.

The widely used perimeters, which offer the normal full threshold testing strategy, are the dynamic strategy (Weber), TOP, Swedish Interactive Thresholding Algorithm (SITA) fast and standard as the main testing strategies. Classical normal full threshold strategy introduced by Flammer in the 1970s still forms the basis of automated perimetry.

Normal Testing Strategy

The normal strategy is the basis of all new strategies. Understanding the normal strategy makes visual field interpretation logical. Normal traditional full threshold tests all points in a random manner in steps of decreasing luminance such that a yes or no answer is obtained to the least amount of stimulus at all test points. The perimetry being computerized helps in correlating all the randomized stimulus intensities and answers in a printout. To make things easy for the patient and duration of test shorter, testing starts at one point in each of four visual field quadrants called anchor points. The anchor points test the general slope of the hill of vision to the age-corrected normal values. The visual field determination starts from this approximate hill of vision test points from the expected age-corrected minus 4 dB. A 'no' answer drops the stimulus luminance by 6 dB if the first response to a minus 4 dB start is negative. A brighter light stimulus is projected which is 8 dB less to quickly approach the depressed sensitivity of the test point. Once the anchor points are determined further testing in a 4-2-1 dB step approach at each of the predetermined test points are determined from the data obtained from

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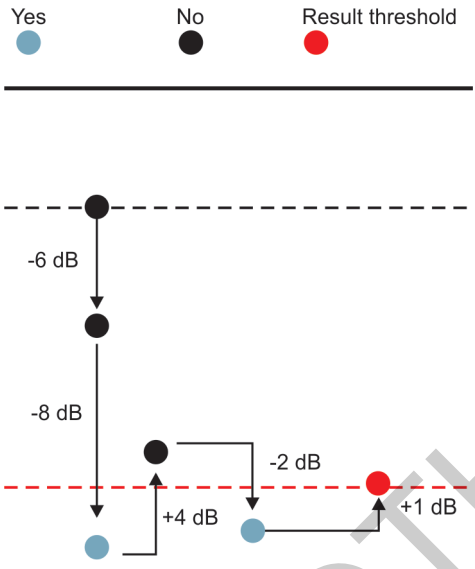

Fig. 4.7: Schematic representation of 4-2-1 bracketing strategy.

the estimated hill of vision rather than starting from normal hill of vision values which would make the testing tedious. This is approximately five questions per test point hence sensitive enough to detect shallow pathology. Normal strategy takes about 15–18 minutes per eye to complete a visual field examination (Fig. 4.7).

Shorter and smarter new strategies minimize the effects of physical and retinal fatigue. Octopus perimeter provides the dynamic strategy and TOP. The Humphrey provides the perimeter strategies SITA fast and SITA standard.

Dynamic Test Strategy

Weber introduced the dynamic strategy of visual field testing. The stimulus luminance step size (bracketing) adapts to the slope of the FOSC. When the depth of the defect is deep the step size increases from increments steps of 2 to 10 dB to achieve final calculated value from the last two tested values. The accuracy obtained with this test is comparable to the regular full threshold test with a 4-2-1 dB strategy. This strategy provides quantitative data, which may be represented as the gray scale, Bebie curve and global indices. Quantitative values are useful for follow-up and to track changes over time. The test duration is about 40–50% in severely depressed fields and 30–40% in marginally depressed fields when compared to normal threshold. Short-term fluctuation values may also be calculated by retesting all locations in the second phase if additional information is needed. Dynamic strategy provides data of the visual field comparable to the regular full threshold determination done in four stages (Figs. 4.8A and B).

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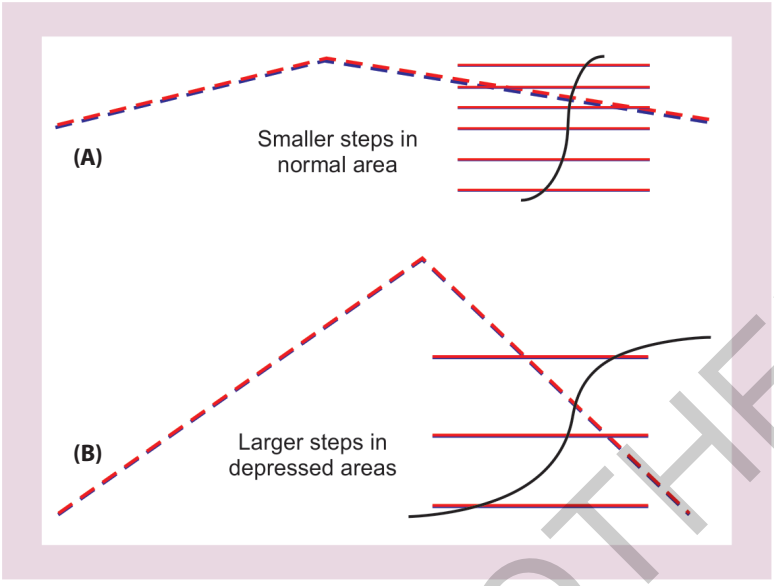

Figs. 4.8A and B: (A) Smaller steps in normal test locations. (B) Larger steps in depressed areas.

Tendency-oriented Perimetry

TOP strategy, introduced by González de la Rosa, reduces the time taken to complete the visual field analysis by 80% to the time taken by normal threshold. TOP takes into consideration the neighboring test locations when the results are interpreted. TOP strategy can be applied to all test methods like blue on yellow and flicker or programs like macular-M2. The neighboring zones in visual field exhibit a topographical interdependence; this establishes a tendency between adjacent points under examination.

TOP evaluates every 'yes' and 'no' in two ways, the location under test is evaluated for the differential sensitivity, which is called the vertical bracketing and the neighboring points are also adjusted by interpolation. A yes answer at the test location will influence the neighboring point positively and a no answer will influence the neighboring point negatively on the dB scale. In regular full threshold perimetry every test location is tested at least four to six times before arrival at the final value of differential sensitivity. A single answer in TOP is adjusted five times from the results of the neighboring test locations in the grid for final results.

These steps may be in either direction to determine the final threshold of dl sensitivity (Fig. 4.9). Grayscales show a rounded effect in TOP compared to regular threshold grayscale values because of the adjustments of the neighboring points. Hence the average sensitivity values obtained may be a little 'shallow' compared with regular threshold testing (Fig. 4.10). This difference is not of any significance when the parameter in follow-up is

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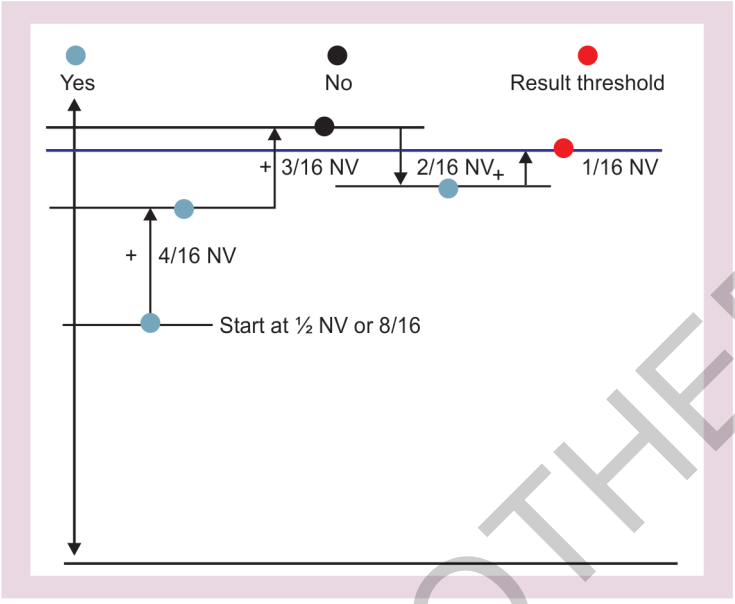

Fig. 4.9: Schematic representation of the bracketing in TOP.

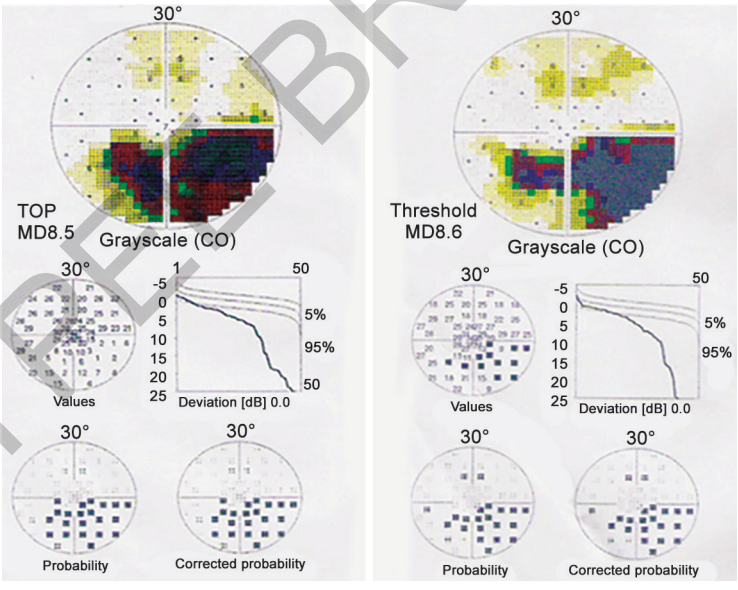

Fig. 4.10: Comparison of TOP and threshold strategy.

only changes over time, since the pathology is already established and the patient compliance is improved for follow-up testing. Note the difference in MD values of only 0.1 between the two strategies (Fig. 4.10). The gray/color scale shows some spread and shallowness of the color scale in the TOP strategy.

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Swedish Interactive Thresholding Algorithm

The SITA strategy optimizes with reduction in time up to 50% without loss of quality of the visual field examination and reduced fatigue for the patient. In the software tests each point to the known predetermined value of threshold is expected. Hence a constant modeling of the normal visual field and glaucomatous defects are calculated. This triggers the testing at a location at the predetermined threshold value to stop. These values are also affected by the neighboring points and location along the nerve fiber layer. The false positive and negatives are calculated values and save time. SITA strategy is very glaucoma-specific. SITA standard is based on bracketing strategy and favored on Humphrey visual field analyzer by clinician. To even further reduce the time, the SITA fast based on FASTPAC is available. SITA standard is used for glaucoma baseline and progression analysis.

Qualitative 2 Level Testing

With the introduction of faster full threshold testing, these screening tests are almost obsolete. 2-level testing uses a maximum of two questions per location and provides a simple quantification of the tested location. The test starts with a stimulus –4 dB less than the age corrected value. A 'yes' answer sums up the test result of that location. A 'no' answer provides the same location the brightest stimuli and a 'yes' tags the test location as relative defect. A 'no' to the brightest stimulus is classified as an absolute defect. The usual time taken for 2 level quantitative testing is around 5 minutes which is more than some of the quantitative test procedures.

PROGRAM AND TEST POINTS

Programs are the fixed locations in the visual fields where the stimuli are presented in a random fashion. The Octopus and Humphrey perimeters have almost similar programs.

Octopus G1/G2 Programs

The two programs are identical in the central 30° consisting of 59 test point locations and differ only in the peripheral 15 additional points tested between the 30° and 60° in G2. The G2 is a program optimized for Octopus 900 series perimeter. The G1 program test locations respect the topography of the nerve fiber layer and are weighted to detect the nasal step in glaucoma (Fig. 4.11A). The foveal and paracentral areas have resolution of 2.8° in the G1/G2 programs compared to 4.2° resolution in a classical Program 32 test location. The increased resolution in the foveal area gives a good follow-up when there is a fixation threat, without the need of an additional visual field test for the fovea. Depressed areas have a high false-negative behavior because of a flatter FOSC and extend the test duration.

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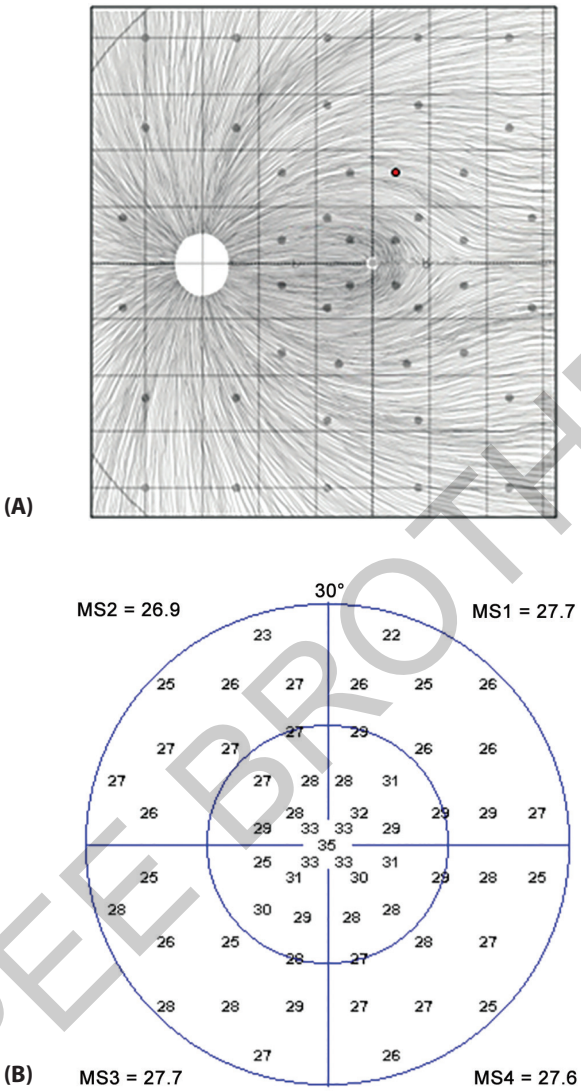

Figs. 4.11A and B: (A) G1 test points superimposed on the nerve fiber layer. (B) Typical G1 locations of test points.

All strategies can run on the G1 and G2 program (Fig. 4.11B). Most clinical needs are satisfied with the 300/600 series Octopus perimeter. The extra test points between 30° and 60° of testing do not give additional information but only confirm what is seen in the central 30° field.

Programs 32, 30-2 and 24-2

This is the classic 'off-axis' program introduced by Octopus and later by the Humphrey perimeter as the 30-2 program. There are 76 test locations in a grid pattern with a resolution of 6°. This program is not related to the topography

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of the nerve fiber layer or pathology with both eyes having identical pattern of test locations. The area where the blind spot appears marks the right and left eye. The program 32 is still an option, since old follow-up with Octopus was done with this program. It may also be used in neurological cases where this program defines the vertical and horizontal meridians well. The 24-2 does not test the peripheral points but retains only the temporal points (nasal step) to reduce the time taken for the strategy to complete the test (Fig. 4.12).

Macular Programs

The macular programs were designed for detection and follow-up of central and paracentral visual field defects in patients with neurological diseases, drug toxicity, macular or peri-macular diseases. This is available in both popular perimeters. (Fig. 4.13).

The M2 program has 45 test locations, which are tested in two stages consisting of the central 4° and the area between 4 and 9°. The 45 test locations in the central 4° gives a 0.7° resolution with a Goldmann Size III, which is 0.43° in diameter (Fig. 4.13). The additional 36 test locations situated in the outer 4–9° gives this program the highest resolution in the central 10° of the visual

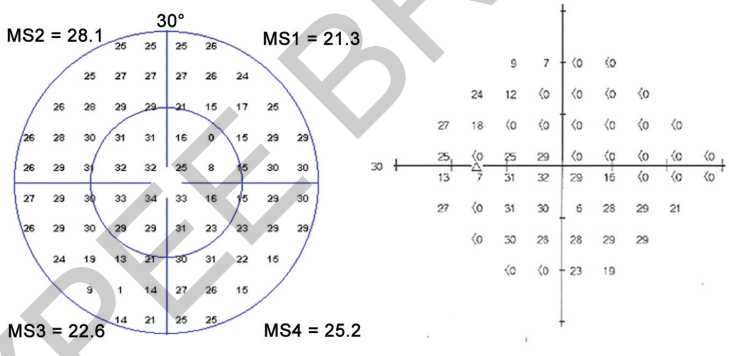

Fig. 4.12: Test point locations in the P32, the 30-2 program 24-2.

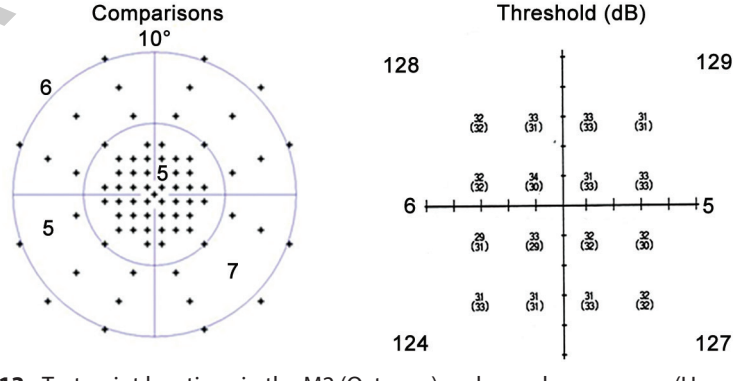

Fig. 4.13: Test point locations in the M2 (Octopus) and macular programs (Humphrey).

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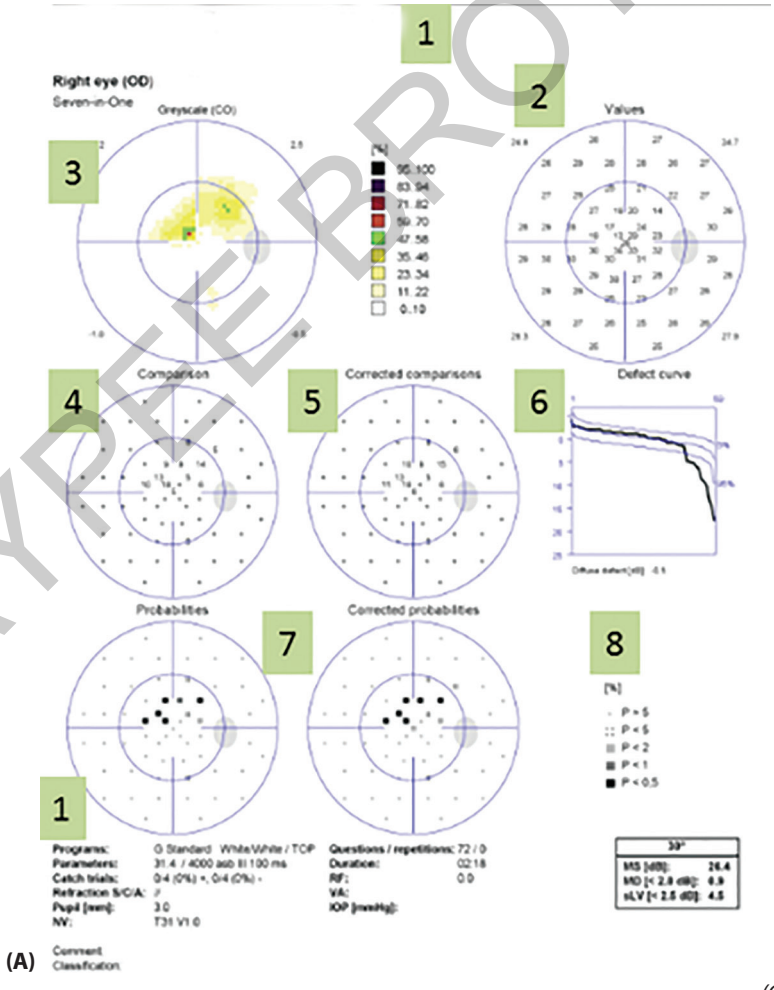
field. The M2 program can be run using the TOP, dynamic or normal strategy to define the visual field pathology in question.

The macular program in Humphrey visual field analyzer tests the central 16 points which are thresholded to improve reliability and repeatability. The 10-2 provides the higher threshold central only test points in the Humphrey perimeter.

Macular and central programs are used to detect split fixation in advance visual field defects in glaucoma and central scotomas due to drug toxicity.

SYSTEMATIC INTERPRETATION OF A SINGLE FIELD REPORT

The seven-in-one printout contains the raw results from the visual field examination and easy to read statistical data interpreting the results in a clinic setting. The single field printout presents the relevant statistical calculations, images, graphs, plots and indices on a single page. (Figs. 4.14A and B).



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- Medical management of primary open-angle glaucoma
- Lasers in glaucoma
- Glaucoma surgery
- Management of coexisting cataract and glaucoma
- Progression of optic disk and visual field changes in glaucoma
- Refractive glaucoma: Management.



HV Nema MS has a distinguished academic career and is well-known for teaching, research and publications. He has served as a Consultant Editor/Advisory Editor to Indian Journal of Ophthalmology, Afro–Asian Journal of Ophthalmology and Indian Journal of Optometry. He has published more than 6 dozen papers in the national and international journals. He is an established author in the field of ophthalmology. *Ophthalmic Syndromes* (Butterworth, London, UK, 1973) and *Textbook of Ophthalmology* (6th ed. 2012, Jaypee Brothers Medical Publishers, New Delhi, India) are some of his popular books. He has edited 13 volumes of *Recent Advances in Ophthalmology*, 3 editions of *Diagnostic Procedures in Ophthalmology* and *Eye in Systemic Disorders* (Wiley India) which were well-received by readers and favorably reviewed in Indian and international journals. He has delivered guest-lectures in many universities.



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