Automated achromatic perimetry
Anand Aggarwal, Kanika Chhabra, Prempal Kaur, Karamjit Singh, Indu Khosa, Pulkit Bansal

Abstract:
Visual field (VF) testing is an important diagnostic tool for Glaucoma. The current gold standard for VF testing is automated perimetry. This article is an attempt to familiarize the reader with components of an achromatic (white on white) automated perimetry printout. It addresses use of Humphrey perimeter to interpret the results. For the purpose of this review, a PubMed search was made using perimetry, Humphrey VFs review as key words and the relevant articles were studied. The references appended with these articles were also analyzed, and any appropriate article was also included. A systematic approach has been outlined that results in a thorough interpretation of the printout. One should be able to identify a normal field and establish glaucomatous progression, detect the presence of a field defect, determine whether it is due to glaucoma or neuro-ophthalmic disease if any. Comprehensive evaluation using clinical examination, tonometry, and perimetry should be considered together to make a proper diagnosis of glaucoma and judge its progression over time.

Keywords:
Glaucoma progression, humphrey field analyzer, standard automated perimetry

Introduction
Visual field (VF) testing is an important diagnostic tool in the evaluation of patients with various pathologies affecting optic nerve and neuro-ophthalmological diseases. Standard automated perimetry is the most widely used method to assess VF deficit in glaucoma.[1]

Systematic interpretation of VF printout and clinical correlation are important to make meaningful diagnosis. For purpose of this review, PubMed search was conducted using perimetry, Humphrey VFs review as key words. The references appended with these articles were also analyzed and appropriate articles were included.

Humphrey Field Analyzer
It is an automated perimeter intended to measure VF using static stimuli. Its statistical software, StatPac, analyses threshold VF test results besides providing highly sensitive and informative analysis of changes in patient’s VF over time. Its advanced Guided Progression Analysis (GPA) helps to identify and monitor increasing VF loss due to glaucoma (see ahead).

Single Field Analysis (SFA) Normative Database
It contains normative data for Swedish Interactive Thresholding Algorithm (SITA) Standard and SITA Fast 30–2, 24–2, and 10–2 threshold VF test results from healthy controls aged 17–89 years.[2] The SITA normative database was developed utilizing 422 subjects (of mixed ethnicity) whose mean age were 53 years. The gender distribution was 44% male and 56% female. It is against these values that Humphrey field analyzer (HFA) compares patient’s sensitivity. The upper 95% of values found in database is normal. The lower 5% values found in these normal people are arbitrarily labeled as abnormal. This is the built-in logic of this machine. Hence, it is important...
to remember that abnormal is not synonymous with disease.

**Examination Strategies**

1. SITA\(^{[3,4]}\) – This strategy is based on probability analysis of patterns of glaucomatous damage. Two versions of SITA are available - SITA Standard and SITA Fast. SITA Standard cuts testing time in half relative to the Full Threshold strategy, without compromising test reproducibility. SITA Fast is a faster version of SITA. It cuts testing time in half relative to the FastPac algorithm and is found to be useful in pediatric population,\(^{[3]}\) although it has somewhat increased variability as compared to SITA Standard.\(^{[6]}\) SITA Fast is thereby useful for mass screening whereas SITA standard is more useful for individual detailed assessment of glaucoma in patients who are either suspects or in those who show defects on SITA Fast

2. Full Threshold – This strategy was used in HFA, before adoption of SITA. In Full Threshold testing, a “bracketing” technique (4-2-2) is used to threshold each test point. The main disadvantage of this strategy is increased testing time of around 15 min which can increase even further in glaucoma patients, and this could be tiring for frail elderly population

3. FastPac – This strategy decreases Full Threshold test time by about 40%. It follows a similar stair-stepping technique as in Full Threshold but uses 3 dB increments instead of 4 dB.

**Test Patterns**

The central 30° or 24° of the field are tested, with spacing of 6° in between points. The central points may be distributed on the horizontal and the vertical axis (programme 30-1 or 24-1) or may straddle the horizontal and the vertical axes (program 30-2 or 24-2). The advantage of central 30-2 or 24-2 programs is their greater sensitivity to changes across horizontal raphe as the points have a spacing of 3° from center of the field.\(^{[7]}\) This helps to differentiate glaucomatous from nonglaucomatous (neuro-ophthalmic) field loss. One should remember that neuro-ophthalmic field defects respect vertical midline [Figure 1] whereas glaucomatous field defects respect horizontal midline. 30-2 and 24-2 program tests 76 and 54 points, respectively.

The central 10-2 program [Figure 2] is useful in advanced glaucoma, testing 68 points with test locations 2° apart. This gives magnification effect and shows the relationship between central field defects and point of fixation more precisely.\(^{[8]}\) This may reflect on the decision to operate or not, and helps in the estimation of risk for postoperative wipe-out phenomenon.

**Test Stimuli**

Goldmann size III (about \(\frac{1}{2}\)° in diameter) is generally used, but Goldmann size V (approximately 2° in diameter) is available for patients with decreased visual acuity (<20/200) or advanced glaucoma. The luminous intensity of stimuli can be varied over a range of 0.08–10,000 apostilbs (asb). The thresholds are preferably reported in decibels (db), in a range of 0–50. Decibel and apostilbs values share an inverse logarithmic relationship. Fifty db is the dimmest, maximally attenuated target the perimeter can project and 0 db being the brightest, unattenuated one. Lower the decibel value, lower the sensitivity.

**The Humphrey Field Analyzer Print Out**

For ease of interpretation, VF printout has been divided into eight sections\(^{[9]}\) [Figure 4]

1. Patient’s data and test parameters
2. Reliability indices
3. Grayscale
4. Total deviation (TD)
5. Pattern deviation (PD)
6. Global indices
Aggarwal, et al.: systematic interpretation of automated fields is important to diagnose glaucoma, differentiate it from neuro-ophthalmological disorders and monitor glaucoma progression

7. Glaucoma hemifield analysis (GHT)
8. Numeric scale.

**Patient’s data and test parameters**
The first priority is to make sure that fields belong to a patient in question, and that specific program requested has been used, with parameters that have been asked. The date of birth has to be correct (for comparison with a range of normal values for corresponding age). A pupil diameter of at least 2.5 mm is essential to avoid overall depression of test values. Finally, using near correction lenses for age 35 years and above, and/or high astigmatic error (>0.75 D) correction lenses are strongly advisable to help patient appreciate test targets. Spectacles must not be worn because they can cause false defects in the VF due to their shape. Thin wire-rimmed corrective lenses are used.

**Foveal threshold and reliability indices**

**Foveal threshold**
It is optional but should be turned on while testing the field. It serves as an internal validation for visual acuity, and the two should correspond.

The second priority is to check test reliability.

**Fixation losses**
Fixation losses occur when patient reports seeing a stimulus that is presented in predicted area of physiologic blind spot. Normally, these are between 0% and 20%. If the loss exceeds 20%, this is generally considered as poor reliability, but it may also indicate advance glaucoma with an abnormally large blind spot.

**False positives**
These are seen in “trigger happy” or anxious patient who is pressing the button in response to auditory click even when no light stimuli are presented. High false positives (FPs) (>15%) result in multiple white scotomas on the grey scale [Figure 5]. High FPs indicate that VF loss in a glaucoma patient is actually worse than what is being depicted on VF printout.

**False negatives**
High false negatives (FNs) are labeled when the patient does not respond to a stimulus 9 dB brighter than the already determined threshold stimulus. They are a result of attention lapses, fatigue or malingering, and in case of advance glaucoma as the points are being tested at the edge of scotoma. Values of 15% or more may result in a typical “clover leaf” pattern on the grey scale. High FNs indicate that VF loss in glaucoma patient is actually less than what is being depicted on VF printout [Figure 6].

**The grayscale**
This is graphic representation of recorded threshold sensitivities in the numeric scale. It is useful for
displaying patterns of loss (nerve fiber layer defects versus neuro-ophthalmological defects). It should not be inspected first, as relying solely on gray scale when evaluating VF can lead to inaccurate identification of VF loss. TD and PD must be assessed to reach an accurate clinical picture. It is a very useful tool, though, in explaining – to patient and family – the stage of disease and its progression.

**Total deviation plot**

It shows portions of patient’s VF that are different from “normal” field of an individual of the same age. It highlights overall sinking of the patient’s vision which is usually caused by media opacities, such as cataract, corneal opacity, or miosis.

It is depicted as numerical plot and probability plot. It is best assessed with shaded boxes at each test location. Solid, fully black squares indicate test points that are statistically more likely to be abnormal compared to lighter shades of grey. One should look at size, shape and location of any abnormal points/ boxes.

Localized defects (see ahead) are key finding in glaucoma or lesions along visual pathway which may be hidden by a generalized depression caused by media opacity. Hence, it does not reveal hidden scotoma.

**Pattern deviation plot**

This analysis tool is helpful for detecting localized VF defects in the presence of generalized depression. This is done by correcting the deviation of seventh-highest threshold location to zero deviation and “adjusting” the entire field by that value. It is also provided as numerical plot and probability plot. We generally look at the probability plot. True defects on PD plot are characterized by their shape and location (i.e., nasal steps, central and arcuate scotomas) [Figures 7 and 8]. Defects on PD plot provide one of the most robust information on the presence of glaucomatous VF defects.

**Global indices**

**Mean deviation**

It reflects overall depression (deviation from normal values) of the field. This parameter provides a single quantitative value to the printout for easy interpretation. Normal mean deviation (MD) is within 0 dB to −2 dB. MD value becomes more negative as overall field worsens (cataract or worsening glaucoma). Its use in tracking changes to localized field loss (as in early glaucoma) is limited but can be helpful in tracking moderate to severe VF loss (−6 dB to −12 dB or higher) [Figure 8].

**Pattern standard deviation**

Pattern standard deviation (PSD) measures the extent to which the shape of patient’s measured field...
systematic interpretation of automated fields is important to diagnose glaucoma, differentiate it from neuro-ophthalmological disorders and monitor glaucoma progression.

A low PSD indicates a smooth hill of vision. A high PSD indicates an irregular hill and may be due either to variability in patient response or to actual field irregularities.

It best quantifies the amount of loss as well as any progression of glaucoma in the early stages (see ahead). PSD is not helpful in tracking advanced glaucomatous [Figure 9] defects once the depression in hill of vision becomes entirely due to glaucoma.

**Corrected pattern standard deviation**

When PSD is corrected for STF in full-threshold testing, corrected pattern standard deviation is generated. It is used as an attempt to better represent the surface of hill of vision by accounting for influence of STF. It is also not available in SITA test.

**Glucomatous Hemifield Test**

This software allows comparison of VF defects across the horizontal axis, i.e., five sectors in the upper field are compared to five mirror images in the lower.[11] The five important responses to look for are:

1. Within normal limits
2. Borderline: If difference between any one of upper and lower mirror zones is what might be expected in <3% of the population
3. Outside normal limits: If values between any sector in upper, and lower zone differ to an extent found in <1% of the normal population, or if anyone pair of sectors is depressed to the extent that would be expected in <0.5% of normal population[12]
4. Generalized reduction of sensitivity: When both conditions for “outside normal limits” are not met and the best part of the VF is depressed to an extent expected in <0.5% of the population
5. Abnormally high sensitivity - If the best 15% of the field exceeds expected values for 99.5% of normal population.

**The numeric scale**

It shows retinal sensitivities at different test locations, expressed in decibels. By concentrating on actual threshold values, one may pick up scotoma. The thresholds of upper and lower arcuate areas can be compared to find a clinical correlation.
Gaze Tracker

It is along the bottom of VF printout and monitor patient’s pupil during testing, and each time pupil moves (representing a loss of fixation or head alignment), an upstroke is recorded. When gaze tracker loses view of pupil (representing blink or droopy upper eyelid), a downstroke is recorded.

Once field defect is identified, one should determine whether it is due to glaucoma or not.

Criteria for Glaucomatos field defect (repeatable in at least two VFs)

(Hodapp-Anderson-Parrish criteria) [Figure 10][14]
1. Three or more nonedge points on PD plot that are depressed to the extent that would be found in 5% of population; one of those points should be depressed to an extent found expected in 1% of population
2. PSD should be depressed to an extent found in <5% of population
3. GHT outside normal limits.

If clinical features strongly indicate glaucoma (raised intraocular pressure (IOP) and suspicious disc with glaucomatos features), even a single criterion is enough to make a diagnosis. On the other hand, if clinical features are not suspicious at all, (normal IOP and healthy neuroretinal rims that maintain ISNT rule), all three criteria must be positive to consider glaucoma diagnosis.

Criteria for Glaucoma Progression

Once it is known that field defect is due to glaucoma, next step is to determine whether it is progressing. Two baseline fields must be available for comparison which are selected after completion of patient’s learning curve (Generally, it is after 3–4 fields in HFA).

Several factors may give false impression of progression which include long-term fluctuation, artifacts (present only in initial fields) and patient factors such as pupil size.

There are two main approaches to analyze progression:
1. Event-based analysis: It looks for defects on current examination that were not present on older one
2. Trend-based analysis: The change is observed as a trend in values plotted over time, and deterioration can be assessed by observing the slope of the regression line. It also helps to estimate the rate of progression. However, one main limitation of trend analysis is that more VFs are required before
Aggarwal, et al.: systematic interpretation of automated fields is important to diagnose glaucoma, differentiate it from neuro-ophthalmological disorders and monitor glaucoma progression.

Small open triangle ∆ – Identifies any test point that has worsened by an amount that exceeds the variability expected in all but the most variable 5% of glaucoma patients having similar VF status (P < 0.05). This symbol is used when the change was not seen on the previous follow-up test.

Half-filled triangle – Identifies a point changing by an amount that is significant at the P < 0.05 level and that is repeated in two consecutive follow-up exams.

Filled triangle ▲ – Identifies a point changing by an amount that is significant at the P < 0.05 level and that is repeated in three consecutive follow-up exams.

If significant change is detected in at least three points, and repeated in the same points for two consecutive follow-up testes, the software will flag the last exam as Possible Progression. If it is repeated in three consecutive follow-ups, it will flag it as likely progression.

Guided Progression Analysis

GPA print out [Figure 11] depicts two baseline fields at top while the most recent test is at bottom. In
middle, a trend plot called “VFI Plot” with linear regression analysis (when appropriate) is shown for all examinations included. The VFI Bar, a histogram that provides a graphical representation of patient’s current VFI value along with a 3–5-year projection of the VFI regression line. The slope of this line is plotted as a rate of change indicator. It allows differentiation of slow progressors that have a shallow, sloped trend line as compared to rapid progressors with a very steep slope trend line. VFI value is a summary measurement of patient’s VF status, expressed as a percentage of a normal age-adjusted VF for all points that have depressions in the PD at the 5% level or higher. Therefore, VFI assigns higher weightage to central test points than midperipheral test points. VFI Values range from 100% (normal) to 0% (perimetrically blind). The index is calculated by considering the PD for defects up to −20 dB and the TD for more advanced VF loss. It is reported to be less sensitive to cataracts and is more sensitive to central deficits in relation to MD. The percentage value can be tracked over a series of tests and used as one indicator for the rate of progression. A further advantage of VFI is that it provides an estimate of additional VF loss for up to 5 years, considering that the same rate of progression is maintained.

**Conclusion**

VF analysis forms a very significant tool for diagnosis of glaucoma and monitoring its progression. Systematic interpretation of the test is paramount for correct evaluation and avoidance of misdiagnosis. Careful analysis of perimetry result goes a long way in the proper treatment of glaucoma besides making the patient understand the stage of his disease and future progression.

**Acknowledgments**

We would like to thank Dr Balwant Rai Kalra for his immense support in preparation of this manuscript. We would also like to thank Dr Gursimran Singh Chahal for his technical support for the present review.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Advanced Glaucoma Intervention Study 2. Visual field test scoring and reliability. Ophthalmology 1994;101:1445-55.
2. Heijl A, Lindgren G, Olsson J. A package for the statistical analysis of computerized visual fields. Doc Ophthalmol 1987;49:153-68.
3. Bourne RR, Jahanbakhsh K, Boden C, Zangwill LM, Hoffmann EM, Medeiros FA, et al. Reproducibility of visual field end point criteria for standard automated perimetry, full-threshold, and Swedish interactive thresholding algorithm strategies: Diagnostic innovations in glaucoma study. Am J Ophthalmol 2007;144:908-13.
4. Budenz DL, Rhee P, Feuer WJ, McSoley J, Johnson CA, Anderson DR. Sensitivity and specificity of the Swedish interactive threshold algorithm for glaucomatous visual field defects. Ophthalmology 2002;109:1052-8.
5. Akar Y, Yilmaz A, Yucel I. Assessment of an effective visual field testing strategy for a normal pediatric population. Ophthalmologica 2008;222:329-33.
6. Roggen X, Herman K, Van Malderen L, Devos M, Spileers W. Different strategies for Humphrey automated perimetry: FASTPAC, SITA standard and SITA fast in normal subjects and glaucoma patients. Bull Soc Belge Ophthalmol 2001;279:23-33.
7. Yaqub M. Visual fields interpretation in glaucoma: A focus on static automated perimetry. Community Eye Health 2012;25:1-8.
8. Much JW, Liu C, Piltz-Seymour JR. Long-term survival of central visual field in end-stage glaucoma. Ophthalmology 2008;115:1162-6.
9. Thomas R, George R. Interpreting automated perimetry. Indian J Ophthalmol 2001;49:125-40.
10. Sample PA, Dannheim F, Artes PH, Dietzsch J, Henson D, Johnson CA, et al. Imaging and perimeter society standards and guidelines. Optom Vis Sci 2011;88:4-7.
11. Asman P, Heijl A. Glaucoma Hemifield Test. Automated visual field evaluation. Arch Ophthalmol 1992;110:812-9.
12. Bosworth CF, Sample PA, Johnson CA, Weinreb RN. Current practice with standard automated perimetry. Semin Ophthalmol 2000;15:172-81.
13. Heijl A, Krakau CE. A note of fixation during perimetry. Acta Ophthalmol (Copenh) 1977;55:854-61.
14. Hodapp E, Parrish RK, Anderson DR. Clinical Decisions in Glaucoma. St. Louis: The CV Mosby Company; 1993. p. 52-61.
15. Arnalich-Montiel F, Casas-Llera P, Muñoz-Negrete FJ, Rebolleda G. Performance of glaucoma progression analysis software in a glaucoma population. Graefes Arch Clin Exp Ophthalmol 2009;247:391-7.
16. Bengtsson B, Heijl A. A visual field index for calculation of glaucoma rate of progression. Am J Ophthalmol 2008;145:343-53.
17. Casas-Llera P, Rebolleda G, Muñoz-Negrete FJ, Arnalich-Montiel F, Pérez López M, Fernández-Buenaga R. Visual field index rate and event-based glaucoma progression analysis: Comparison in a glaucoma population. Br J Ophthalmol 2009;93:1576-9.