Automated Perimetry -- Interpreting the Data

Junaid. S. Wani, Mohd. Sajid Mir, A.R. Nasti

Visual field measurement is a critical component in the armament against potentially blinding diseases. The use in glaucoma is often discussed and well understood, however it has various other applications that render it useful in disease management and blindness prevention. These include the detection and/or management of conditions such as intraorbital lesions, afferent pupillary defect, papilledema, retinitis pigmentosa, cranial tumors and others.

Visual field measurement has undergone an evolution from the mechanical to the automated measurement process, resulting in greater accuracy, ease of use and greater depth of analysis.

The Humphreys visual field Analyser is most commonly used and will be the focus of this paper.

Concepts underlying Perimetry

Kinetic Perimetry

This technique is highly dependent on the operator efficiency as the examiner moves a target from an area where it is not visible to an area where it is visible. The target is of fixed size and brightness. The stimulus size, colour and brightness can be varied by the examiner. Threshold points are measured for each point tested and thereafter isopters are generated by connecting points of equal sensitivity. The disadvantages of this technique include the subjectivity, the reliance on examiner technique, the time consumed, the difficulties with randomising targets and patient cooperation. The measurement is approached in a horizontal manner as opposed to Static perimetry which utilises a vertical approach.

Static Perimetry

Discrete points along the island of vision or visual field are probed using a non-moving stimulus. The target is increased in brightness or size (usually brightness) until it is first seen by the patient, which indicates the threshold brightness for that point in the visual field. This strategy allows for a quantitative measure of the relative density of a defect, more easily than in kinetic perimetry. More testing strategies are available when static perimetry utilises a projection system since there is greater variability in the resolution and the stimulus size can be varied more readily.

Terminology related to Perimetry

Hill or island of Vision. Traquair’s apt comparison of the visual field to an island or hill of vision surrounded by a sea of blindness, depicts the visual field as a three-dimensional spatial model. The contour of the island represents various levels of retinal sensitivity, the narrowest peak the fovea (greatest sensitivity) while the outer borders correspond to the least sensitive areas in the peripheral field.

Threshold

Threshold is defined as the dimmest target perceived by the patient at a given discrete point; psychophysicists define the term as the ability to perceive a stimulus 50% of the time. The sensitivity of the eye varies from moment to moment and from day to day and this needs to be considered in the designing of visual field tests.

Isopter

A line within the visual field which connects points of equal sensitivity or threshold is defined as an isopter.

Brightness

Brightness is defined in terms of decibels (db) and apostibs (abs).

Decibels

Decibels can be thought of as a relative, logarithmic, unit of change in stimulus brightness. A decibel is one-tenth of a log unit.
decibels equals one log unit. Useful in measuring retinal sensitivity loss or difference in retinal sensitivity. Data needs to be captured on the same instrument for comparisons to be made as different values are used by various manufacturers.

Apostilbs: Bowl and target brightness is measured in apostilbs. One apostilb equals one lumen per square meter and a healthy patient can perceive a stimulus of 1 abs in the macular area. Background illumination for the Goldmann, Dicon, and Humphreys.

**Fixation methods** Fixation is central to the validity of a visual field. The ideal fixation device should move the stimuli with the movement of the eye, but at present this type of device is too costly to be practical. The following strategies are employed to ensure adequate fixation:
- Video monitoring of the eye
- The manual method which requires constant supervision of the patient during the test.
- Video camera with contrast monitor which is an objective method of monitoring pupil contrast.
- Heijl-Krakau blind spot monitoring technique which provides and index of the quality of patient fixation during an examination by periodically exposing stimuli in the blind spot.

**Normal Visual Field** The normal monocular visual field is a slightly irregular oval approximately 60 degrees inward (nasally) and upward (superiorly), 70 to 75 degrees downward (inferiorly) and up to 100 degrees outward (temporally). The visual field measurement can be affected by the patient’s age, size and position of the nose and orbital structures, location of eye within the orbit, colour of stimuli, refractive error, fixation and eye movement, and patient cooperation and ease of operation of the instrument.

**PRINCIPLES OF AUTOMATED VISUAL FIELD TESTING**

Given the significant dominance of the Humphrey Visual Field Analyser (HFA) in clinical practice, these concepts will be discussed in relation to this instrument. The basic principles are similar for other instruments such as the Dicon and the Octopus.

Unlike Goldman Perimetry that uses different size stimuli, the HFA uses the size III (0.42") target unless otherwise instructed. The stimulus is varied in intensity from 0.8 to 10 000 apostilb, a range of about 5 log units. The differential threshold is inversely related to the intensity of the stimulus and is recorded in decibels (dB). The background luminance is 31.5 abs and the testing distance 33 cm.

**Screening Strategies**

For threshold related, two zone, three-zone and quantify defects the four primary points in each quadrant are thresholded. The second most sensitive value is used to calculate the expected height of the hill of vision. This constitutes the central reference number which is used to then calculate the theoretical hill of vision. Targets are then presented 6d brighter than the theoretical hill of vision and if the point is not seen it is tested for a second time. Failure to detect the stimulus after it is presented for the second time will result in different strategies in the following approaches:

- **Two Zone** Points are presented the 6dB above the theoretical hill of vision level. Printouts display circles for seen stimuli and solid squares for unseen stimuli.
- **Three-zone**

  Those points that are not detected after being presented twice at the 6dB above the theoretical hill of vision level, are retested at the brightest level which is 10 000 abs. If the target is seen a circle is displayed, "x"s are indicated on the printout for a relative defect or a solid block if the target is not seen.

- **Quantify defects**

  The points missed twice at the 6dB brighter than the theoretical hill of vision level, are thresholded. The depth of the defect is recorded relative to the expected threshold at that location. Printouts display circles for seen stimuli, and numbers for defects.

  A value of 10dB means that the threshold is 10dB away from the theoretical hill of vision.

  This is derived at by:

  Expected Threshold - actual threshold

  20dB - 10dB = 10dB

**ANALYSIS OF THE PRINTOUT STATPAC**

Statpac provides immediate expert system analysis of visual field test results. It analyses test results at the time of examination, stores test results and can be analysed later. With this analytic package, the clinician can examine visual fields from up to 10 visits and assess whether the patient is recovering or losing field. Statpac includes the following features:

- **Using results from a single test it can point out suspicious areas that otherwise might not be evident until subsequent tests are done.**
- **Identify areas that look suspicious but which, in fact compare favourably with normals data.**
- **Using results from a series of tests, Statpac provides a highly sensitive and informative analysis of changes in the patient’s visual field over time.**

1. **Name, ID and Age**

   Ensure that this data is accurate. The correct age is essential as the patient is compared to age matched normals.

2. **Type of Test**

   This indicates whether the test was a threshold or screening test. Screening tests are a fast effective method to detect suspect areas in the visual field and indicate the need for further evaluation.

   Threshold tests determine the sensitivity at various points in the visual field and detect early changes in retinal sensitivity.

   The following table indicates screening tests and the points tested.

<table>
<thead>
<tr>
<th>Screening Test</th>
<th>Extent of Visual Field/Number of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central 40</td>
<td>30 degrees/40 points</td>
</tr>
<tr>
<td>Central 76</td>
<td>30 degrees/76 points</td>
</tr>
<tr>
<td>Central Armaly</td>
<td>30 degrees/84 points</td>
</tr>
<tr>
<td>Peripheral 60</td>
<td>30 to 60 degrees/60 points</td>
</tr>
<tr>
<td>Nasal step</td>
<td>50 degrees/14 points</td>
</tr>
<tr>
<td>Armaly full</td>
<td>50 degrees/98 points</td>
</tr>
<tr>
<td>Full Field 81</td>
<td>55 degrees/81 points</td>
</tr>
<tr>
<td>Full Field 120</td>
<td>55 degrees/120 points</td>
</tr>
</tbody>
</table>

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If a 30-2 is indicated then this means that the central 30 degrees of the field is tested with 76 points tested. The following table indicates the thresholds tests and the points tested:

<table>
<thead>
<tr>
<th>Threshold Test</th>
<th>Extent of Visual Field/Number of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-2</td>
<td>10 degrees/68 point grid</td>
</tr>
<tr>
<td>24-2</td>
<td>24 degrees/54 point grid</td>
</tr>
<tr>
<td>30-2</td>
<td>30 degrees/76 point grid</td>
</tr>
<tr>
<td>60-4</td>
<td>30 to 60 degrees/60 points</td>
</tr>
<tr>
<td>Nasal Step</td>
<td>50 degrees/14 points</td>
</tr>
</tbody>
</table>

3. Strategy
The options are full threshold, Fastpac, SITA-standard and SITA-fast.

Full threshold
A bracketing technique is used to threshold each test point. The stimulus is presented at a level the patient is expected to see. If seen, the intensity is decreased in 4 decibel steps (0.4 log units) until the patient no longer sees stimulus. If the stimulus is not seen the the instrument changes direction in 2dB steps until a change in patient response is made. The last stimulus seen is the threshold point for the patient.

FASTPAC
Fastpac decreases the threshold time by about 40% (Humphreys). It follows a similar stair-stepping technique as in Full Threshold, but uses 3dB increments instead of 4dB and crosses the threshold only once.

Swedish Interactive Thresholding Algorithm (SITA)
The Swedish interactive threshold algorithm (SITA) is a strategy that dramatically reduces test time. It is available as either SITA standard or SITA-fast.

The SITA strategy was intended to gather the same information as a full threshold field in much less time by calculating expected thresholds and begin testing close to the actual threshold value.

SITA utilises an alternative strategy to the bracketing method. Two likelihood functions are calculated for each test location, one based on the assumption that the test location is glaucomatous and the other based on the assumption that the location is normal. The likelihood functions are updated as the examination progresses. The updating is informed by a combination of patient responses and internal models of normality and glaucoma. Once the likelihood functions reaches a predetermined level of accuracy thresholds are recalculated according to model of the spatial interdependence between test locations and based on the recalculation of response windows from the responses obtained during the examination.

4. Rx Used
The clinician should ensure that the necessary calculations are made for the prescription needed. This can be done manually or the distance and near Rx entered and the field analyser then calculates the necessary Rx.

Ensure that the correct lenses are placed in the lens holder and the holder is appropriately located. Should it be too far from the eye then a false defect could be induced which is often a circular area of lost field located peripherally.

Use Trial lenses only for central tests (within 30°), or the central part of a full field test. For Peripheral test > 30 degrees, remove the lenses.

5. Pupil Diameter
While large pupils do not affect the results significantly, miotic pupils can induce a defect. The pupil should be at least 3mm to avoid false defects. Ensure that the repeat test is conducted at the similar pupil diameter as the previous test.

6. Reliability Indices
Patient cooperation and response determines the value of the visual field. Unreliable responses are monitored by the HVF and key indicators of reliability flagged. Should they be flagged (usually with XX) then the visual field cannot be used to draw clinical conclusions as this indicates a statistically significant error rate.

The clinician should take the appropriate steps to ensure compliance and reliability of the field. These include:
- Clear and unambiguous instructions
- Ensuring that the patient is comfortable
- Providing a pause in the test if the patient is tired
- Constantly monitoring the patient and providing encouragement and support
- Utilise the video eye monitor to observe and correct the patient.

Key indices:

Fluctuation:
The fluctuation test is an option that can be used with any threshold test. The threshold is measured twice at 10 pre-selected points. A fluctuation value is then determined by using the difference between the first and the second readings and indicates how the reliability of the patient responses. Fluctuation values outside the normal limits are flagged with p values, eg. P<0.01. Poor fluctuation values are a result of poor patient compliance or a sign of glaucomatous field loss.

Fixation losses:
This figure indicates whether the patient has maintained fixation on the fixation target. When the fixation monitoring test parameter is set to blind spot, a periodic checking of the blind spot area occurs during the test. This is done by projecting a stimulus in the blind spot area. The patient should not respond when the stimulus is projected into the blind spot area. If the patient indicates seeing the blind spot then the machine records a fixation loss. A high
The fixation loss score is indicative of poor fixation or that the blind spot was not correctly mapped out.

The printout shows the total number of fixation losses followed by the total number of stimuli presented within the blind spot eg. 2 out of 15 will be presented as 2/10. If fixation losses exceed 20% of those presented and is 4/15 then XX will be printed next to the numbers.

Consider replotting the blind spot or reinstructing the patient if the machine beeps after two failures within 5 presentations at the blind spot.

**False Positives**
This indicates a response in the absence of a stimuli and occurs when the patient pushes the button in anticipation of stimuli or is just plain trigger happy and pushes the button prior to the stimulus presentation. During the test at least one false positive trial occurs for every 30 points presented. The scores are flagged if errors exceed 33% of the trials.

**False Negatives**
Occasionally the HVF projects a stimulus at 9dB brighter than was seen earlier in testing. If the error exceeds 33% of the brighter stimuli presented then the scores are flagged with XX. If the patient misses the stimulus then it is recorded as one of the false positive errors. This may occur because of fatigue or lack of concentration or in the case of severe retinal disease.

**7. The numeric data**
This is data that expresses the patient’s test responses in decibels. The statpac software data analyses this info and gives it age adjusted significance and it is then that this information is really relevant and worth drawing conclusions from.

**8. The Grayscale**
The grayscale is a colour scheme of the visual loss. It is useful to provide an overview of the visual field loss but cannot be relied on by the clinician to make a definitive diagnosis of the extent of the visual field loss. Patients find the scale useful in understanding the extent of the visual field loss and the risks that they face.

**9. Total Deviation**
This is a comparison of the patients responses with that of known normal patients of their age and a representation of this relationship both in numbers and probability plots.

**10. Pattern Deviation**
Certain condition e.g. cataracts cause a generalised depression of the field of view and could mask underlying defects such as subtle changes secondary to glaucoma. The pattern deviation factors out the generalised depression that is commonly seen with cataracts, miotic pupils or an incorrect testing lens. It presents the data via a numeric and probability plot. The darker the symbol in the probability plot the more significant the deviation from the normal threshold.

**11. The Glaucoma Hemifield Test**
The GHT is based on the fact that glaucoma usually causes asymmetric field loss and not a generalised global depression.

The glaucoma hemifield test (GHT) evaluates five zones in the superior field and compares these zones to their mirror image zones in the inferior field. The GHT evaluates the severity of disturbed points in each zone and prints one of three messages below the graytone format:

- GHT within normal limits
Outside Normal limits
Borderline

The test is not available with tests using Fastpac.6

12. The Global Indices

The Statpac program makes calculations to assess the field results as a whole rather than the individual components. Four global indices are calculated. These include:

Mean Deviation(MD): weighted average of how much this patient’s overall function deviates from that of age-matched normals. It is a general barometer of overall field depression. A generalised depression causes a significant increase in the mean defect. A significant mean deviation may indicate that the patient has an overall depression, or that there is significant loss in one part of the field and not in others.

Pattern Standard Deviation(PSD): Is a measurement of the degree to which the shape of the patient’s measured field departs from the normal, age-corrected reference field. A low PSD indicates a smooth hill of vision, a high PSD indicates an irregular hill. PSD characterises localised changes in the visual field.

Short Term Fluctuation(SF): It is a measure of the consistency of the patient’s response during a test and is obtained by testing twice at ten pre-selected points. Points with reduced sensitivity have a broader range of fluctuation. The time involved to collect this data is considerable and adds very little to clinical meaningfulness. This calculation is deleted in the newer SITA algorithms.

Corrected Pattern Standard Deviation(CPSD): It is a measure of how much the total shape of the patient’s hill of vision deviates from the shape of the hill of vision normal for the patient’s age, corrected for intra-test variability (SF). The hill of vision may be irregular in shape because of unreliable patient responses or actual field losses. It is the most useful of the global indices.

For the MD, PSD, SF and CPSD it is not the numbers that are of real value but the indication of the statistical significance of them. If there is a very low probability of these data being normal, a probability percentage (ie. P<10%, P<5%, P<2%, P<0.5%) is printed beside each global index. P<10% indicates that there is a <10% chance of this being within the normal limits.8

Conclusion

HVF offers the clinician a very valuable tool to detect glaucomatous and other changes. However the full benefit for both the patient and clinician can only be derived if the various functions and facilities of the software is properly understood and utilised. This skill has become an absolute necessity for optometrists as optometrists are now playing a greater role in co-management of patients.

REFERENCES: