Understanding Visual Fields

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Objectives

- Understand principles and techniques of manual and automated perimetry
- Describe visual field interpretation
- Discuss measures of visual field reliability
- Describe methods of change analysis
Perimetry

• Purpose:
  – **Diagnosis**: Detection of defects in the peripheral vision for the diagnosis of glaucoma or other diseases of the visual system.
  – **Monitoring**: Periodic retesting helps determine if the disease is under control or if vision loss is progressing.
Perimetric Techniques

- Confrontation visual fields
  - Are not sensitive or reproducible
- Manual Kinetic Perimetry
  - Calibrated, standardized background and stimulus
  - Goldmann
Perimetric Techniques

• Automated Static Threshold Perimetry
  – Standardized testing strategy
  – Skill and experience of perimetrist is less important
  – Humphrey, Octopus, Dicon

Humphrey

Octopus
Manual Kinetic Perimetry

• Goldmann perimeter
  – Measures visual field using targets of different sizes and intensities
  – Patient puts chin in chinrest and forehead against strap facing a semicircular bowl
  – One eye is patched
  – Patient looks at central target (fixation)
Stimuli are brought inward from peripheral area of non-seeing to area of seeing along several meridians.
Points where the stimuli are first seen are plotted.
Multiple points are then connected to form an isopter.
Smaller or dimmer stimulus ⇒ smaller isopter

Multiple isopters and the blind spot are plotted
Manual Kinetic Perimetry

- Stimulus **size** is represented by Roman numerals (V=largest, I=smallest)
- Stimulus **intensity** (brightness) is represented by Arabic letters and numbers (4 is brightest category in 5 steps from e to a)
- Most commonly tested isopters: V4e, III4e, I4e, I3e, I2e usually drawn in standard colors
  - V4e, III4e and I4e are all the same intensity, progressively smaller size
  - I4e, I3e and I2e are all the same size, progressively dimmer intensity
The Visual Field

- Normal extent (monocular)
  - Nasal: 60°
  - Temporal: 100-110°
  - Inferior: 70-75°
  - Superior: 60°
Advantages

• Full extent of visual field is tested
• More patient friendly because it is given by a human and moves at a slower pace
• Often better for very old or very young patients
• Short learning curve
• Accurately maps the shape of defects
• Preferable in end-stage disease when only far peripheral vision remains
Manual Kinetic Perimetry
Goldmann

Disadvantages

• Requires highly trained perimetrist
• Perimetrist can significantly affect test results
  – Test object moved quickly ⇒ smaller isopter
• Less reproducible than automated perimetry
• More difficult to detect subtle changes
• No numeric data for comparison with normative database or previous examinations
Automated Perimetry

Humphrey Visual Field (HVF)

- Computerized automated perimetry
- Measures visual field with stationary test object that is increased in intensity from below threshold until perceived by the patient
- **Threshold** = light intensity at which stimulus can be seen 50% of the time
Automated Perimetry

- **Staircase Strategy:**
  - Retinal sensitivity at each point is tested by increasing the stimulus intensity in steps until the threshold is crossed (seen by patient) and then is recrossed to confirm

- Threshold values are displayed graphically
Automated Perimetry

Advantages

- **Standardized** and reproducible
- More **sensitive** for subtle defects
- **Numerical data** allows statistical interpretation and comparison
- Perimetrist requires less training and skill and has less influence on test results
Automated Perimetry

Disadvantages

- More challenging for patients
- Learning curve may make initial fields unreliable
- Higher retest variability, especially in areas of significant field loss
- Fixed test grid size
- Limited area of field is tested
Automated Perimetry

Testing Strategies

• **Standard Full Threshold**: Most accurate, but longest test time ⇒ patient fatigue ⇒ high variability

• **SITA**: Swedish Interactive Threshold Algorithm
SITA

- **SITA Standard** test time 50% shorter than Standard Full Threshold with similar or better reliability and reproducibility
- **SITA-Fast**
  - 30% of SITA-Standard test time
  - results slightly less precise/reproducible
- **SITA-Faster**
  - 30% of SITA-Fast test time
  - 50% of SITA-Std test time
  - Equivalent precision /reproducibility to SITA-Fast
  - Most tests completed in <3 minutes
  - Greatest reduction in test time in those with severe VF loss
Why it’s faster:

• Smarter questions
  – age, normal and abnormal databases and results of earlier tests are used to customize the exam for each patient
  – exam is adjusted during the test based on responses of the patient
  – patient’s response times are used to adjust pace of the test

• SITA Faster
  – False negative and Fixation catch trials eliminated
  – Fixation only monitored by gaze tracker
Automated Perimetry

• Threshold Tests
  – Humphrey 30-2 tests central 30° using a 6° grid with 76 test points 3° above and below the horizontal midline
  – Humphrey 24-2 tests central 24° except nasally, where test extends to 30°
    • Shortens test considerably
    • Eliminates the most variable points of the test
    • Most pathology occurs within this area
  – BEST TEST for glaucoma: 24-2 SITA Standard
Faster Visual Fields

- Less fatigue during testing may improve reliability of patient performance
- Easier for elderly, anxious, short attention span, physical infirmities, tremors
- Increase patient turnover: more VF tests performed per day
- Improved patient acceptance allows more frequent testing.

Minutes of test time per eye
Interpretation

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
5. Stable or progressive
Always examine the visual field printout systematically:

1. **Demographics**: Was the correct test done correctly on the correct patient?
2. **Technician reliability** - test artifacts
3. **Patient reliability**
4. **Is the field normal or abnormal?**

   - If abnormal, is the pattern consistent with glaucomatous field loss, neurologic loss or is it non-specific?
   - Is the pattern consistent with optic nerve and nerve fiber layer abnormalities?
   - Does it fit with the clinical picture?
5. **Is the field stable or progressive?**
   - Does this fit with the clinical picture?
     - IOP control
     - Optic disc exam
     - Nerve fiber layer measurement (OCT)
INTERPRETATION

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
5. Stable or progressive
1. Was the correct test done correctly on the correct patient?

- Name, ID
- Date of birth
- Test strategy
Interpretation

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
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**Technician Reliability**

- Correct patient information: name and age
- Correct test and strategy performed
- Correct eye tested
- Correct Rx and add
- Pupil size >2mm
- Visual acuity recorded
- Technician induced artifacts
• Longer tests show deeper and more extensive defects than shorter tests
• Caution when comparing tests of different strategies

Full Threshold 30-2
16:40

SITA Standard 30-2
7:10

Incorrect Test
OD test given to left eye. Blind spot located in **nasal** visual field
Incorrect Rx

Wrong Rx

Correct Rx
Incorrect Age

- Statistical analysis of data is compared to a normal database of patients of the same age

Birthdate 1937

Birthdate 1997
Miosis

- Apparent worsening due to change in pupil size

On Pilo, no dilation  Dilated
Lens Rim Artifact

- Abrupt change from normal sensitivity to sensitivity of zero in raw data plot
Ptosis

- Technician should be alert for ptosis that may affect visual field
Incorrect Fixation

- Patient maintains fixation on foveal threshold determination point after test has begun
  - Defects don’t respect horizontal
  - Blind spot is low
  - Upper field more depressed than expected
Interpretation

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
5. Stable or progressive
Patient Reliability

Patients
- are distractible and lose concentration
- fall asleep
- cheat
- want to please the doctor
- try to beat the test
- are nervous
- don’t really understand what they are supposed to do
Measures of Reliability

- Test duration
  - VF with inconsistent responses will increase the number of stimuli presented

- Foveal threshold
  - should correspond with visual acuity
Standard Reliability Parameters

- Fixation losses
- False positive rate
- False negative rate
- Low Reliability warning
  - FL >20%
  - FP >33% (>15%)
  - FN >33%
Fixation Losses

• A measure of how attentive the patient was in looking at the fixation target
Fixation Losses Measurement

• Perimetrist observation
  – telescope, periscope or video camera
• Blind spot method
• Gaze Tracker
Fixation Losses effects

- Difficulty in interpretation: Points that should have been seen are not seen and points that should not have been seen are seen
Fixation Losses
Blind Spot Method

• Initial stimuli are to locate blind spot
• 5% of remaining stimuli are at this location
  – response to these stimuli suggest blind spot has moved (fixation has been lost)
• Blind spot presentations are concentrated early in the test so perimetrist can correct problems
Fixation Losses
Blind Spot Method

• High fixation losses: causes
  – poor fixation OR
  – good fixation with:
    • head tilt or drift during test
    • multiple false positive responses
    • incomplete occlusion of nasal field of untested eye
    • incorrect location of blind spot
  – The perimetrist’s observation can detect the difference
Fixation Losses
Gaze Tracker

- Monitors location of corneal light reflex relative to the center of the pupil
- Depends on gaze direction, but not affected by head position
Fixation Losses
Gaze Tracker

• upward deflection = gaze deviation
• downward deflection = no signal (eye closed)
Fixation Losses
Gaze Tracker

- Fixation deterioration towards end of test: points tested last (edge points) are less reliable
Fixation Losses
Gaze Tracker

- Problems with gaze tracker are related to initialization (location of pupil and corneal light reflex)
  - perimetrist should stop and reinitialize
  - ptosis or miosis may make initialization difficult
- Newest testing strategy (SITA Faster) only uses gaze tracker to monitor fixation
Fixation Losses prevention

- Pre-test and post-test patient education
- Constant monitoring of head position, fixation, blind spot test and gaze tracker by perimetrist
- Relocate blind spot, reinitialize gaze tracker if needed
- Stop test to reinstruct patient if needed
False Positives

- Response made when no stimulus was presented
  - random
  - in expectation of a stimulus
  - in response to a non-visual cue
False Positives
Causes

- patient anxiety
- poor understanding of test
- desire to please clinician or improve test results
- “trigger happy”
  - response ASAP after stimulus
False Positives Measurement

- Standard Full Threshold
  - catch trials: machine makes noise in preparation to present a stimulus but does not
False Positives Measurement

- SITA
  - machine looks for false responses made before a stimulus, simultaneous with or too quickly after a stimulus
    - Responses outside patient’s own typical response window
  - calculated during post-test analysis of data
**False Positives**

**Results**

- VF will appear better than it really is
- white scotomas
- threshold values > 37-40
- MD high positive value
- GHT: abnormally high sensitivity
False Positives

Prevention

• Patient education
  – push button only when light is seen not when light is expected
  – responses should be slow and deliberate.
  – response does not need to be made during the stimulus or ASAP after the stimulus
  – normal patients will see only half the stimuli
    • Threshold = light intensity at which stimulus can be seen 50% of the time
False Negatives

• No response made when visible stimulus is presented (no response to retest with a brighter stimulus)
False Negatives

Causes

- fatigue
- poor attention / concentration
- pathology (visual field loss)
False Negatives Measurement

- Standard Full Threshold
  - catch trial: **maximum** intensity stimulus is presented at location where threshold has already been measured
  - thresholds in diseased areas of the field may be markedly inconsistent ⇔ inconsistency in whether a stimulus is visible ⇔ FN’s in a reliable patient
False Negatives Measurement

- **SITA**
  - a few catch trials are performed, only in normal areas of the field
  - FN’s also calculated: post test analysis of data determines what stimuli the patient should have been able to see based on their other responses
  - minimizes contribution of disease to the FN rate
  - Catch trials eliminated in SITA-Faster
False Negatives

Effects

- VF looks worse than it really is
- Randomly patchy defects, especially near edge points
False Negatives

Effects

- Cloverleaf field
  - Patient responds accurately to primary points in each quadrant early in the test, then becomes progressively less responsive as test proceeds
False Negatives prevention

• Perimetrist must be watchful for fatigue or inattentiveness
  – Encouragement, keep patient awake with conversation, rest breaks
• Patient instructed to pause test if tired
  – Hold button down and do not release
• Repeat test at a time when patient is better rested, after coffee
The inexperienced patient

- overall sensitivity is low
- central 10 degrees affected less
- edge point defects
- learning curve
INTERPRETATION

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
5. Stable or progressive
Raw Data

- Threshold sensitivity values in decibels
  - **Threshold** = light intensity at which stimulus can be seen 50% of the time
  - **Larger number** = greater sensitivity
  - **Zero** = no light perception

![Graph showing threshold sensitivity values with circled normal blindspot and paracentral scotoma.]
Grayscale

- Threshold values are assigned to 8 shades of gray
- Estimated sensitivity values are assigned to locations between tested points
Grayscale

• Helpful in identifying patterns of VF loss and abnormal locations
• May not highlight mild loss
• Two locations only 1dB apart may have different shade of gray
Total Deviation

- Difference from normal-for-age values at each test location
  - 0 = expected value
  - Negative number = worse than expected
- Probability plot shows statistical significance of each measured deviation
  - P<1%: fewer than 1% of reliable normal fields have this sensitivity value
Total Deviation

- Probability plot
  - Center-weighted: a peripheral point depressed by the same amount as a center point is less significant
  - calls attention to subtle abnormalities even when grayscale appears unremarkable
  - May indicate dark region on grayscale is not outside normal limits
Pattern Deviation

- Correction of the field for diffuse depression so that focal defects are highlighted
  - 7th most sensitive non-edge point is adjusted to zero deviation

Diffuse depression (cataract) with superior arcuate defect (glaucoma)
Global Indices

- Mean Deviation (MD):
  - the average difference of the patient’s responses from the age-matched normal values
  - Related to total deviation plot
  - Probability that an abnormal MD could occur in a normal person is listed (i.e. p<0.5%)
Global Indices

• Pattern Standard Deviation (PSD):
  – an indicator of the “roughness” of the hill of vision
  – describes the degree of focal deficit
  – is not related to the pattern deviation plot
**Global Indices**

- **Pattern Standard Deviation (PSD):**
  - small PSD = VF is normal or all points are equally abnormal
  - In advanced glaucoma, progression may cause the PSD to decrease as focal defects converge and become widespread loss
  - large PSD = localized loss
Global Indices

- Visual Field Index (VFI)
  - A numerical description of the visual field as percent of visual function
    - 100 = normal field
    - 0 = perimetrically blind field
Glaucoma Hemifield Test

- Compares zones in the superior hemifield with mirror-image zones in the inferior hemifield
- Zones approximate pattern of nerve fiber layer bundles in the retina
Glaucoma Hemifield Test

- Classifies field as
  - Within normal limits
  - Generalized reduction in sensitivity
  - Abnormally high sensitivity
  - Borderline
  - Outside normal limits

- Specific for glaucoma: does not apply to neurologic disease
If the field is abnormal, is it due to glaucoma or something else?
**Glaucomatous Loss**

- Respect for the horizontal midline
- Defects consistent with nerve fiber layer pattern
  - Arcuate defects
  - Nasal step
  - Temporal wedge
Non-GLAUCOMATOUS LOSS

- Respect for vertical midline (neurologic loss – stroke)
- Congruent defects
- Bitemporal loss (pituitary disease)
Non-Glaucomatous Loss

- Central scotomas (macular disease)
- Generalized depression (primarily cataract-- rarely due to glaucoma)
- Defects not consistent with optic nerve appearance
Interpretation

1. Demographics
2. Technician Reliability
3. Patient Reliability
4. Normal or Abnormal
5. Stable or progressive
Progression

• Accurate detection of visual field progression is important to determine if a patient’s glaucoma is adequately treated or whether therapy needs to be advanced

• Multiple obstacles make detection of progression by perimetry challenging
Progression

• Obstacles to detection of progression:
  – Visual sensitivity at each visual field location fluctuates
    • During a single test (short-term fluctuation)
    • Over repeat testing (long-term fluctuation)
  – Variation in measured threshold values are:
    • Physiologic and present in normal patients
    • Greater in magnitude in glaucoma patients
    • Higher in patients with more advanced field loss
Progression

- Thresholds at a given point in the field vary depending on
  - Distance from fixation
  - Severity of damage at that point
  - The testing algorithm used
- Variability also depends on
  - Patient experience with perimetry
  - Patient concentration or fatigue
- Variability can both mask and mimic glaucomatous change
Progression

• To identify glaucomatous visual field progression, the clinician must
  – Recognize if the patient’s performance is reliable
  – Detect changes that exceed the test-retest fluctuation (long-term or inter-test fluctuation)
  – Identify that the change is consistent with glaucoma
  – If possible, correlate this change with other clinical information
Progression

• **New** defects
• **Deepening or enlargement** of previous defects
• May include diffuse depression
  • Only a small minority of VF show diffuse loss in the absence of focal loss
  • With increasing damage there is an increasing component of diffuse glaucomatous loss

Chauhan et al Ophthalmology 1997
Progression

• OHTS study showed 86% of VF abnormalities were not confirmed on a second field (Arch Ophthalmol 2000)

• Suspected progression should be verified with repeat visual field testing to confirm findings
Progression

• Judgment of progression unaided by statistical analysis is inconsistent
  – expert observers show considerable disagreement about whether a given VF series is stable or progressing\(^1\)

• Modern automated perimeters offer multiple methods of analyzing visual field data and assisting with detection of progression

Overview Analysis

- Judgment of progression by comparing a chronologic series of fields
  - Evaluate overall trend: degree, nature and consistency of change
Overview Analysis

- Grayscale should be used only for identifying general patterns of field loss and calling attention to abnormal locations.
- It should not be used to judge progression:
  - 1 step difference on the gray scale may indicate only 1dB or up to 9 decibels difference in sensitivity.
**Change Analysis Plot**

- Global indices (MD, PSD) are also plotted over time
  - Significant downward slope can indicate **diffuse progression** (MD) or **focal progression** (PSD)
Test-Retest Variability

- Humphrey perimeters currently offer Glaucoma Progression Analysis (GPA) to assist in distinguishing true change from long-term fluctuation
  - Detects progression by evaluating whether patient performance has exceeded known limits of test-retest variability
The limits of test-retest variability were determined by repeatedly testing hundreds of stable glaucoma patients at all stages of the disease over a one month period.

GPA: Test locations are flagged as progressing if change from baseline is greater than the variability seen in 95% of patients at the same stage of the disease (p<.05)
Glaucoma Progression Analysis

• Current field pattern deviation plot values are compared with an average of 2 baseline fields
  – Using pattern deviation plot reduces effect of factors that cause diffuse change in visual field (cataract)
Glaucoma Progression Analysis

- Indicates significant deterioration from baseline at that point on the current VF and is expected <5% of the time in a stable patient (p<5%)
  - 2-3 open triangles can be expected by chance on a 76 point 30-2 test
- Indicates deterioration on 2 consecutive VF (p<5%)
- Indicates deterioration on 3 consecutive VF (p<5%)
Glaucoma Progression Analysis

\[ \textbf{X} \] indicates the data at that point was out of range for analysis

- The software cannot determine the significance of the change from baseline
- Occurs with field defects that were already deep at baseline
- Must compare raw data for these areas
Glaucoma Progression Analysis

- Plain language analysis
- Progression is defined as statistically significant change that is also repeatable and consistent
- "Possible Progression": Significant change seen in the same three or more points on two consecutive follow-up tests (2 or more half-filled triangles)
- "Likely Progression": Significant change seen in the same three or more points on three consecutive follow-up tests (3 or more filled triangles)
Glaucoma Progression Analysis

- Baseline tests are chosen automatically by the perimeter
  - Baseline for comparison is the average of the first two tests available
  - GPA identifies and excludes
    - Tests exhibiting learning effects
    - Tests with high false positive rates
  - Important to verify default baselines make sense
  - In a long term glaucoma patient with years of visual fields, the earliest tests may not be appropriate for comparison
Glaucoma Progression Analysis

- A new baseline should be established when
  - There is a significant change in course of therapy and the patient has been stabilized
  - The patient undergoes ocular surgery
  - The patient develops another ocular condition affecting vision
  - Learning effects are identified later
Glaucoma Progression Analysis

- Worsening of glaucoma should be based on all available clinical evidence
- Before changing therapy
  - Reconfirm baseline tests were appropriate and representative
  - Confirm follow-up tests were reliable
  - Consider etiologies other than glaucoma for the visual field change
Glaucoma Progression Index (GPI)

• Helps to estimate the rate of progression
  – Rate of progression was shown in one study to be the strongest risk factor for further progression. Nouri-Mahdavi et al IOVS 2004

  – GPI is expressed as VFI (% of visual function) plotted against patient age
    • Percentages used to help in staging functional loss: 100% = normal VF, 0% = perimetrically blind VF
Glaucoma Progression Index

- Rate of progression (VFI change per year) calculated and projected forward to estimate future loss.
Glaucoma Progression Index

- Age is used to emphasize the role of life expectancy in therapeutic considerations
  - A progression rate that might be acceptable at age 85 may not be acceptable at age 65
  - With data on both visual function and rate of progression, it can be estimated if the disease is progressing quickly enough to risk the patient’s quality of life in his lifetime
Glaucoma Progression Index

• Potential limitations:
  – Requires a large number of VF to be sufficiently predictive
  – GPI is not specific for glaucoma and will be sensitive to any disease that causes localized visual field defects

Caprioli AJO 2008
**Advanced Glaucoma**

- With advanced visual field loss, progression can be difficult to detect
  - Many points on the GPA will be “out of range”
  - Pattern deviation analysis is not reliable when MD is worse than -20 dB
    - Latest version of HFA does not display pattern deviation plots in severely depressed fields
- Consider:
  - 10-2 to follow central VF
  - Size V target to increase threshold values
  - Goldmann perimetry
Advanced Glaucoma

- Sensitivities are higher with larger size V stimulus and progression is more easily recognized
**Advanced Glaucoma**

- 10-2 test (10°) can help monitor a central island in a severely depressed field (size III or V)
Advanced Glaucoma

• 10-2 test should also be considered for monitoring for progression in patients with parafoveal scotomas.
  – 10-2 test has a more closely spaced grid in the central 10 degrees
  – Detects more progressing eyes with paracentral scotomas than does the 24-2¹

1. Park et al. Ophthalmology 2013
Advanced Glaucoma

- Goldmann perimetry can allow visual field monitoring for patients with sensitivities too low for automated perimetry
Summary

• The technician plays a significant role in determining accuracy of testing
• The technician must stay alert and carefully observe the patient and the perimeter during testing
• Patient education before and after testing can improve performance
• Visual fields should be interpreted in a systematic way to determine reliability of results
• A series of visual fields can be used to confirm stability or identify progression of disease
Summary

• Visual field results should be consistent with other clinical findings
• Causes of VF loss other than glaucoma should be ruled out
• New VF abnormalities require confirmation with subsequent exams
• Statistical software can identify possible progression and assist in distinguishing from fluctuation
• Detecting progression in advanced disease may require alternative methods
QUESTIONS?