Classification of Visual Field Abnormalities in the Ocular Hypertension Treatment Study

John L. Keltner, MD; Chris A. Johnson, PhD; Kimberly E. Cello, BSc; Mary A. Edwards, BSc; Shannan E. Bandermann, MA; Michael A. Kass, MD; Mae O. Gordon, PhD; for the Ocular Hypertension Treatment Study Group

Objectives: (1) To develop a classification system for visual field (VF) abnormalities, (2) to determine inter-reader and test-retest agreement, and (3) to determine the frequency of various VF defects in the Ocular Hypertension Treatment Study.

Methods: Follow-up VFs are performed every 6 months and are monitored for abnormality, indicated by a glaucoma hemifield test result or a corrected pattern SD outside the normal limits. As of January 1, 2002, 1636 patients had 2509 abnormal VFs. Three readers independently classified each hemifield using a classification system developed at the VF reading center. A subset (50%) of the abnormal VFs was reread to evaluate test-retest reader agreement. A mean deviation was calculated separately for the hemifields as an index to the severity of VF loss.

Main Outcome Measures: A 97% interreader hemifield agreement.

Results: The average hemifield classification agreement (between any 2 of 3 readers) for 5018 hemifields was 97% and 88% for the 1266 abnormal VFs that were reread (agreement between the first and second classifications). Glaucomatous patterns of loss (partial arcuate, paracentral, and nasal step defects) composed the majority of VF defects.

Conclusion: The Ocular Hypertension Treatment Study classification system has high reproducibility and provides a possible nomenclature for characterizing VF defects.

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the frequency, location, and shape of initial glaucoma-
tous visual field deficits.\textsuperscript{10-12,14} By using inclusion/ exclusion criteria that restrict the study sample to indi-
viduals with small, shallow visual field deficits, some
investigations have assumed that these visual field de-
fects represent early glaucomatous visual field loss.

Unlike other studies, the OHTS provides a unique
opportunity to examine the characteristics of initial glau-
comatous visual field loss in a longitudinal study. There
are many reports that use quantitative methods for de-
scribing progressive visual field loss. However, quanti-
tative methods may not capture information on the pat-
tern and location of visual field loss that may be more
helpful in tracking the progression of glaucoma.

To be eligible for the OHTS, each eye was required to
have 2 sets of normal and reliable visual fields at en-
try in addition to other eye-specific and patient-specific
eligibility criteria. Follow-up visual fields were then ob-
tained at 6-month intervals. The purpose of this report
was to characterize visual field defects in OHTS partici-
pants observed during follow-up. To accomplish this, it
was necessary to develop a classification system and to
use trained readers to perform these classifications with
high interreader agreement (agreement between read-
ers for a given reading) and high test-retest reader
agreement (agreement between the first and second
reading).

**METHODS**

The procedures employed by the OHTS and the baseline char-
acteristics of OHTS participants have been previously de-
scribed.\textsuperscript{2} Briefly, 1636 participants were randomized in the OHTS
at 22 participating clinical centers. To be eligible for the OHTS,
participants were required to have an intraocular pressure be-
tween 24 and 32 mm Hg in one eye and between 21 and 32
mm Hg in the fellow eye. Visual fields were performed using
Humphrey (Carl Zeiss Meditech, Dublin, Calif) 30-2 full
threshold, white-on-white, static perimetry. To meet visual field eligibil-
ity criteria, individuals completed a minimum of 2 and a
maximum of 3 visual field tests. Two of the 3 tests had to meet
reliability criteria of less than 33% false positives, less than 33%
fake negatives, and less than 33% fixation losses. Two of the 3
visual fields had to be judged normal by the visual field reading
center, requiring a STATPAC II (Carl Zeiss Meditech) global indi-
ces for corrected pattern SD (CPSD) within the 95% age-
specific population norm, and a glaucoma hemifield test re-
sult within the 97% age-specific population norm. The fields
had to be normal and reliable in both eyes on 2 examinations
as determined by the visual field reading center, and the optic
nerve heads had to be normal in both eyes on clinical exami-
nation and in stereoscopic optic disc photographs as deter-
mined by the optic disc reading center. Follow-up visual field
examinations were performed at 6-month intervals.

According to the OHTS protocol, an abnormal visual field
(abnormal from any cause) is defined as having a glaucoma hemi-
field test outside normal limits and/or a CPSD with $P<$.05. In add-
dition to the OHTS criteria for an abnormal visual field during
follow-up, a secondary definition for the abnormality of each hemi-
field was created by the visual field reading center to describe the
type and extent of the visual field defect. According to OHTS cri-
teria, one hemifield could be abnormal and the other could be
normal but still contain abnormal points. The secondary defini-
tion of abnormality is defined as: (1) having a single point that is
worse than the .05 probability level on the total and/or pattern
deviation plots; (2) 3 adjacent points (cluster) beyond normal limits
($P<.05$) and at least 1 point worse than the .01 probability
level on the total and/or pattern deviation plots (a cluster is de-
fined as $\geq$2 horizontally or vertically contiguous abnormal points
with $P<.05$); and (3) 3 or more clustered points worse than the
.05 probability level on the total and/or pattern deviation plot.
For all 3 classification evaluations, the pattern of loss has to be
consistent with ocular visual field abnormalities. Thus, for a hemi-
field to be classified as normal, it must not meet any of the afore-
mentioned criteria for hemifield abnormality.

The procedures for hemifield classification are as fol-
lows: (1) The superior and inferior hemifields of visual fields
that meet the OHTS abnormality criteria are evaluated sepa-
rately, with the superior hemifield being classified first. Hemi-
field classifications are separated by a slash. If a defect straddles
the horizontal midline, only a single designation is given and
no slash is presented. (2) In general, the pattern on the devia-
tion plot ("total" or "pattern") showing the greater number of
abnormal points is used to determine the appropriate classifi-
cation for a hemifield abnormality. However, the other devia-
tion plot as well as the gray scale are evaluated to confirm the
appropriateness of the classification. Abnormal points that are
extraneous to the salient pattern are considered less impor-
tant for the determination of the hemifield classification. Thus,
the most predominant pattern is classified.

Between February 28, 1994, and January 1, 2002, 38328
follow-up visual fields were evaluated in this report, which in-
cluded 2509 that met the OHTS criteria for abnormality (glau-
comatous and nonglaucomatous; reproducible and not
reproducible). Hemifields were not evaluated for the second-
ary definition of abnormality unless the visual field first met
the OHTS criteria for abnormality. Approximately 94% (2345/2509)
of the abnormal visual fields classified in this report were
reliable, and only 6% (164/2509) were unreliable.

In 1990, 2 of us (J.L.K. and C.A.J.) began characterizing
the types and severity of visual field defects in the Optic Neu-
ritis Treatment Trial (ONTT).\textsuperscript{23,24} As with ONTT, the authors
developed a classification system for the OHTS in 1997 to iden-
tify glaucomatous visual field abnormalities in patients with ocu-
lar hypertension. The categories included patterns of visual field
loss that were characteristic of glaucoma, patterns that were
characteristic of other ocular and neurologic diseases, and pat-
tens that were associated with testing artifacts. In the devel-
mental stages of the classification system, each of the read-
ers evaluated a subset of 120 abnormal visual fields. These fields
were subsequently included in the final set of the 2509 abnor-
mal fields. Each reader’s classification from this training set was
compared and discussed to refine and standardize the criteria
for developing the 17 mutually exclusive categories presented in
Table 1. Once a true collaboration of visual field classifi-
cations was established for the subset, the 2 experienced read-
ers trained a third visual field reader. To become a certified vi-
sual field reader, one must be able to earn a score of 80% or
better on (1) 10 questions related to the OHTS visual field clas-
sifications system and (2) a set of 200 previously classified ab-
normal fields. If the required score is not obtained on either
test on the first try, a second set of 10 questions and a second
set of 200 abnormal visual fields are given. Since the visual field
reading center is masked to the participant’s diagnosis, optic
disc characteristics, and randomization assignment, the clas-
sification of the visual field deficit is strictly based on the pat-
tern of visual field abnormality.

Following the training set, 2509 abnormal visual fields were
selected by querying the visual field reading center dataset for
visual fields that met the OHTS criteria for abnormality (ab-
normal glaucoma hemifield test and/or CPSD with $P<.05$). Each
of the readers classified the entire group of 2509 abnormal vi-
sual fields in groups of approximately 100. The hemifields were
Table 1. OHTS Classifications

<table>
<thead>
<tr>
<th>Nerve fiber bundle abnormalities</th>
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<tr>
<td>Altitudinal (Alt): Severe visual field loss throughout the entire superior or inferior hemifield that respects the horizontal midline. Most points in the hemifield have a P value of less than .05 on the total deviation plot. The horizontal midline demonstrates abnormality.</td>
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<tr>
<td>Accute (Arc): Significant visual field loss in the nerve fiber bundle region. Extends across contiguous abnormal points from the blind spot to at least 1 point outside 15° adjacent to the nasal meridian. Nasal Step (NS): Limited field loss adjacent to the nasal horizontal meridian. Includes at least 1 abnormal point at or outside 15° on the meridian. Cannot include more than 1 significant point (on either plot) in the nerve fiber bundle region on the temporal side.</td>
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<tr>
<td>Peripheral Rim (PR): Generally continuous visual field loss outside 15° in all 4 quadrants. Partial Peripheral Rim (PPR): Generally continuous field loss outside 15°.</td>
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<tr>
<td>Inferior Depression (ID): 2 or more abnormal points in the very inferior region. Paracentral (Pc): A relatively small visual field abnormality in the nerve fiber bundle region. Generally not contiguous with the blind spot or the nasal meridian. Does not involve points outside 15° that are adjacent to the nasal meridian.</td>
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<td>Hemianopia (H): A visual field defect that respects the vertical meridian. Includes at least 2 abnormal points at or outside 15° along the vertical meridian. Must include at least 1 abnormal location in the temporal visual field.</td>
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<tr>
<td>Total Loss (TL): Severe widespread visual field loss (MD &lt;−20.00 dB). Vertical Step (VS): Limited visual field loss that respects the vertical meridian. Includes at least 2 abnormal points at or outside 15° along the vertical meridian.</td>
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<tr>
<td>Widespread (Wsp): Diffuse visual field loss that includes all 4 quadrants. The corrected pattern SD must not show a value of less than .05 on the total deviation plot.</td>
<td></td>
</tr>
<tr>
<td>Altitudinal (Alt): Severe visual field loss throughout the entire superior or inferior hemifield that respects the horizontal midline. Most points in the hemifield have a P value of less than .05 on the total deviation plot.</td>
<td></td>
</tr>
<tr>
<td>Accute (Arc): Significant visual field loss in the nerve fiber bundle region. Extends across contiguous abnormal points from the blind spot to at least 1 point outside 15° adjacent to the nasal meridian. Nasal Step (NS): Limited field loss adjacent to the nasal horizontal meridian. Includes at least 1 abnormal point at or outside 15° on the meridian. Cannot include more than 1 significant point (on either plot) in the nerve fiber bundle region on the temporal side.</td>
<td></td>
</tr>
<tr>
<td>Peripheral Rim (PR): Generally continuous visual field loss outside 15° in all 4 quadrants. Usually no visual field loss inside 15° on either deviation plot. Must be visual field loss temporal to the blind spot.</td>
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<tr>
<td>Quadrant (Q): Significant visual field loss throughout an entire quadrant that respects the vertical and horizontal midlines. Essentially all points must have a P value of less than .05 on the total deviation plot.</td>
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<tr>
<td>Superior Depression (SD): Two or more abnormal points in the very superior region. Total Loss (TL): Severe widespread visual field loss (MD &lt;−20.00 dB). Vertical Step (VS): Limited visual field loss that respects the vertical meridian. Includes at least 2 abnormal points at or outside 15° along the vertical meridian.</td>
<td></td>
</tr>
<tr>
<td>Widespread (Wsp): Diffuse visual field loss that includes all 4 quadrants. The glaucoma hemifield test may show a general reduction of sensitivity or the mean deviation must show a P value of less than .05. The corrected pattern SD must not show a P value of less than .05.</td>
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<td>Most abnormal points on the total deviation plot are not abnormal on the pattern deviation plot.</td>
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Abbreviation: OHTS, Ocular Hypertension Treatment Study.
ample is shown to demonstrate the variation in severity for some classification categories.

To determine the extent of visual field loss associated with each of the visual field classifications, we calculated the mean deviation (MD) separately for the superior and inferior hemifields. This was accomplished by modifying a statistical analysis package previously developed for other purposes and referred to as Statpac-like Analysis for Glaucoma Evaluation. The analysis package was based on visual field data obtained from 348 normal control subjects between the ages of 18 and 85 years. The data were obtained from 5 North American sites (University of California–Davis, Sacramento; University of Cali-
RESULTS

Figure 4 shows the number and frequency of final classifications for the 5018 hemifields in the OHTS. Based strictly on the pattern of visual field loss, 57.7% (2893/5018) of the hemifields were judged to be typically glaucomatous, and 20.3% (1017/5018) were judged to be typically nonglaucomatous (possibly owing to other ocular abnormalities and/or testing artifacts). The most frequent hemifield classifications were those likely to be associated with glaucoma, including partial arcuate, paracentral, and nasal step defects. A total of 11.5% of the hemifield classifications were possibly associated with other ocular or neurologic abnormalities, such as widespread, central, and total loss, partial hemianopia, vertical step, and quadrant defects. A total of 8.8% of the hemifield classifications were likely to be associated with testing artifacts, such as partial peripheral rim, superior depression, inferior depression, and peripheral rim defects. Hemifields exhibiting advanced visual field loss were also classified. A total of 7.6% of the hemifield classifications included patterns indicative of advanced glaucomatous abnormalities.

Table 2 presents the interreader agreement for 5018 hemifields using our classification system prior to adjudication, with agreement between any 2 of the 3 possible readers at 97% for superior hemifields, and 97% for inferior hemifields. All 3 readers were in complete agreement on 66% of the superior hemifields and on 64% of the inferior hemifields.
To evaluate the agreement (2 of 3 readers) of visual field classifications, 50% (1266/2509) of the total number of abnormal visual fields were evaluated a second time. Table 3 presents the hemifield classification agreement, with the final classification following adjudication, as 88% for superior hemifields and 89% for inferior hemifields.

Figure 5 shows a box and whisker plot of the mean deviation values of the Ocular Hypertension Treatment Study combined hemifield abnormalities following final adjudication (mean/10th, 25th, 75th, and 90th percentiles). (Note: No hemianopic defects are shown here since there were none classified.)
Automated perimetry has become an accepted standard of practice, allowing physicians to monitor the development of glaucomatous visual field loss. Very few longitudinal studies of any size and magnitude involving the classification of abnormal glaucomatous visual fields have been conducted.

Previous investigators have developed classification systems to identify the pattern and severity of glaucomatous visual field loss. In general, they have looked at the pattern of visual field loss in a cross-sectional fashion, which has been used to predict future progressive glaucomatous visual field changes.

Recent glaucoma trials, such as the Glaucoma Laser Trial, Normal Tension Glaucoma Collaborative Study, Advanced Glaucoma Intervention Study, Collaborative Initial Glaucoma Treatment Study, and Early Manifest Glaucoma Trial, developed visual field analysis systems to determine if change and progression had taken place. Of these trials, none that used automated perimetric techniques attempted to classify the visual fields on a systematic basis to characterize the pattern, frequency, location, and shape of the initial glaucomatous field defects. To our knowledge, the OHTS is the first prospective, longitudinal study to examine the characteristics of the earliest glaucomatous field changes in a large group of participants with ocular hypertension. At baseline, all OHTS participants were required to have 2 sets of normal and reliable visual fields for each eye. In contrast with many of the previous glaucoma trials, a strict quality control system was developed to emphasize reliable visual field information using modern automated perimetric techniques. These OHTS participants have been studied longitudinally for more than 7 years, with a total of 38,328 follow-up visual field evaluations performed thus far, using the classification system described in this report.

Our findings indicate that a classification system for characterizing the pattern and extent of glaucomatous and other visual field abnormalities can be implemented with high system agreement and high system reproducibility when used by trained visual field readers. We have previously developed a similar visual field classification system for characterizing deficits associated with optic neuritis as part of the Optic Neuritis Treatment Trial. With more than 10 years of experience, the 2 visual field readers have created strict criteria for certification (a score ≥80% or better on 10 questions related to the OHTS visual field classifications system and on a set of 200 previously classified abnormal fields) and have successfully trained a third reader. A fourth visual field reader is currently being trained as a “back-up” reader. It is possible to obtain a high degree of consistency in classifying visual fields with this system when a criterion of agreement by 2 of 3 readers is employed. We obtained an average reader agreement of 97% for all hemifield classifications (Table 2); system reproducibility was also found to be very good at 88% for superior hemifield agreement and 89% for inferior hemifield agreement (Table 3).

There are current limitations in using this classification system. This system has not been evaluated using the 24-2 standard test pattern or the Swedish Interactive Testing Algorithm test patterns. The sample of visual field abnormalities detected in the OHTS at this time contains few visual fields with advanced glaucomatous changes. Only 7.6% (381/5018) of the hemifields show advanced glaucomatous visual field loss. Nevertheless, given these limitations, the principles could apply with our classification definitions and procedures in classifying future patterns of visual field changes while using various testing parameters.

The most common classifications observed in this report were those likely to be associated with early glaucomatous damage, such as partial arcuate (21.7%), paracentral (15.6%), and nasal step (10.6%) defects (Figure 4). Although the frequency and type of glaucomatous defects have been previously reported by other studies, they have been based on cross-sectional data obtained from participants with existing visual field loss. Since the OHTS participants began the study with normal visual fields and were followed up longitudinally at 6-month intervals, the results from this study clearly represent early glaucomatous visual field loss.

A number of visual field abnormalities are related to other medical conditions, such as partial hemianopia (0.8%) and quadrant (0.1%) defects. Altitudinal defects (0.7%) could be related to glaucoma, anterior ischemic optic neuropathy, or other optic neuropathies. Additional visual field abnormalities, such as central loss (1.2%) and diffuse widespread loss (7.8%) could be related to macular degeneration and cataracts, respectively, or other retinal abnormalities. The paracentral scotoma (15.6%) is a common abnormality and could represent early glaucoma, noise in the testing system, or other abnormalities (Figure 4).

Approximately 9% (437/5018) of the total number of hemifields examined in this report were likely to be associated with testing artifacts: superior depression and inferior depression (2.9%) and partial and total peripheral rim (5.9%) (Figure 4). This represents only 0.6% (437/76656) of the total number of hemifields (as of January 1, 2002) associated with testing artifacts, signifying a remarkably low percentage of artifactual test results in OHTS follow-up visual fields. We have previously reported that reliability indices (false positives, false negatives, and fixation losses) have also been very low for the OHTS, with an unreliability rate of only 3%. Our current findings are consistent with the prior results and suggest that the use of a standardized protocol, training and certification of technicians, and ongoing quality control assessment of all visual fields make it possible to obtain quality visual field data with low unreliability rates.

The OHTS outcome information can be found in recently published articles by Kass et al and Gordon et al that report whether topical ocular hypotensive medication delays or prevents the onset of POAG and what baseline factors predict the onset of POAG in the OHTS. The present report serves as a baseline for the OHTS classification system. Now that the OHTS findings have become available, we will begin to analyze these data.

The classification system that we have developed for the OHTS has been used to characterize the pattern and extent of visual field defects observed in visual fields clas-
sified as abnormal according to the study protocol. It is important to remember that not all abnormal visual fields in this article reflect visual field defects attributable to glaucoma; they only demonstrate patterns of visual field loss. Future articles will examine this relationship. The most current sample of abnormal hemifields in OHTS predominantly reflects early damage, since only 7.6% of the hemifields reflected advanced damage. Further follow-up will define the classifications for advanced glaucomatous visual field loss. As the OHTS continues, we will report longitudinal glaucomatous changes and determine the pattern of progressive visual field loss. The ability of this classification system to provide alternative methods of tracking visual field progression is yet to be determined and will be evaluated in future reports.

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Corresponding author and reprints: John L. Keltner, MD, Department of Ophthalmology, University of California—Davis, 4860 “Y” St, Suite 2400, Sacramento, CA 95817 (e-mail: jl_keltner@ucdavis.edu).

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forms). Third, potential study subjects with significant opacification of the anterior chamber or without light perception were excluded from the EVS. Because these eyes with more severe infection or involving more virulent organisms were excluded from the EVS, the effect might have shifted the EVS outcomes to more favorable results. Although the EVS provides general guidelines, the clinician ultimately must decide on the best treatment strategy for the individual patient.

In summary, the EVS has had a significant effect on the management of patients with acute-onset endophthalmitis following cataract surgery and secondary intraocular lens implantation, as well as on the cost associated with management of this disease. Most patients are treated in an office setting with vitreous tap and intravitreal antibiotic injection rather than in the operating room with pars plana vitrectomy, and most are managed as outpatients without intravenous administration of antibiotics.

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Correspondence: Harry W. Flynn Jr, MD, Department of Ophthalmology, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, 900 NW 17th St, Miami, FL 33136 (hflynn@med.miami.edu).

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Correction

Error in “Methods” Section. In the Clinical Sciences article titled “Classification of Visual Field Abnormalities in the Ocular Hypertension Treatment Study” published in the May 2003 issue of the Archives (2003;121[5]:643-650), on page 644, second column, line 1, the incorrect published statement reads “(2) 3 adjacent points (cluster) beyond normal limits (P<.05) and at least 1 point worse than the .01 probability level on the total and/or pattern deviation plots (a cluster is defined as ≥2 horizontally or vertically contiguous abnormal points with P<.03); and...” The statement should read “(2) 2 adjacent points (cluster) beyond normal limits (P<.05) and at least 1 point worse than the .01 probability level on the total and/or pattern deviation plots (a cluster is defined as ≥2 horizontally or vertically contiguous abnormal points with P<.05) and...”