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Patterns of Binocular Visual Field Loss Derived from Large-Scale Patient Data from Glaucoma Clinics

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Purpose: To estimate prevalence of visual field (VF) loss in superior and inferior hemifields in binocular VFs in a large sample of patients with bilateral glaucoma.

Design: Retrospective cohort study.

Participants: Glaucoma patients and suspects attending 4 regionally different secondary-care eye clinics in the United Kingdom.

Methods: Binocular integrated visual fields (IVFs) using a best location method were constructed for 16 642 patients with bilateral VF loss. A significant VF defect was defined as 3 or more VF locations less than a certain sensitivity threshold, such as 20 dB. Patients were classified as having a VF defect in the inferior hemifield, superior hemifield, both hemifields, or neither hemifield. The criteria for number of locations and sensitivity threshold (in decibels) were varied across a large range of values. In addition, factor analysis was applied to the sensitivity values (in decibels) of the IVFs to determine common defect patterns in an automated fashion.

Main Outcome Measures: Ratio of patients with binocular VF defects in the superior compared with the inferior areas of the IVF.

Results: Estimates of the ratio of patients having binocular VF defects in the superior compared with the inferior region of the IVF ranged from 2.1 (95% confidence interval, 2.1–2.4) to as high as 5.1 (95% confidence interval, 4.7–5.5), depending on the defect criteria used. Fewer than 10% of those patients exhibiting relatively early binocular VF loss had a defect confined to the inferior region only. Common patterns of binocular VF loss were dominated chiefly by superior hemifield defects.

Conclusions: In a clinical population of patients with measurable VF loss in both eyes, superior-only binocular VF loss is more common than inferior-only loss. These estimates, derived from large collections of electronic medical records, are useful for interpreting findings about location of binocular VF loss impacting everyday activities and examining visual disability in glaucoma. *Ophthalmology 2015;122:2399-2406 © 2015 by the American Academy of Ophthalmology.*

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Glaucoma causes progressive visual field (VF) loss resulting in loss of visual function. As VF loss worsens, it impacts directly on many aspects of a patient's daily life, including problems with mobility,[1–3] driving,[4–8] reading,[3,9,10] visual search,[11] and face recognition.[12] Advanced binocular VF loss certainly is associated with worse self-reported vision-related quality of life.[13–15] Impact of VF loss not only depends on its severity, but also likely on its location. Measures of vision-related quality of life have been found to be affected more by defects in the inferior hemifield compared with those in the superior hemifield, both binocularly[2,16] and monocularly.[17,18] Some studies have indicated inferior VF loss to be associated with risk of falling[2,19] and other aspects of mobility like reaching and grasping objects.[20] Cheng et al,[21] using binocular integrated VFs, recently reported interesting associations between hemifield regions of VF loss and self-reported vision-related quality of life. Specifically, superior hemifield VF loss interferes with near activities like reading, whereas inferior hemifield VF loss impacts vision-specific roles and peripheral vision used in mobility. More recently, superior VF loss was demonstrated to have a greater impact on hazard detection in a computer-based driving task when compared with inferior VF loss.[22] Conversely, another study indicated inferior VF loss to have a greater association with being involved in a motor vehicle accident when compared with superior VF loss.[23]

Given this recent debate about the importance of the location of VF damage in its impact on visual function, it is surprising that, to our knowledge, there has been no study of the prevalence of binocular superior and inferior VF defects in clinical practice. In the clinic, only monocular VFs are examined to monitor disease progression, whereas the binocular VF is critical to real-world function.[24] Previous studies have shown that in monocular VFs, superior defects are more common than inferior defects,[25–27]

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particularly in the superior paracentral and nasal area[28–30]; one study suggests that superior defects are approximately twice as common for early stage glaucoma.[31] Many of these studies were published more than 30 years ago and not all used automated perimetry, for example.

The primary objective of this study was to estimate the relative proportion of clinic-based patients with bilateral glaucoma who have superior-only and inferior-only binocular VF defects. Although common patterns of monocular VF loss have been established,[32–36] to date there has been no research into the features of glaucomatous defects in binocular VFs, and we explored this as a secondary objective.

Methods

In this study, we analyzed Medisoft VF databases (Medisoft Ltd, Leeds, UK; available at: www.medisoft.co.uk) containing 473 252 VFs from 88 954 patients recorded at 4 regionally different glaucoma centers in the United Kingdom. These data are described in detail elsewhere.[37,38] All patient data were anonymized and transferred to a single secure database. No other clinical data were made available apart from patient's age and the dates of the VF examinations. Subsequent analyses of the data were approved by a research ethics committee of City University London, and this study adhered to the Declaration of Helsinki. Only patients older than 40 years tested with the Humphrey Field Analyzer (Carl Zeiss Meditec, Dublin, CA) using the 24-2 test pattern with Goldmann size III target and the Swedish interactive testing algorithm (standard or fast protocol) were selected for inclusion.

We defined the study population as patients with measurable VF loss in both eyes at their most recent clinical visit. Humphrey Field Analyzer mean deviation (MD) was used as a surrogate for measurable VF loss. (Mean deviation is a standard measure of the overall severity of VF loss, relative to healthy age-matched observers, with more negative values indicating greater VF loss.) Patients were included only if they had VFs with an MD flagged as outside the 95% normative limits by the Humphrey Field Analyzer VF analysis software.[39] This criterion had to be satisfied for at least 2 examinations at the clinic to improve the likelihood of an individual having bilateral glaucomatous VF loss, in the absence of any other clinical information. We assumed VF loss was the result of glaucoma and not from other optic neuropathies. The latter cannot be ruled out, but it is safe to say that the vast majority of patients included will have bilateral glaucoma. The software written to filter the data also produced Humphrey Field Analyzer grayscales, and these were inspected to remove a few records that were from patients with homonymous hemianopic VF loss (where VF loss obviously respected the vertical meridians). After applying all exclusion criteria, 16 642 patients remained for examination. This attrition of patient records, given the initial size of the database, simply reflects that many of the recorded VFs are from sequences of follow-ups or are individuals who are glaucoma suspects or had unilateral glaucoma.

The binocular VF was constructed for each patient using the integrated visual field (IVF) method. This was calculated by comparing each patient's most recently recorded monocular VFs and taking the higher sensitivity at each test location.[40,41] This method has been shown to give measurements that correlate well with true binocular testing[40–43] as well as patient-reported measures of visual function.[44]

Each IVF was categorized as having a significant defect in the superior or inferior hemifield and then allocated into 1 of 4 categories: superior loss only, inferior loss only, no loss in either hemifield, or loss in both hemifields. A significant defect was estimated by having a prespecified number of test locations below a specific cutoff threshold (sensitivity, measured in decibels). Hence, for each patient, every individual IVF location was converted into a binary no defect or defect value in relation to a threshold value, such as 20 dB. A single (superior or inferior) hemifield was defined as defective if there were more than 3 defective locations, and the difference between the numbers of defective locations in each hemifield was 3 or more (Fig 1). The decibel threshold and the criterion of 3 defective locations were varied to cover a range of sensitive and conservative definitions of VF loss. To summarize findings, results at thresholds of 20 dB and 10 dB are highlighted because these values represent unequivocal VF defects. The former is approximately 10 dB less than a normal sensitivity value, whereas the latter is equivalent to a value that is used in Binocular Esterman VF testing.[43] All analyses were automated and carried out using custom-written code in Python Language Reference version 3.4 (Python Software Foundation, Available at http://www.python.org).

In a second analysis of the data, common features, or patterns, of binocular VF loss were extracted by performing factor analysis on IVF raw sensitivity data (in decibels). Factor analysis takes into account the relationship between the test locations and creates variables (called *factors*) that identify clusters of test locations related by the sensitivity value. The data are processed as a series of vectors each containing 16 642 separate decibel values with 1 vector for each IVF location. A varimax rotation is a statistical procedure used in factor analysis to identify a parsimonious combination of factors that best explain the associations in the data. In short, this procedure was used to yield clusters of IVF locations automatically that are most likely related by their sensitivity (in decibels). This analysis was implemented in MATLAB software version R2014b (The MathWorks, Inc, Natick, MA).

Results

The median age of the 16 642 patients was 74 years (interquartile range, 65–82 years). Median MD in the better eye (where the better eye refers to the eye with better MD) and the worse eye was −4.9 dB (interquartile range, −8.5 to −3.2 dB) and −9.5 dB (interquartile range, −16.1 to −5.6 dB), respectively. The distribution of mean IVF sensitivity and VF loss in the better eye is shown in Figure 2. Figure 3 (available at www.aaojournal.org) gives the distributions of VF sensitivities values at each test location for all patients.

The relative prevalence of superior-only and inferior-only binocular VF defects across the full range of defect threshold (1–30 dB) and using a 3-defective location definition is shown in Figure 4. The relative proportion of superior-only and inferior-only patients stayed approximately consistent across varying definitions of defect size (from 2 to 5 defective locations). (See Figs 5–7 for 2, 4, and 5 defective locations, available at www.aaojournal.org.) The prevalence of patients with VF loss in both hemifields was inversely proportional to the prevalence of those with VF loss in neither hemifield. The latter increased in number as the criteria defining the depth of defect was relaxed (i.e., the decibel threshold was lowered). Patients with inferior-only VF loss (Fig 4, yellow area) accounted for only a