COMPARISON OF CONTRAST SENSITIVITY, VISUAL ACUITY, AND HUMPHREY VISUAL FIELD TESTING IN PATIENTS WITH GLAUCOMA*

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ABSTRACT

Purpose: To investigate the relationship between large-letter contrast sensitivity, high-contrast visual acuity, and visual field defects in patients with glaucoma.

Methods: Patients with a diagnosis of glaucoma, glaucoma suspect, or ocular hypertension whose visual acuity was 20/40 (logMAR = 0.3) or better were included in the study. Visual acuity was measured using the Lighthouse visual acuity charts. Contrast sensitivity was measured using the Pelli-Robson (PR) chart. The mean depression (MD) score from the most recent Humphrey visual field was used to quantify the visual field defect.

Results: A total of 120 eyes were studied. The PR contrast sensitivity score correlated more strongly with the MD of the visual field (r = .589, P < .001) than did the logMAR visual acuity (r =.193, P=.035). When just the eyes with open-angle glaucoma were considered (N=54), the correlation was even greater for the PR score (r =.638). In ocular hypertensive eyes (N=25), the correlations to PR and logMAR were not that different (r =.394 for PR, r =.303 for logMAR). Pseudophakic eyes did not show as strong a correlation (r =.335) as did phakic eyes (r =.591).

Conclusion: For glaucomatous eyes with visual acuity of 20/40 or better, a decrease in the contrast sensitivity correlates with increased visual field loss. We speculate that this decrease in contrast sensitivity in glaucoma patients may account for their complaints of poor vision despite normal or near normal visual acuity.

Tr Am Ophth Soc 2001;99:213-218

INTRODUCTION

It has been well demonstrated that contrast sensitivity in visual function is affected in glaucoma.[1-3] Numerous reports have indicated that contrast sensitivity does seem to be selectively affected by the glaucoma process to a greater extent than is Snellen (high contrast) visual acuity. However, most of these studies have concentrated on investigations as to whether it would be possible to detect glaucoma in patients with various contrast sensitivity tests prior to visual field damage.[4] We have been impressed that some of the functional complaints of some of our glaucoma patients might represent manifestations of their loss of contrast sensitivity, and we wanted to try to quantitate this loss related to their glaucoma damage. To this end, we began a preliminary study in which we obtained contrast sensitivity measurements by use of the Pelli-Robson chart[5] and related these findings to visual field performance on the Humphrey visual field analyzer.

METHODS

Patients with the diagnosis of glaucoma, suspected glaucoma, or ocular hypertension were studied. Patients were diagnosed as having glaucoma if they had characteristic visual field loss and optic nerve head changes; as suspected of having glaucoma if they had suspicious optic nerve head changes, but not characteristic visual field loss; and as having ocular hypertension if they had intraocular pressure (IOP) greater than 21 mm Hg but no definite visual field loss or optic nerve head changes. Only patients whose best corrected Snellen visual acuity on a projected office chart was 20/40 or better were included.

Best corrected visual acuity of the patients was remeasured using a back-illuminated Lighthouse visual acuity chart at 4 m (Fig 1). Acuity measured was reported using the logMAR scale. The contrast sensitivity was measured using the Pelli-Robson chart in a front-illuminated box so that the illumination of the chart was standardized. The Pelli-Robson chart consists of opto types 20/60 in size, whose size remained constant throughout but whose contrast decreased both across and down the chart (Fig 2). The visual fields of the patients were plotted using the 24-2 program on the Humphrey visual field analyzer.

Regression analysis programs were used to compare the logMAR visual acuity scores with the Pelli-Robson scores, and each of these scores with the mean deviation score from the Humphrey visual fields. These analyses were performed for all patients. We arbitrarily decided to analyze left eyes only because of the problems with using

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both eyes of the same patient. Multivariant analysis was also performed with consideration of factors such as age, race, and lens status. In addition, the results of the visual acuity and the contrast sensitivity tests were compared with those of a group of age-matched normal patients who had had these tests performed on the same equipment as part of a separate study. However, visual field tests were not performed for these patients.

RESULTS

A total of 120 patients were analyzed: 54 had open-angle glaucoma, 14 had suspected glaucoma, and 25 had ocular hypertension; the remainder had other forms of glaucoma. The mean age was 61.72 ± 12.67 years. The male-female ratio was almost equal. Sixty-seven patients were white, 41 were black, and 12 were Asian or Hispanic. There was a significant correlation between the mean deviation on the Humphrey perimeter and the contrast sensitivity score on the Pelli-Robson charts (Fig 3). For the left eyes of all the patients in the study, this correlation was 0.589 with a *P* value of less than .001. In contrast, the correlation between the mean deviation on the Humphrey visual field and the logMAR visual acuity was 0.193 (Fig 4). In patients with chronic open-angle glaucoma, the correlation between the visual field deviation and the Pelli-Robson score was 0.638 with a *P* value of less than .001 (Fig 5). For the logMAR visual acuity, the correlation was 0.266 and *P* value was 0.054 (Fig 6). In contrast, the correlation of ocular hypertensive patients was 0.394 for the Pelli-Robson score (Fig 7) and 0.303 for the logMAR visual acuity (Fig 8). Correlations were calculated for phakic and aphakic eyes. In phakic eyes, the correlation was 0.591 (n=105) (Fig 9), while in pseudophakic eyes, it was 0.335 (n=15) (Fig 10).

DISCUSSION

Contrast describes the difference in the average luminance between 2 visible areas. *Contrast sensitivity* is the measure of the ability to detect a difference in the luminance between 2 areas. If the 2 areas are adjacent to each other, the ability to detect a difference in luminance is called *spatial contrast sensitivity*. If the areas occur sequentially in time, the ability to detect a difference in luminance is called *temporal contrast sensitivity*.

The effects of glaucoma on both types of contrast sensitivity have been studied with use of a large number of different tests.[1-4] The Pelli-Robson chart represents a low-tech, reasonably available method of measuring spatial contrast sensitivity that is compatible with clinical practice. It has been shown to yield reliable, reproducible results.[6] Accordingly, we chose to use this fairly quick and inexpensive test to study our glaucoma patients to see what we could learn about the association of contrast sensitivity measurement and visual field loss. To minimize other variables such as cataracts and possible intercurrent ocular conditions (eg, diabetic retinopathy, age-related maculopathy), we chose to limit our test population to individuals with visual acuity of 20/40 or better as measured in the office. The patients were then retested using the Lighthouse visual acuity charts and the Pelli-Robson charts in a standardized fashion with controlled illumination.

We were uncertain which visual field measurement should be studied. We assumed that diffuse ganglion cell damage should affect contrast sensitivity more than focal damage, so we chose to use the mean deviation as the indication of visual field damage rather than number or location of depressed test spots.

As we expected, there was a correlation between increasing visual field deficit and decreased contrast sensitivity. This was much greater than the correlation between logMAR visual acuity level and field loss. These findings, however, were somewhat limited by the fact that there were relatively few patients with even moderately advanced visual field deficits. As we test more patients with more advanced field defects but still good visual acuity, we feel that this correlation will show up even better.

We find it interesting that the correlation in the ocular hypertensive group was much less strong than in the open-angle glaucoma population. There are several possible explanations. First, the number of patients is relatively small. Second, it may be that some of these ocular hypertensive patients are just that and do not have any glaucoma damage. It would be interesting to try to identify patients who do seem to show a decreased Pelli-Robson score and to observe them prospectively to determine whether they are more likely over time to develop visual field loss than are ocular hypertensive individuals who have normal scores.

One somewhat unexpected finding is the difference between the phakic and pseudophakic individuals. It may be that some haze on the posterior capsule or some optical elements of the intraocular lens itself may negatively affect contrast sensitivity. In one study of the effects of cataracts on Pelli-Robson scores,[7] posterior subcapsular cataracts had the greatest impact. We did not assess the status of the posterior capsule in our pseudophakic patients. If it is the intraocular lens itself that is responsible for this finding, then this will have to be factored in when we study pseudophakic individuals in the future. On the other hand, the number of pseudophakic patients is small. We need to study more pseudophakic eyes to see if this difference persists.

We have been impressed clinically that many patients with more advanced glaucoma frequently complain of hazy or misty vision even though they are able to read 20/30 or 20/40 on the Snellen chart in the office. We

FIGURE 1
Back-illuminated Lighthouse visual acuity chart.

FIGURE 2
Pelli-Robson chart.

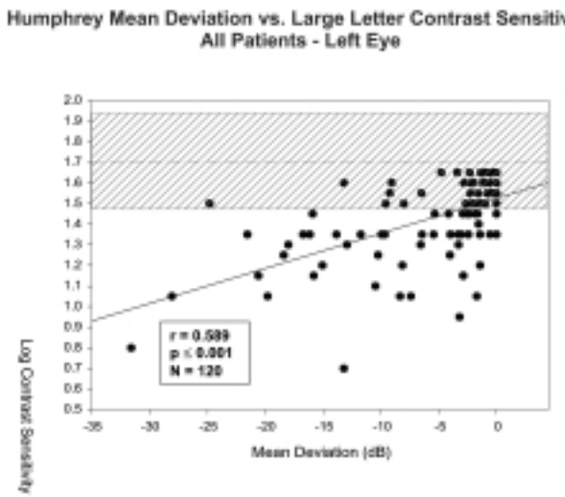

FIGURE 3
Correlation between mean deviation on Humphrey perimeter and contrast sensitivity score on Pelli-Robson chart in all patients.

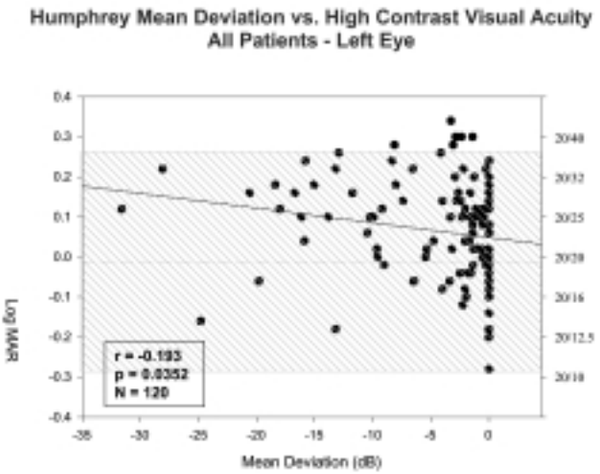

FIGURE 4
Correlation between mean deviation on Humphrey visual field and logMAR visual acuity in all patients.

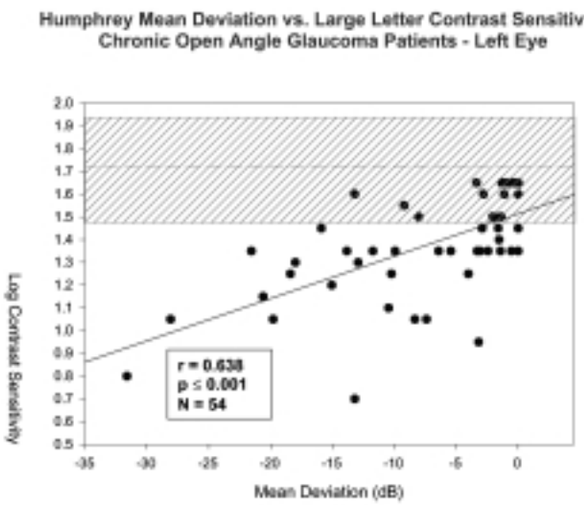

FIGURE 5
Correlation between mean deviation on Humphrey visual field and contrast sensitivity score.

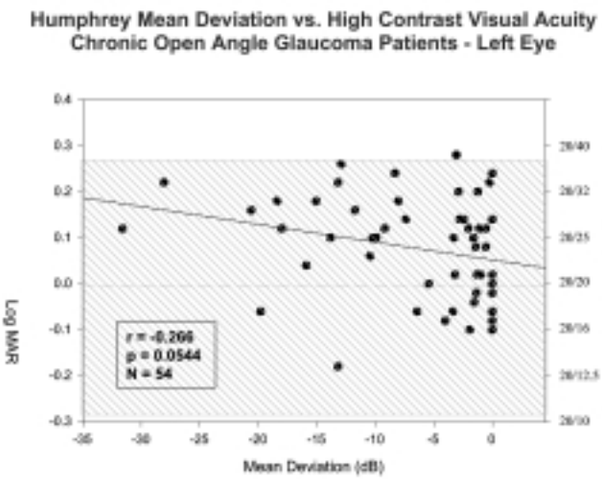

FIGURE 6
Correlation between mean deviation on logMAR visual acuity and on Humphrey visual fields in patients with chronic open-angle glaucome.

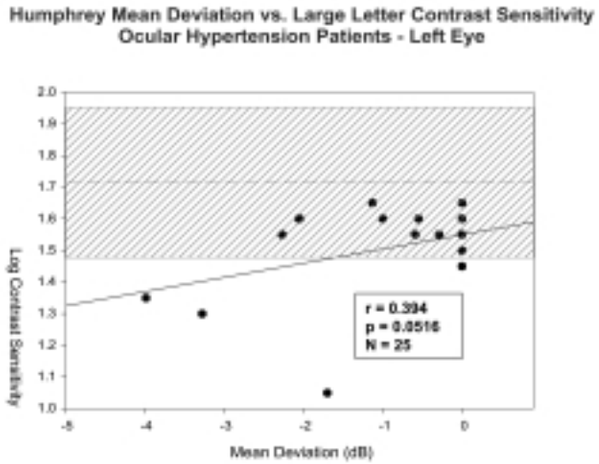

FIGURE 7
Correlation between mean deviation on Humphrey visual field and contrast sensitivity in patients with ocular hypertension.

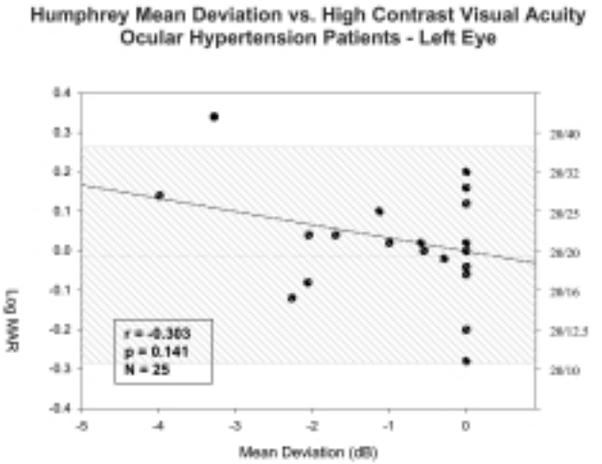

FIGURE 8
Correlation between mean deviation on Humphrey visual field and contrast sensitivity in patients with ocular hypertension.

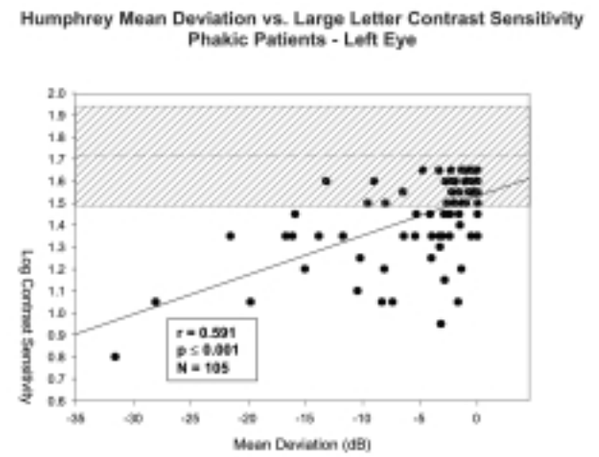

FIGURE 9
Correlation between mean deviation on Humphrey visual field and contrast sensitivity in phakic patients.

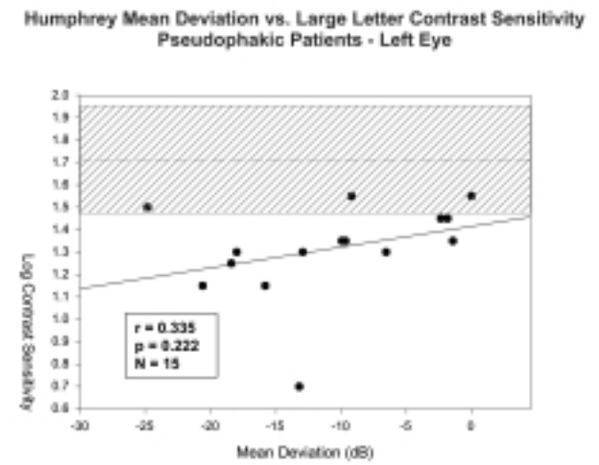

FIGURE 10
Correlation between mean deviation on Humphrey visual field and contrast sensitivity in aphakic patients.

believe that this may be a manifestation of the their loss of contrast sensitivity and that the world around them is a gray mist because of this lack of contrast sensitivity. With the type of testing we describe here, we should be able to document and quantify such loss of contrast sensitivity in such patients. Potentially, changes in contrast sensitivity over time might be a more sensitive indicator of progression of glaucoma damage than some of the other tests that we are using now. Obviously, much more extensive testing and prospective studies will be required before we can find out whether this supposition has any validity.

SUMMARY

We have demonstrated that in patients with good visual acuity and early glaucomatous visual field damage, there is a positive correlation between decrease in contrast sensitivity as measured by the Pelli-Robson chart and the amount of visual field loss as indicated by the mean deviation. We feel that this correlation may help explain some of the symptoms that our patients exhibit and may serve to develop improved testing to monitor the status of our glaucoma patients prospectively.

REFERENCES

1. Stamper RL. Psychophysical changes in glaucoma. *Surv Ophthalmol* 1989;33:309-318.
2. Horn F, Martus P, Korth M. Comparison of temporal and spatiotemporal contrast-sensitivity tests in normal subjects and glaucoma patients. *Ger J Ophthalmol* 1993;231(3):146-150.
3. Sample PA, Juang PSC, Weinreb RN. Isolating the effects of primary open-angle glaucoma on the contrast sensitivity function. *Am J Ophthalmol* 1991;112:308-316.

4. Wood MW, Livie-Kitchin JE. Evaluation of the efficacy of contrast sensitivity measures for the detection of early primary open-angle glaucoma. *Optom Vis Sci* 1992;63:175-181.
5. Pelli DG, Robson JG, Wilkins AJ. The design of a new letter chart for measuring contrast sensitivity. *Clin Vis Sci* 1988;2:187-199.
6. Elliott DB, Sanderson K, Conky A. The reliability of the Pelli-Robson contrast sensitivity chart. *Ophthal Physiol Opt* 1990;10:21-24.
7. Adamsons I, Rubin GS, Vitale S, et al: The effect of early cataracts on glare and contrast sensitivity: A pilot study. *Arch Ophthalmol* 1992;110:1081-1086.

DISCUSSION

DR RICHARD P. MILLS. My thanks to the program committee for selecting me to discuss this fine paper. I have chosen to focus on 2 facets of this work: first, the correlation between contrast sensitivity and visual fields, and second, the speculation that contrast sensitivity might be a better predictor of glaucoma patient complaints than our traditional measures.

First of all, if I may be permitted a global summary of the literature on spatial contrast sensitivity and visual fields in glaucoma, it is as follows:

1. contrast sensitivity is moderately well correlated with loss of differential light sensitivity over the entire visual field, especially centrally, and
2. there is good evidence that contrast sensitivity abnormalities often precede glaucomatous visual field loss in early glaucoma, but
3. contrast sensitivity is an insufficiently sensitive predictor of visual field loss either at onset of disease or as it progresses to be used in place of traditional measures.

Table I shows the correlations between spatial contrast sensitivity and mean defect in the visual field found by Dr Wilensky and others[1,2] in mixed groups of glaucoma and ocular hypertensive patients. All Pearson "r" coefficients are in the moderate range, somewhat lower for Mutlukan and Skarf perhaps because some of their patients had neuro-ophthalmic diagnoses and because they were using a contrast sensitivity test of their own design. Note the higher correlations for the central visual field points; perhaps Dr Wilensky could comment about central field data in his patients.

This paper finds modest correlation of contrast sensitivity and mean defect at r = 0.4 in the ocular hypertensive subset of patients, possibly because some of them had early glaucoma without definite glaucomatous field loss, similar to what others have found. The fact that pseudophakes had weaker correlations than phakic patients comes as no great surprise, and could relate to posterior capsular haze or IOL type.[3]

Enthusiastic as we may become about contrast sensitivity measurement, there is insufficient sensitivity to warrant displacing our tried and true clinical measures. Wood and Lovie-Kitchin[4] found a low sensitivity at acceptable specificity levels for all contrast sensitivity tests they studied, including Pelli-Robson, in detection of glaucoma. Mizokami and Asai[5] showed that contrast sensitivity testing at 2.5 and 3.5 cycles/degree, where the Pelli-Robson test operates, does not discriminate well between stages of visual field loss from early to late.

Can contrast sensitivity better predict the troubles about which our patients complain than our current clinical measures? Pelli-Robson scores and visual field extent were better predictors of mobility performance in patients with macular degeneration[6] and retinitis pigmentosa[7] than visual acuity, motion sensitivity, scanning ability, and figure-ground discrimination in dim light. From a group of tests used by Ross et al, perceived visual disability among glaucoma patients was best predicted by near visual acuity, visual field mean defect, and contrast sensitivity measures.[8] We are fortunate that Pelli-Robson testing has been added to the testing in the Collaborative Initial Glaucoma Treatment Study (CIGTS), with its robust quality of life measurement and large sample size, so we should be able to answer the question of the use of contrast sensitivity tests in predicting patient-perceived disability within the next several years.

REFERENCES

1. Zulauf M, Flammer J. Correlation of spatial contrast sensitivity and visual fields in glaucoma. *Graefes Arch Clin Exp Ophthalmol* 1993;231:146-150.
2. Mutlukan E, Skarf B. Macular contrast sensitivity function correlates with automated threshold perimetry. In Wall M, Heijl A, eds. Perimetry Update 1996/1997, *Proceedings of the XIIth International Perimetric Society Meeting*. Kugler, Amsterdam 1997;243-250.

TABLE I: CORRELATIONS BETWEEN CONTRAST SENSITIVITY AND GLOBAL VISUAL FIELD SENSITIVITY (GLAUCOMA AND OCULAR HYPERTENSIVE PATIENTS)

	WILENSKY AND HAWKINS N = 120	ZULAUF AND FLAMMER[1] N = 60	MUTLUKAN AND SKARF[2] N = 143
	HUMPHREY MD V. PELLI-ROBSON (3CY/DEG)	OCTOPUS MS V. HAAG STREIT VISOMETER	HUMPHREY MD V. CUSTOM CS TEST (5 CY/DEG)
Total VF	0.59	0.63	0.42
Central VF	-	0.76	0.53

3. Tan JC, Spalton DJ, Arden GB. The effect of neodymium: YAG capsulotomy on contrast sensitivity and the evaluation of methods for its assessment. *Ophthalmology* 1999;106:703-709.
4. Wood JM, Lovie-Kitchin JE. Contrast sensitivity measurement in the detection of primary open angle glaucoma. In Mills R, Heijl A, eds. Perimetry Update 1990/1991, *Proceedings of the IXth International Perimetric Society Meeting*. Kugler, Amsterdam 1991;497-502.
5. Mizokami K, Asai T. Contrast sensitivity, visual field defect, and retinal nerve fiber layer defect in glaucoma. In Heijl A, ed. Perimetry Update 1988/1989, *Proceedings of the VIIIth International Perimetric Society Meeting*. Kugler and Ghedini, Amsterdam 1989;297-302.
6. Kuyk T, Elliott JL. Visual factors and mobility in persons with age-related macular degeneration. *J Rehabil Res Dev* 1999;36:303-312.
7. Haymes S, Guest D, Heyes A, et al. Mobility of people with retinitis pigmentosa as a function of vision and psychological variables. *Optom Vis Sci* 1996;73:621-637.
8. Ross JE, Bron AJ, Clarke DD. Contrast sensitivity and visual disability in chronic simple glaucoma. *Br J Ophthalmol* 1984;68:821-827.