New approaches for assessment of vision in refractive surgery and cataract

Kim P. Eckroth  
Pacific University

Garley C. Leon  
Pacific University

Amanda Mendez Roberts  
Pacific University

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New approaches for assessment of vision in refractive surgery and cataract

Abstract
The purpose of this study was to test new methods of evaluating contrast sensitivity (CS) and disability glare. These measurements are particularly useful in evaluating the effects of cataract and refractive surgery on the visual system. In this study we compared the right eye of 20 subjects and both eyes of eight subjects who had bilateral LASIK. We tested contrast sensitivity and visual acuity (VA) in normal and low photopic luminance conditions. VA measurements were taken using high (96%) and low (5%) contrast logarithmic charts. CS measurements were taken using prototype charts with 20/50 and 20/40 demands. Disability glare was simulated by using a dark filter cut to cover only the letters, so that the luminance was 10 cd/m² in the center with 100 cd/m² surrounding it, resulting in a diffuse surrounding glare. Under photopic viewing conditions, visually normal observers demonstrated VA and CS values with well-defined confidence intervals. Between-subject variability with 20/50 letters was less than that observed with 20/40, making the 20/50 letter size more desirable for clinical application. In visually normal subjects we observed a significant decrease in performance with a modest decrease in photopic luminance. This effect was most apparent for low contrast acuity and 20/50 CS, demonstrating the potential usefulness of these measurements as clinical tools. While the most LASIK patients performed within normal limits on this test, there was a tendency for decreased performance. The debilitating effects of glare were observed in normal subjects as well as LASIK patients. The addition of diffuse surrounding glare to our low photopic CS stimulus led to a significant decrease in performance. Our approach to measuring disability glare produced a reliable decrease in performance evident in visually normal observer as well as in our non-symptomatic LASIK patients. While these findings are significant, further studies are underway to explore the utility of this methodology.

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NEW APPROACHES FOR ASSESSMENT OF VISION IN REFRACTIVE SURGERY AND CATARACT

By

KIM P. ECKROTH
GARLEY C. LEON
AMANDA MENDEZ ROBERTS

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JEFF RABIN, O.D. Ph.D.
BIOGRAPHY

Kim P. Eckroth graduated from Pacific University with a Bachelors degree in Visual Science. Upon graduation from Pacific University College of Optometry, she plans to work as an associate in private practice in Washington State.

Amanda M. Roberts graduated from the University of Arizona with a Bachelors of Science in Molecular and Cellular Biology. She plans to complete a residency at a VA medical center upon graduation from Pacific University College of Optometry.

Garley C. Leon graduated from the University of San Francisco with a Bachelors of Science in Biology. She is considering a residency in contact lenses upon graduation from Pacific University College of Optometry. After completion of her residency, she plans on returning to the Bay Area and enter into private practice.
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ABSTRACT

The purpose of this study was to test new methods of evaluating contrast sensitivity (CS) and disability glare. These measurements are particularly useful in evaluating the effects of cataract and refractive surgery on the visual system. In this study we compared the right eye of 20 subjects and both eyes of eight subjects who had bilateral LASIK. We tested contrast sensitivity and visual acuity (VA) in normal and low photopic luminance conditions. VA measurements were taken using high (96%) and low (5%) contrast logarithmic charts. CS measurements were taken using prototype charts with 20/50 and 20/40 demands. Disability glare was simulated by using a dark filter cut to cover only the letters, so that the luminance was 10 cd/m² in the center with 100 cd/m² surrounding it, resulting in a diffuse surrounding glare. Under photopic viewing conditions, visually normal observers demonstrated VA and CS values with well-defined confidence intervals. Between-subject variability with 20/50 letters was less than that observed with 20/40, making the 20/50 letter size more desirable for clinical application. In visually normal subjects we observed a significant decrease in performance with a modest decrease in photopic luminance. This effect was most apparent for low contrast acuity and 20/50 CS, demonstrating the potential usefulness of these measurements as clinical tools. While the most LASIK patients performed within normal limits on this test, there was a tendency for decreased performance. The debilitating effects of glare were observed in normal subjects as well as LASIK patients. The addition of diffuse surrounding glare to our low photopic CS stimulus led to a significant decrease in performance. Our approach to measuring disability glare produced a reliable decrease in performance evident in visually normal observer as well as in our non-symptomatic LASIK patients. While these findings are significant, further studies are underway to explore the utility of this methodology.
INTRODUCTION

A directly viewed object emanates a bundle of light rays that are focused sharply on the retina by the optics of the eye. The pupil of the eye limits the extent of this bundle, as well as the optics utilized in image formation (e.g. central vs. peripheral optics). Extraneous light sources (e.g. headlights from a vehicle off to the side) typically are focused less accurately, and blend with the focused image, reducing its visibility. This phenomenon, often referred to as “glare,” can be extremely debilitating, particularly when the pupil is large and the optics of the eye are compromised. Large pupils occur under dim illumination; and imperfect optics often occur with opacities (cataracts) in the human lens, and can be present following refractive surgery (e.g., laser in-situ keratomileusis [LASIK] and photorefractive keratectomy [PRK]).

Whereas LASIK and PRK have proven to be safe and effective for correction of refractive error, some patients do complain of glare, particularly at night. Conventional glare tests typically use a standard viewing target (e.g. visual acuity chart) with a bright glare source. Recent research demonstrated that the addition of glare in a conventional paradigm produced a paradoxical improvement in vision in refractive surgery patients. This improvement with the addition of glare was attributed to constriction of the pupil, which decreases adverse defocus effects of peripheral optical imperfections.

The paradoxical effect of glare was overcome in a recent preliminary study by using a low-intensity (mesopic) target, combined with diffuse, surrounding glare. The researchers found that, by maintaining a low stimulus luminance, constriction of the pupil was minimized and performance was consistently reduced in the presence of glare.

In what follows, we describe new approaches to assess vision and disability glare in refractive surgery and related conditions. Previous studies demonstrated that small letter contrast sensitivity (CS) provides a sensitive measure of defocus, changes in stimulus luminance, and binocular function. Here we expand the scope of this approach by using larger letters to include a broader patient population, and an extended contrast range to assess anomalous as well as super-normal vision. We combine measurement of CS approach with low luminance filters and diffuse surround glare to assess function in refractive surgery. We report initial application of this methodology in comparison to standard measures of visual acuity (VA).
METHODS

The right eye of 20 volunteer subjects with no history of eye disease or trauma, and both eyes of eight volunteer subjects who had bilateral LASIK within the previous four years (all were at least one year post-operative) were tested in a research laboratory at Pacific University College of Optometry. All subjects were correctable to at least 20/20 and were refracted to best visual acuity using a Greens phoroptor, through which all responses were obtained.

VA and CS were then measured in dark room conditions with a retro-illuminated chart placed 4 meters from the phoroptor, occupying 3.3 x 5.1 degrees of the subject's visual field. VA measurements were taken using high (96%) and low (5%) contrast logarithmic charts. CS measurements were taken using prototype charts with 20/50 and 20/40 demands. The charts were printed on translucent material to allow standardized retro-illumination from the fluorescent light box. The VA charts decrease progressively in letter size, while the CS charts consist of letters of constant size that decrease in contrast from top to bottom. All charts are manufactured by Precision Vision, Inc. (see Figure 1).

![Figure 1. The charts used in this study.](image)

Three luminance levels from the chart box were created by using two densities of neutral filters (dark and medium, creating luminance of 10 and 25 cd/m², respectively) affixed to the front of the chart box with magnetic side strips, as well as no filter (100 cd/m²). A glare source was created by using a dark filter cut to cover only the letters, so that the luminance was 10 cd/m² in the center with 100 cd/m² surrounding it, resulting in a diffuse surrounding glare (see Figure 2). Measurements were taken by having the subject call out the letters, starting from a suprathreshold level (at least four rows above anticipated threshold), and continuing until they could no longer distinguish the letters. Guessing was encouraged to reach a true threshold value. Responses were recorded by marking the letters identified incorrectly (and those below threshold) on a score sheet for each testing condition.
The following testing sequence was used to ensure adequate dark adaptation and minimize potential chart familiarization. After monocular refraction in dark room conditions, the glare filter was placed over the 20/50 and 20/40 CS charts and responses were recorded. Then these charts were used to determine CS in low luminance (10 cd/m$^2$) using the dark filter. VA was then tested using the high and low contrast charts using the dark filter. Then CS and VA were tested in moderately low luminance (25 cd/m$^2$) using the medium filter. These measurements were then repeated with no filter in place (100 cd/m$^2$). The diameter of the tested pupil was then measured in this dark condition using a standard millimeter pupil gauge.

This protocol was approved by our institutional review board and informed consent was obtained by all subjects prior to their participation.

![Figure 2. Examples of filters used over the charts to produce different levels of luminance and/or surrounding glare.](image-url)
RESULTS

Figure 3 shows mean (±2SE) monocular VA and CS for optically corrected normal observers (n=20) under photopic, low photopic and glare conditions. For both VA and CS, there is a systematic decrease in performance with decreasing luminance within the photopic range. Two-way repeated-measures analysis of variance (ANOVA) indicates significant effects of luminance (F=41.9) and letter size on CS (40.7; p<0.0001); and significant effects of luminance (F=43.3) and contrast on VA (F=791.9; p<0.0001) with a significant interaction (F=10.4; p<0.0001). The interaction between luminance and contrast for VA reflects the relatively greater decline in low contrast VA, as compared to high contrast VA, with decreasing luminance.

Figure 3. Log scores of normal subjects on each chart and luminance condition tested, demonstrating significant differences between each test condition.

VA and CS represent distinct letter recognition thresholds (VA is a size threshold while CS is a contrast threshold) making it problematic to compare these measurements directly. To facilitate comparison between VA and CS, all scores were standardized relative to variability by taking the difference between each score and the mean value under normal photopic luminance (100 cd/m²), and dividing by the standard deviation (SD) of the measurement. This expresses all values as Z-scores, allowing for direct comparison between the results of distinct tests. Figure 4 shows VA and CS Z-scores plotted against luminance. Each function decreases systematically with the logarithm of luminance (r²>0.95). At low photopic luminance (10 cd/m²), both high contrast VA and 20/40 CS are within normal limits (i.e., within 2 SDs of mean performance at normal luminance), while low contrast VA and 20/50 CS are greater than 2 SDs below normal. This finding underscores the sensitivity of these measures for detecting subtle effects of
decreased luminance on visual performance. Because the performance difference between normal and low photopic light levels was diminished when retested with a 3 mm artificial pupil, it is likely due to contrast reduction from peripheral optical aberrations. At luminance levels less than that used in this study (10 cd/m²), quantal fluctuations (i.e., stimulus variability) impose a limit on detection and recognition of small targets comparable to those used in this study.\(^7,9\)

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**Figure 4.** A plot of number of standard deviations below the photopic mean vs. luminance conditions shows that change in luminance had the greatest effect on sensitivity using the 20/50 CS and low contrast VA charts.

Figure 5 shows mean and 95% confidence interval (mean ± 2SD) 20/50 CS for normal observers, along with individual results for eight patients who underwent uncomplicated LASIK during the previous four years. All subjects were optically corrected during testing, and both right and left eye results are shown for LASIK patients to demonstrate possible trends. Whereas the majority of CS measures for LASIK patients fall within normal limits, values are shifted toward decreased performance, with this effect most apparent under normal photopic viewing conditions. Nonparametric comparison between the right eyes of LASIK patients (n=8) and monocular values from normal controls (n=20) revealed a significant decrease in CS in the LASIK group (Wilcoxon rank sum test, Z=-3.34, P<0.001), as did comparison of left eyes (n=8) to normal controls (Z=-1.83, P<0.05).

Figure 6 shows results from the right eye of a patient with high myopia (-8.00-0.50x130) in comparison to the mean normal values. Despite near normal VA, CS is significantly decreased relative to normal values, with the greatest decrement under normal photopic viewing conditions.
Figure 5. Plot of log CS vs. luminance comparing the results of LASIK subjects to the mean (±2SD) for normal observers on the 20/50 CS chart. Some LASIK subjects performed worse than the norms under regular (high) luminance conditions.

Figure 6. A highly myopic of subject, whose correction was -8.00 - 0.50 x 130, showed an overall decrease in CS despite near normal VA. The greatest difference was under regular (high) luminance.
DISCUSSION

This study describes new methods for quantifying CS and disability glare in a clinical setting. The methodology includes a small, retro-illuminated letter chart in an otherwise dark environment. These test conditions, which favor moderate pupil dilation, assess the contribution of mid-peripheral to peripheral optical components of the eye. Because peripheral aberrations are known to be increased following refractive surgery, the approach is appropriate for quantifying vision in these patients. The inclusion of low photopic filters and disability glare to simulate conditions of reduced visibility provide additional bases for assessment.

Under photopic viewing conditions, visually normal observers demonstrated VA and CS values with well-defined confidence intervals. Between-subject variability with 20/50 letters was less than that observed with 20/40, making the 20/50 letter size more desirable for clinical application. This assumption received support from our sample of asymptomatic LASIK patients, who showed slightly reduced performance on the 20/50 CS test despite normal levels of VA. Moreover, a patient with high myopia and astigmatism showed a significant reduction in 20/50 CS under the photopic test condition, underscoring the sensitivity of this test condition for revealing substantive decrements in function.

In visually normal subjects we observed a significant decrease in performance with a modest decrease in photopic luminance. This effect was most apparent for low contrast acuity and 20/50 CS, demonstrating the potential usefulness of these measurements as clinical tools. Presumably, the modest decrease in luminance promotes pupil and involvement of peripheral optics. While the most LASIK patients performed within normal limits on this test, there was a tendency for decreased performance, which may be more apparent in symptomatic patients or those with surgical complications. A patient with high myopic astigmatism was well below normal at low photopic and at normal luminance levels, underscoring the potential utility of this approach despite normal levels of visual acuity.

The debilitating effects of glare were observed in normal subjects as well as LASIK patients. The addition of diffuse surrounding glare to our low photopic CS stimulus led to a significant decrease in performance. The diffuse surrounding glare blends with the central lower luminance letter chart, reducing its retinal contrast. Whereas commercially available glare devices can improve performance by decreasing pupil size, the present approach produced a reliable decrease in performance evident in visually normal observer as well as in LASIK patients. While the effect observed in LASIK patients appeared to be no greater than that observed in normals, the efficacy of this approach may be more evident in symptomatic patients or in cases with surgical complication. Insofar as disability glare has detrimental effects on driving safety, it remains an important function to quantify clinically.

In summary, this new approach offers the potential to quantify CS in rapid, clinically expedient manner. The test conditions, which allow for modest pupil dilation, and
include low luminance with disability glare, are particularly suitable for quantifying visual function in refractive surgery and related conditions such as keratoconus, irregular astigmatism and cataracts. Studies are underway to further explore the utility of this methodology.
REFERENCES


