Capacity of straylight and disk halo size to diagnose cataract

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PURPOSE: To examine the capacity of straylight and disk halo size to diagnose cataract.

SETTING: Faculty of Optics and Optometry, Universidad Complutense de Madrid, Spain.

DESIGN: Prospective study.

METHODS: Straylight, disk halo radius, and high-contrast corrected distance visual acuity (CDVA) measurements were compared between patients with age-related cataract and age-matched normal-sighted control subjects by calculating the area under the curve (AUC) receiver operating characteristic.

RESULTS: Measurements were made in 53 eyes of 53 patients with a mean age of 67.94 years ± 7.11 (SD) and 31 eyes of 31 controls with a mean age 66.06 ± 5.43 years. Significantly worse ($P < .001$) mean straylight (1.38 ± 0.24 log[s]), mean disk halo radius (2.40 ± 0.18 log minutes of arc [arcmin]), and mean CDVA (0.17 ± 0.11 logMAR) were recorded in the cataract group than in the control group (1.17 ± 0.11 log[s], 2.10 ± 0.16 log arcmin, and 0.08 ± 0.08 logMAR). Significant differences in AUCs were observed for disk halo radius (0.89 ± 0.04) versus straylight (0.77 ± 0.05) ($P = .03$) and disk halo radius versus CDVA (0.72 ± 0.05) ($P = .001$). The comparison of disk halo radius versus the discriminant function with input from CDVA and straylight (0.80 ± 0.05) was at the limit of significance only (0.091 ± 0.05, $P = .051$).

CONCLUSION: Although all 3 variables discriminated well between normal eyes and eyes with cataract, the disk halo radius showed the best diagnostic capacity.

Financial Disclosure: Neither author has a financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2015; 41:2069–2074 © 2015 ASCRS and ESCRS

Cataract is the leading cause of visual impairment in the world. Crystalline lens opacities directly affect vision and can have a serious impact on patients' daily living activities and quality of life. At present, the indication for cataract surgery is usually a loss of high-contrast corrected distance visual acuity (CDVA).[1–3] However, many cataract patients with excellent visual acuity report glare and other visual problems. Such problems are produced by an increased amount of light scattering, which may cause disabling glare and halos, especially at night. Several studies have shown that additional vision tests provide important preoperative information that correlates with patients' complaints and that is valuable for assessing quality of vision. Thus, besides visual acuity,[4,5] contrast sensitivity,[3–5] disabling glare,[4] straylight,[2,3,6] and halo size[7] should also be assessed.

Intraocular forward-scattered light[8] measured using a straylight meter (C-Quant, Oculus Optikgeräte GmbH) is gradually being incorporated into the preoperative assessment for cataract extraction in addition to visual acuity.[9–11] In the healthy eye, straylight increases with age[12–14]; however, this occurs in a much larger measure when the optical media are affected, such as in cataract,[3,6] thereby reducing an individual's quality of vision. In fact, night-driving difficulties are among the first complaints of patients with cataract because of glare. Bal et al.[3] argued that even when visual acuity was compatible with driving, patients with posterior subcapsular cataract were unfit to drive when they showed a straylight value of 1.4 log(s). This threshold has been proposed both as a safety margin for driving and as an indication for cataract surgery.[10] Similarly, van der Meulen et al.[9]

Published by Elsevier Inc.

http://dx.doi.org/10.1016/j.jcrs.2015.10.047
0886-3350

reported that straylight, in addition to visual acuity, improved the preoperative decision-making process for cataract surgery.

Measuring the size of a disk halo induced by a glare source has been suggested as an objective method to quantify quality of vision in subjects, such as those with night-vision problems due to cataract,[7] those having refractive surgery,[15,16] or those implanted with an intraocular lens.[17] Disk halos[18] can be induced by scattering and may also be the result of refractive aberrations.[19] Several methods and testing protocols have been developed to measure halo size.[7,17,20–22] A recently developed test measures the angular radius of the disk halo area.[23] A vision monitor (MonCv3, Metrovision) measures this variable, which has been found to be significantly correlated with straylight and mesopic low-contrast visual acuity.[24] It should be noted that this is the only method that provides the normal disk halo radius values by age along with repeatability values. This procedure offers adequate repeatable results, and there is no learning process involved in repeated measurements.[22] However, no study has yet assessed the impact of cataract on the disk halo size.

The present study was designed to assess the cataract diagnostic capacity of measurements of the disk halo radius, straylight, and high-contrast CDVA.

PATIENTS AND METHODS

Study Group and Protocol

This study was conducted at the Faculty of Optics and Optometry, Universidad Complutense de Madrid, Madrid, Spain. The study protocol adhered to the guidelines of the Declaration of Helsinki and was approved by the institution's review board. Subjects were informed about the study protocol before giving their written consent to participate.

Cataract patients were recruited from subjects visiting the Hospital Universitario del Henares, Madrid, Spain, for a routine ophthalmologic examination. Inclusion criteria were nuclear, cortical, posterior subcapsular, or mixed cataract grade 2 or higher (on a scale of 0 to 4, indicating no opacification to severe opacification) in at least 1 eye based on the Lens Opacities Classification System III (LOCS III) criteria.[25] All participants had visual acuity measurement, subjective refraction, slitlamp biomicroscopy, and ophthalmoscopy. Exclusion criteria were a history of ocular disease, previous intraocular surgery, laser treatment, glaucoma, diabetic retinopathy, amblyopia, age-related macular degeneration, age-related cataract according to LOCS III lower than grade 2 or higher than or equal to grade 4, and a CDVA worse than 0.3 logMAR. Patients with grade 4 cataract were excluded because of the low number of patients with this grade of cataract who had not had surgery. Grading was performed by the same experienced examiner. Inclusion criteria for the control subjects were no eye disease and a CDVA of at least 0.2 logMAR. These subjects either were relatives of the cataract patients recruited or were recruited through advertisements placed at and around the university. In both the patient and control groups, measurements were made in 1 eye only.

Visual Acuity

The CDVA was measured monocularly with spectacle correction using high-contrast (96%) Bailey-Lovie logMAR letter charts under photopic (85 candelas [cd]/m^2) luminance conditions at a distance of 4 m. Subjects were encouraged to guess letters even if they were unsure. Each letter read correctly on each line was given a score of 0.02 log units. In this chart, a loss of 1 line of letters corresponds to a logMAR increase of 0.1.

Retinal Straylight

Intraocular forward-scattered light on the retina was measured using the C-Quant straylight meter according to the psychophysical compensation comparison method described elsewhere.[26] This method is easy to perform in a clinical setting and has been reported to provide valid measurements. Values were expressed as straylight log(s); the higher the value, the greater the straylight and sensitivity to glare. Only eyes providing straylight measurements of acceptable quality (ie, a repeated-measures standard deviation [SD] parameter, Esd, lower than 0.08, and a measurement quality parameter, Q, higher than 1.0) were included. If a measurement was unacceptable, a rest period of 1 minute was allowed before the procedure was repeated.

Halo Size

Disk halo radius was measured using a vision monitor (MonCv3) at a distance of 2.5 m. The method has been previously described in detail.[22] Briefly, the right light source illuminates 1 of the patient's eyes and produces stray intraocular light, reducing the contrast of a foveal target. A letter luminance level of 5 cd/m^2 was used for this test. Optotypes were arranged in 3 radial lines of letters appearing from the periphery toward the glare source. Each line contains 10 letters forming 10 rings at intervals of 33 minutes of arc (arcmin) at a distance of 2.5 m. Each letter subtends an angle of 15 arcmin corresponding to a visual acuity of 20/60. Before testing, the patient was allowed to adapt to the dark for 5 minutes. Monocular testing took place in a dark room with spectacle correction. For the test, the patient was seated 2.5 m from the monitor with the head aligned with the center of the monitor using a chinrest. The subject

Submitted: November 20, 2014.
Final revision submitted: March 20, 2015.
Accepted: March 22, 2015.

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Supported by a grant from Industrias de Optica Prats S.L. The supporting source had no involvement in this study.

Raquel Coca-Serrano, Eva Zurita-Rosa, Celeste Marina-Verde, and Irene Fuentes-Vega helped with the recruitment of patients.

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was requested to cover the eye not being tested and asked to identify the optotype during simultaneous illumination of the eye with the glare source. Subjects were instructed not to look directly at the light source to avoid a retinal afterimage. Thereafter, the subject read each line starting from the side opposite the light source; that is, optotypes were read from the periphery toward the glare source until a letter could not be identified. The subject was encouraged to read each letter despite being unsure. Letters not identified in each line were recorded, and the test result was calculated as the average distance from the glare source for the 3 lines. This distance was taken as the radius of the disk halo. Next, the visual angle formed by the radius of the disk halo was calculated in log arcmin to compare measurements with visual acuity and straylight expressed in log units.

Statistical Analysis

Statistical tests were performed using SPSS for Windows software (version 15.00, SPSS Inc.). The normal distribution of data was confirmed by the Kolmogorov-Smirnov normality test. All data are provided as the mean and standard deviation. A Student *t* test was used to compare data between the cataract and control group.

The eyes were classified into 2 groups (cataract and normal) by linear discriminant analysis. All 3 variables were entered into the model and selected by the forward method to obtain the best predictive variables. Disk halo was the parameter that best discriminated between normal and cataract eyes (Wilk $\lambda = 0.59$, F = 58.06, $P = .00001$). However, to compare the capacity of the disk halo size and the combination of straylight plus CDVA to diagnose cataract, a new linear discriminant function was constructed.

Individual variables and this discriminant function were assessed for their usefulness to discriminate between eyes with cataract and normal eyes by comparing areas under receiver operating characteristic (ROC) curves (AUCs) for these variables. A test was defined as valid when the AUC was more than 0.70.[27] For ROC analysis, Sigmaplot 11 software (Systat Software, Inc.) was used. The ROC curves were compared using Medcalc (version 7.3, Medcalc Software bvba). Significance was set as a *P* value of less than 0.05.

RESULTS

Fifty-three patients with age-related cataract (mean age 67.94 years ± 7.11 [SD]; range 50 to 84 years) and 31 normal-sighted control subjects (mean age 66.06 ± 5.43 years; range 58 to 76 years) were enrolled in this study. The cataract and control groups were well matched for age (67.94 ± 7.11 years versus 66.06 ± 5.43 years, respectively, $P > .05$). Descriptive statistics and statistical comparisons of the results obtained for straylight, halo size, and CDVA in the cataract versus control group are displayed in Table 1.

Cataracts were graded under mydriasis at the slitlamp as follows: 30 nuclear (grade 2 = 21; grade 3 = 9), 16 nuclear–cortical (grade 2 = 9; grade 3 = 7), and 7 nuclear–posterior subcapsular (grade 2 = 5; grade 3 = 2).

In all tests, the cataract group performed worse than the control group. Thus, straylight and halo size were significantly elevated (worse) in the cataract group relative to the control group (Table 1). Also, the CDVA was worse in the cataract group.

Linear discriminant analysis revealed that disk halo was the only parameter that significantly discriminated between normal eyes and cataract eyes (Wilk $\lambda = 0.59$, F = 58.06, $P = .00001$). However, to compare the capacity of disk halo size and straylight plus CDVA to diagnose cataract, a new linear discriminant function was constructed based on a combination of CDVA and straylight ($0.51 \times \text{CDVA} + 0.71 \times \text{straylight}$). The discriminant function was significantly worse in the cataract group than in the control group ($P = .00001$, F = 26.27).

The capacity of straylight, disk halo, CDVA, and the combination CDVA plus straylight (discriminant function) to discriminate between eyes with cataract and normal eyes was assessed using the ROC curves provided in Table 2 and Figure 1. Areas under the curve for straylight, disk halo radius, CDVA, and discriminant function were higher than 0.70, indicating good diagnostic capacity, with the greatest AUC recorded for halo size (0.89 ± 0.04, $P < .0001$). Pairwise comparisons of the ROC curves revealed significant differences between AUCs for disk halo radius versus straylight ($P = .03$) and halo size versus CDVA ($P = .001$). Comparison between disk halo radius and discriminant function returned a probability value at the limit of significance (0.091 ± 0.05; $P = .051$), with higher AUCs recorded for halo size and similar values obtained for straylight and CDVA ($P = .39$). Disk halo radius showed a better ability to distinguish between normal eyes and eyes with cataract.

Using the ROC curves for these variables, the values corresponding to the greater accuracy (maximum specificity with respect to sensitivity) or cutoffs were obtained. These cutoffs are shown in Table 3. Sensitivities and specificities, along with their corresponding 95% confidence intervals, are also provided.

DISCUSSION

In this study, we set out to determine whether straylight and disk halo radius measurements could play a useful role in the diagnosis of cataract. By plotting ROC curves, the accuracy of straylight, disk halo radius, and CDVA tests to detect cataract were compared. Our findings revealed an intraocular straylight value that was 0.2 log(s) higher on average in patients with cataract (1.38 ± 0.24 log[s]) than in those without cataract (1.17 ± 0.11 log[s]). The straylight values recorded in our cataract group were slightly better (lower) than those reported elsewhere.[3,6,9]

Table 1. Descriptive statistics (mean ± SD and range) of the results obtained for straylight, disk halo radius, CDVA, and CDVA and straylight discriminant function in eyes with cataract versus control eyes.

	Cataract Group (n = 53)		Control Group (n = 31)	
Variable	Mean ± SD	Range	Mean ± SD	Range
Straylight (log [s])	1.38 ± 0.24	0.96, 1.97	1.17 ± 0.11	0.9, 1.38
Disk halo radius (log arcmin)	2.40 ± 0.18	1.88, 2.60	2.10 ± 0.16	1.81, 2.40
CDVA (logMAR)	0.17 ± 0.10	0.0, 0.3	0.08 ± 0.08	–0.06, 0.2
CDVA and straylight discriminant function (log units)	1.06 ± 0.19	0.68, 1.50	0.87 ± 0.09	0.66, 1.07

The reason for this could be the small size of our patient group, which included both nuclear and posterior subcapsular cataract rather than only posterior subcapsular cataract. In effect, it is well known that eyes with posterior subcapsular cataract show greater straylight and functional impairment than eyes with other grades of cataract.[3,6,28] Similarly, our mean halo values measured using the vision monitor were 0.3 log arcmin higher in the cataract group (2.40 ± 0.18 log arcmin) than in the control group (2.10 ± 0.16 log arcmin). Lens transparency loss due to cataract increases ocular light scattering.[3,6,11] In turn, scattering affects retinal image quality and contributes to disabling glare (straylight)[4,6,11] and to the perception of halos around central lights.[29] Although few studies have examined the effects of cataract on disk halo radius, larger halos have been described in patients with cataract.[7,29] The different methods and measurement units used in these studies preclude comparisons with our data.

Our results indicate a mean CDVA lower by 0.1 logMAR (five letters) in the eyes with cataract than in the control eyes. Other studies have provided similar data.[3,6] A common finding in many patients is that straylight and halos may be considerably elevated, whereas visual acuity is unaffected. Indeed, visual acuity shows a weak correlation with straylight[3,6,28] or halos.[24] The independence of straylight and CDVA may be understood if we bear in mind that detrimental effects on visual acuity are produced mainly by wavefront aberrations (lower and higher order). Such aberrations are determined by the central peak of the point-spread function (PSF) causing light spreading over angles of around 0.1 degree.[30] In contrast, scattering and halo affects the PSF skirts, causing light to spread across angles larger than 1

Table 2. Cataract diagnostic capacity of straylight, disk halo radius, CDVA, and CDVA and straylight discriminant function.

Variable	Control vs Cataract AUC
Straylight	
Mean ± standard error	0.77 ± 0.05
95% confidence interval	0.67, 0.86
P value	.0001
Disk halo radius	
Mean ± standard error	0.89 ± 0.04
95% confidence interval	0.80, 0.95
P value	.0001
CDVA	
Mean ± standard error	0.72 ± 0.06
95% confidence interval	0.61, 0.81
P value	.0001
CDVA and straylight discriminant function	
Mean ± standard error	0.80 ± 0.05
95% confidence interval	0.70, 0.88
P value	.0001

AUC = area under the ROC curve
Data expressed as areas under the receiver operating characteristic (ROC) curve.

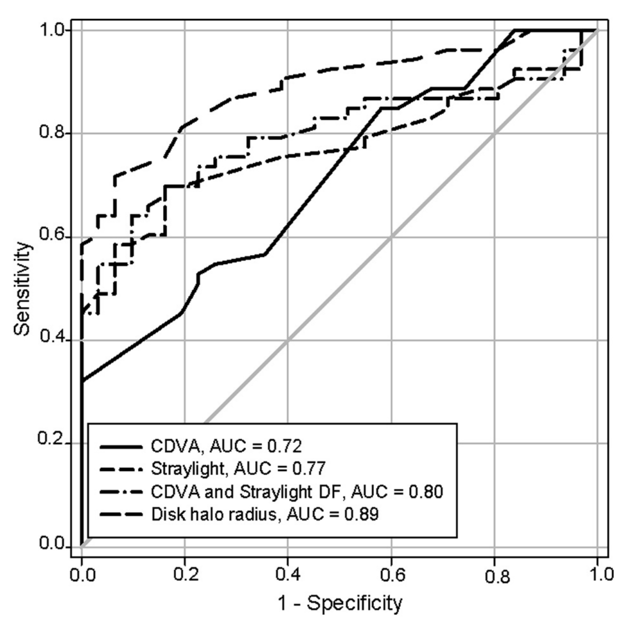

Figure 1. Areas under the ROC curves for CDVA, straylight, disk halo radius, and the discriminant function CDVA plus straylight (AUC = area under the receiving operating characteristic; CDVA = corrected distance visual acuity).

Table 3. Specificity relative to sensitivity (%) and sensitivity (%) of AUC cutoffs with 95% CIs.

AUC Cutoff	Sensitivity	95% CI	Specificity	95% CI
Straylight >1.24	69.8	55.7, 81.7	83.9	66.3, 94.5
Disk halo radius >2.3	71.7	57.7, 83.2	93.5	78.5, 99.0
CDVA >0.2	32.1	19.9, 46.3	100.0	88.7-100.0
CDVA and straylight discriminant function >0.97	64.2	49.8, 76.9	90.3	74.2, 97.8

AUC = area under the receiving operating characteristic; CDVA = corrected distance visual acuity; CI = confidence interval

degree.[28] Disk halo also has been related to straylight and mesopic low-contrast visual acuity in healthy young individuals.[24]

We believe that the present study is the first to provide data on the discriminating capacity of straylight, CDVA, and disk halo measurements for a diagnosis of cataract. All 3 variables (CDVA, straylight, and halo radius) discriminated well between normal eyes and eyes with cataract. However, the disk halo radius was better able to quantify functional abnormalities in eyes affected by cataract (AUC = 0.89 ± 0.03) than straylight (0.77 ± 0.05), CDVA (0.72 ± 0.04), or a discriminant function based on a combination of CDVA and straylight (AUC = 0.80 ± 0.05). The CDVA is the method that is most universally accepted to indicate cataract by researchers and clinicians. The area under the ROC curve measures the capacity of tests to correctly classify eyes with and without cataract. In our study, the ROC curve procedure confirmed the improved discriminating power of the disk halo radius over that of straylight or CDVA. This improved capacity may be explained by the fact that both straylight and wavefront aberrations contribute to halo size measured with the MonCv3 vision monitor.[24] Through pairwise comparisons of ROC curves, a significantly greater AUC was detected for the disk halo radius relative to straylight (P = .03) or to CDVA (P = .001). No significant differences were observed between AUCs for straylight and CDVA.

The discriminant function constructed was used to measure the capacity of CDVA plus straylight to detect cataract compared with straylight or CDVA alone. Our results indicate that straylight and CDVA should be considered together when measuring the quality of vision.[9] Although a greater AUC was observed for the disk halo radius relative to the discriminant function, the difference did not quite reach significance (P = .051). This suggests that measuring the size of a disk halo induced by a glare source or the combined factors, CDVA and straylight, could be a useful complementary test for cataract screening.

Table 3 shows the straylight, disk halo radius, and CDVA cutoff values that indicate the maximum specificity with respect to sensitivity to diagnose cataract. The cutoff for straylight to diagnose cataract was 1.24 log(s) (specificity 83.9, sensitivity 69.8). This is lower than the value suggested for referral to surgery.[10] Corresponding cutoffs were 2.3 log arcmin (specificity 93.5, sensitivity 71.7) for disk halo radius and 0.2 logMAR (specificity 100, sensitivity 32.1) for CDVA. The discriminant function based on CDVA plus straylight showed an optimal cutoff point of more than 0.97 log unit, corresponding to a specificity of 90.3 and sensitivity of 64.2. Despite wide variation in the visual acuity values used by practitioners to refer a patient for cataract surgery, recommended values are usually higher (worse) than the value of 0.3 logMAR detected here.[1]

In conclusion, all of the tests discussed here discriminated well between normal eyes and eyes with cataract, although the disk halo radius measured using the vision monitor showed better diagnostic capacity.

WHAT WAS KNOWN

- Eyes with cataract show elevated intraocular light scattering, which affects measurements of both straylight and halo size.
- The capacity of straylight, the disk halo radius, and CDVA to differentiate between eyes with and without cataract remains unknown.

WHAT THIS PAPER ADDS

- The findings indicate that the disk halo radius better reflects functional abnormalities in eyes with cataract than straylight, CDVA, or straylight plus CDVA.

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