Macular Pigment Optical Density before and after Cataract Extraction

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PURPOSE. Psychophysical methods of measuring macular pigment (MP) use comparisons of short- and midwave light in the fovea and parafovea to derive optical density estimates. This light must pass through the crystalline lens before absorption by the MPs can occur. The effect of lens absorption on these measures has not been adequately determined. The present study assesses the influence of lens absorption on MP measurements by comparing MP optical density (MPOD) measured before and after cataract extraction.

METHODS. MPOD was measured using flicker photometry in free view at 458 nm with a 1° stimulus. Twenty-nine eyes from 24 patients with cataracts sufficiently severe to require cataract extraction were evaluated.

RESULTS. In the entire group of 24 patients, the mean (±SD) age measured 68.7 ± 9.5 years, and the mean MPOD measured 0.19 ± 0.11. For all 29 eyes measured, MPOD averaged 0.206 ± 0.13 before and 0.18 ± 0.12 after cataract extraction. MPOD measurements at the two time points (mean 8.1 ± 4.7 weeks after surgery) were highly correlated (r = 0.58), suggesting that a cataractous lens does not influence the MP measurement technique.

CONCLUSIONS. Psychophysical techniques can be used to obtain reliable measurements of MP in elderly subjects, even in those with cataracts. Moreover, differences in retinal illuminance due to varying opaqueness of the crystalline lens do not seem to have a measurable influence on MPOD. (Invest Ophthalmol Vis Sci. 2001;42:1338–1341)

Before the neural retina can process light, it is reflected, absorbed, and scattered by the anterior structures of the eye. Of these structures, it is the crystalline lens that tends to influence visible light most strongly and that may therefore impact visual performance most significantly.1 For instance, a dense lens increases the forward scatter of light, reducing contrast sensitivity by producing a veiling illumination across the retinal image.2 The crystalline lens also decreases retinal illumination as a function of age, particularly at short wavelengths.3

Measurements of the retina are therefore affected by light loss due to lens absorption. For example, Maxwellian view optics focus a narrow ray of light through the center of the pupil, and this light passes through the central nucleus of the lens. Stimuli seen in natural view must pass through a wider area of the lens defined by the size of the pupil. Both psychophysical and physical methods must correct for the wide individual differences in this type of preretinal light loss to precisely specify retinal illumination. Psychophysical methods are further limited, in that corrections are made for light absorption but not for the negative effects of a dense lens on visual performance.

There are generally two methods used to correct for absorption by the crystalline lens. One method involves measuring the optical density (OD) of the lens at specific wavelengths (see Snodderly and Hammond4) and then subtracting these values from the overall amount of light used in retinal measurements. Another method used to correct for lens absorption is to compare measures of retinal areas that differ only in the parameter being measured. In this way, light absorption by the lens is the same for both measures, and the only factor that differs is the variable being measured. This is the basic psychophysical method used when measuring macular pigment optical density (MPOD). In essence, retinal sensitivity to visible light is measured in an area where MP is dense (the fovea), and that measure is compared with an area where MP is optically immeasurable (usually at approximately 4°–8° in the parafovea). When these two photopic sensitivity curves are equated at long wavelengths, they differ in the short-wave end of the visible spectrum. When these differences are plotted against wavelength, a spectral density curve is generated that has the same basic shape as the extinction spectrum of xanthophylls.2 Because absorption by the lens is equal in both cases, it is assumed that lens absorption does not influence the difference in these two spectral curves. Simulation data from Wooten et al.6 suggest that this is the case.

In the present study, we assessed the influence of lens absorption on MP measurements by comparing MP measured before and after cataract extraction. Although the subjects’ overall sensitivity to light increased after the extraction, their measured MPOD did not change significantly.

METHODS

Subjects

Twenty-four patients (age range, 48–82 years) from a university-based general ophthalmology practice in Indianapolis were recruited for this study. All subjects were recruited from a cohort of patients who had initially had cataract sufficiently symptomatic to warrant extraction. All patients underwent dilated fundus examination before and after cataract extraction. Only patients with normal results from retinal evaluations were asked to participate in this study. In particular, no patient showed optic nerve cupping, diabetic retinopathy, or signs of macular degeneration. The mean age of the subjects was 68.7 years; 21%, 29%, 42%, and 8% of the subjects were aged 45 to 60, 60 to 70, 70 to 80, and 80 to 90 years, respectively. Moreover, 67%, 21%, 8%, and 4% had brown, blue, green, and gray irides, respectively. Fifty percent of the subjects were past smokers, 42% had never smoked, and 8% were current smokers. In short, the subjects were representative of the population of patients under the care of an attending comprehensive ophthalmologist at a teaching hospital in a major midwestern city.
All patients underwent planned phacoemulsification and placement of a foldable acrylic posterior chamber intraocular lens for cataract of sufficient severity to interfere with their activities of daily living. The median preoperative best corrected Snellen distance visual acuity measured 20/50. Patients were deemed eligible for this study if their near acuity could be refractioned to 20/25 or better. In five patients, both eyes were considered cataractous, and MPOD was assessed in both. MP was originally measured before cataract extraction and then a mean (±SD) of 8.1 ± 4.7 weeks (range, 3–17; median 6 weeks) after completion of the surgery. During MPOD measurement, visual acuity was corrected to 20/25 near acuity. All subjects were naïve about the purpose of the study and were not experienced in psychophysical tasks. Informed consent was obtained, and the tenets of the Declaration of Helsinki were followed.

**Measurement of MPOD**

Schematics and an expanded discussion of the device and stimuli used in the present study can be found in Wooten et al. For details regarding the procedure used, see Snodderly and Hammond.4

**Stimuli.** A circular test stimulus was presented near the center of a 6°, 10.5-candela (cd)/mm², 470-nm circular background. The size of the test stimulus was 1°. The wavelength composition of the test stimulus alternated between a 458-nm measuring field (peak MP absorbance) and a 570-nm, 16.7-cd/mm² reference field (minimal MP absorbance). The measuring and reference fields were superposed and presented out of phase in a square wave alternation rate of 11 to 12 Hz in the foveal condition and 6 to 7 Hz in the parafoveal condition.

**Apparatus.** The apparatus used for the MP measurement delivered the stimulus in natural view but used a stimulus that was similar to the stimulations used in past studies in which the stimulus was presented in Maxwellian view.7–11 Recent data6 on 52 subjects (age range, 18–72 years) have shown that MPOD measured in natural view, with a slightly different stimulus configuration (e.g., this study used a 4° rather than a 6° parafoveal reference), provides the same values as MPOD measured in Maxwellian view.

Light for the 6° background was produced by three LEDs (packed tightly in a triangular array) with peak energy at 470 nm and half-widths of approximately 20 nm. Light for the 570-nm reference field was produced by an LED with peak energy at 570 nm (half-width, 20 nm). Light for the 458-nm measuring field was produced by two LEDs with peak energy at 458 nm (half-width, 20 nm). Light from the LED sources was collimated with planoconvex lenses and was then passed through polycarbonate diffusers (high-efficiency, holographic type; Physical Optics, Torrance CA), which served essentially as back-projection screens.

The sizes of the background and test stimulus were defined by circular apertures (constructed by computer-generated images exposed on high-density, photographic mylar film) placed after the collimating lenses. The background and test stimuli were then combined and reflected to the subject by a 2-in. beam splitter with the front surface located 16 in. from the subject’s eye. The entire optical system was contained in a rectangular, black plexiglas box. One side of the box contained a 1-in. hole centered on the subject’s optical axis through which the stimulus could be viewed. Subjects requiring refractive correction were allowed to wear the appropriate corrective lenses (where MP is the most dense) and at 4° in the parafovea (where light absorption by MP is negligible). A tiny (5-minute) opaque fixation point was located on the left edge of the background, and subjects fixated on this point when making the parafoveal measurement. The peak optical density of MP was derived by subtracting the log foveal sensitivity from the log parafoveal sensitivity at 458 nm. Five foveal and five parafoveal measurements were made after brief instructions and a few practice settings. The means ± SD of these numbers are provided in Table 1.

The MP measurement technique has been validated on normal subjects by measuring the entire spectral absorption curve of MP and comparing it with the extinction spectrum of the macular pigments measured in excised tissue.5 The reliability of the method has also been evaluated in younger subjects. In addition, a recent study at the same institution with the identical apparatus has demonstrated that naïve subjects recruited from the general population can reliably undergo testing.12,13 In this study, 280 healthy adult volunteers (138 men, 142 women; age range, 18–50 years) were found to have a mean MPOD measuring 0.211 ± 0.13,12,13

**RESULTS**

MPODs measured before and after cataract removal are presented in Table 1. As shown in the table, the average MPODs were slightly lower after cataract removal (0.18 compared with 0.206), but this effect was small and not statistically significant. As shown in Figure 1, the measured MPODs were similar before and after cataract extraction ($r = +0.58$, $P < 0.001$). This relationship improved when two statistical outliers (indicated by open squares) were removed ($r = +0.74$).

In contrast, the foveal and parafoveal values used in the derivation of MPOD were significantly different before and after cataract removal (see Table 1). For example, the values (i.e., the energy output of the LED in relative energy units) obtained in the foveal and parafoveal conditions are significantly ($P < 0.001$) lower after cataract removal. For example, average foveal settings were 651 and 305 nm before and after cataract removal, respectively. These numbers translate to a corneal irradiance of 1.55 and 3.16 nW, respectively. Because higher foveal values reflect higher energy output, this implies that cataract removal significantly increased the subject’s sensitivity to light. This change, however, did not significantly alter the derived MPOD.

As shown in Figure 1, the results of this study also suggest that the method used for measuring MPOD is reliable in older experimentally naïve subjects. The two values measured before and after cataract and at disparate time points yielded similar MPODs ($r = +0.58$). The absolute value of the average change between the first and second session was 0.085 ± 0.08. Nonetheless, as also shown in Figure 1 (open squares), there were two subjects whose data did not replicate well. When these two subjects (MH and NC) were removed, the correlation was improved ($r = +0.74$).

Table 1 lists the SDs of the five foveal and parafoveal measures used to derive MPOD. Although the changes in the variance of the parafoveal measures before and after cataract were minimal, the variance in the postoperative foveal values decreased by approximately 45%. These findings suggest that a dense lens can influence a subject’s performance, particularly when making the foveal settings. It is unclear, however, whether increased variability in performance actually leads to less replicable data. There were instances (e.g., subject NC) when high within-session variability predicted poor replicabil-
Table 1. Comparison of Macular Pigment Measurements

<table>
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<tr>
<th>Subject</th>
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Measurements were made before (Pre MPOD) and after (Post MPOD) cataract extraction. Eye is the eye that was tested. The ethnicity of the subjects was white (W) and African American (AA). Whether nutrient supplements (Suppl) were used is indicated by Yes or No. Cataract severity expressed as means subtracted from the log of the measurements made in the parafovea (Pre PF before cataract removal and Post PF after cataract removal). Data are expressed as means ± SD.

* Those subjects in whom both eyes were evaluated.

The change in MPOD for the other two subjects was less clear but must have been due to measurement error not linked to task consistency (e.g., criterion changes) and/or true biologic variation (e.g., changes in diet). These two possibilities can actually be disentangled. For example, because the spectral absorption characteristics of MP are well known, measurements at differing wavelengths can be used to cross-check the accuracy of the data. Moreover, physical methods for measuring MP have recently been developed that do not rely on the performance of subjects (e.g., Raman spectroscopy and fundus reflectance). Considered as a whole, these data confirm the tendency for flicker photometric measures of MP to be reliable in naïve older subjects. The validity of the method in older subjects with lenticular and/or retinal disease, however, remains to be determined.

The similarity in the MP measurements before and after cataract has implications for both basic and applied research. From a basic-methods perspective, techniques analogous to the flicker photometry method used in the present study can assume minimal confounding due to absorption by the lens. Thus, comparative measures of two retinal loci are valid as long as the receptor populations between the two loci are equivalent or the differences are experimentally controlled. From an applied perspective, these results further motivate the need to measure lutein and zeaxanthin within the retina in elderly subjects who are most susceptible to age-related retinal and lenticular disease. Numerous epidemiologic studies have...
linked low dietary intake and blood levels of lutein and zeaxanthin to age-related cataract and macular degeneration. These studies, however, tend to be inconsistent. One explanation for the inconsistencies is that dietary intake and blood carotenoid levels may actually be poor predictors of the amount of lutein and zeaxanthin available to the eye, particularly in females. The ability to measure lutein and zeaxanthin directly provides a better assessment of the availability of these carotenoids to ocular tissue.

Recent years have seen a proliferation of lutein supplements being touted for their ability to protect the retina and lens from oxidative damage. It is probable that not all subjects will respond to these types of supplements equally. The ability to measure MPOD in vivo and repeatedly in the elderly would one method of evaluating the efficacy of using these supplements and/or dietary modifications designed to increase MPOD.

References

4. Snodderly DM, Hammond BR. In vivo psychophysical assessment of nutritional and environmental influences on human ocular tissue.

FIGURE 1. The relationship between MPOD measured before and after cataract extraction. The regression line shown (y = 0.03 + 0.69x; r = +0.75, P < 0.0001) was calculated without including the outliers (□). The regression line is slightly different (y = 0.07 + 0.53x; r = +0.58, P < 0.0005) when these outliers are included.

Macular Pigment Density and Cataracts

Recent years have seen a proliferation of lutein supplements being touted for their ability to protect the retina and lens from oxidative damage. It is probable that not all subjects will respond to these types of supplements equally. The ability to measure MPOD in vivo and repeatedly in the elderly would be one method of evaluating the efficacy of using these supplements and/or dietary modifications designed to increase MPOD.

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