Impact of Cataract on the Results of Frequency-Doubling Technology Perimetry

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Purpose: To determine the effect of cataract on the results of frequency-doubling technology (FDT) perimetry.

Design: Consecutive cohort study.

Participants: Forty-four patients with normal ophthalmic examinations, with the exception of cataract, scheduled to undergo phacoemulsification and posterior chamber lens implantation were prospectively identified and completed the study.

Methods: All subjects underwent FDT perimetry using the full-threshold C-20 strategy. Both eyes were tested within 1 month before cataract surgery and up to 3 months after surgery. The unoperated fellow eyes served as controls.

Main Outcome Measures: Changes in visual acuity (VA), mean deviation (MD), and pattern standard deviation (PSD) were evaluated. For each subject, the change in MD and PSD in the eye that underwent cataract surgery was adjusted for change in the control eye that is thought to occur due to a learning effect.

Results: Among the eyes that underwent cataract surgery, the median preoperative VA was 20/60 (range, 20/30–20/800) and the mean preoperative MD was -4.00 ± 3.72 decibels (dB). Postoperatively, the median VA improved to 20/30 (range, 20/20–20/70) and the mean postoperative MD was -0.26 ± 3.09 dB ($P<0.001$). Among the control eyes, MDs were -1.74 ± 3.71 dB preoperatively and -0.94 ± 3.85 dB postoperatively ($P = 0.019$). The adjusted improvement in MD among eyes that underwent cataract surgery was 2.94 ± 3.44 dB ($P<0.001$). There was no significant change in PSD. Preoperative VA correlated significantly with preoperative MD ($r = 0.39$, $P = 0.01$). The improvement in VA correlated significantly with the adjusted improvement in MD ($r = 0.38$, $P = 0.01$).

Conclusions: Cataract has an adverse effect on the MD but not the PSD in FDT perimetry. Among eyes with visually significant cataract, the MD correlates significantly with VA. After cataract surgery, the change in VA correlates significantly with the adjusted change in MD. *Ophthalmology 2004;111:1504–1507 © 2004 by the American Academy of Ophthalmology.*

The diagnosis of glaucoma and the detection of progressive glaucomatous damage are heavily dependent on visual field (VF) evaluation. However, it has been demonstrated that in some eyes a large proportion of retinal ganglion cells are lost before the development of a reproducible VF defect using standard, white on white, automated static perimetry.[1,2] This has led to the development of newer perimetric techniques, such as frequency-doubling technology (FDT) perimetry and short-wavelength automated perimetry, which may be able to detect VF deficits earlier in the disease course.[3–5]

Although controversial, detection of the FDT stimulus is thought to be at least partially dependent on the frequency-doubling illusion, in which the spatial frequency of a sinusoidal grating appears doubled when it undergoes high temporal frequency counterphase flicker.[6–9] It is thought that the frequency-doubling stimulus may, to some degree, isolate the function of the nonlinear magnocellular ganglion cell system.[3,10] Because there is evidence that large-diameter magnocellular ganglion cells are preferentially lost in glaucoma,[11] FDT perimetry may, theoretically, be more effective in the detection of glaucomatous VF deficits. An alternative hypothesis is that FDT perimetry may detect deficits earlier because at low contrast levels there are fewer redundant systems available for the detection of the stimulus. Additionally, there is evidence that the frequency-doubling illusion may be mediated by cortical mechanisms and is related to phase discrimination difficulties at high temporal frequencies.[8]

A shortcoming of standard clinical perimetry in the detection of glaucomatous VF progression is the confounding issue of cataract. It has been demonstrated that cataract adversely impacts visual sensitivity as measured by standard automated perimetry.[12–16] As demonstrated in large multicenter, prospective clinical trials such as the Collaborative Normal-Tension Glaucoma Study[17] and the Advanced Glaucoma Intervention Study,[18] progressive lens

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opacity may frequently mimic progressive glaucomatous VF loss. Glaucoma and cataract are both more prevalent with increasing age, and additionally, surgical and medical modalities used in the treatment of glaucoma may themselves increase the likelihood of cataract development.

Because it has been demonstrated that the FDT stimulus may be resistant to refractive blur,[19,20] we hypothesized that it may also be resistant to the effects of cataract to some degree. We prospectively performed FDT perimetry in a consecutive series of otherwise normal patients scheduled to undergo cataract surgery, both preoperatively and postoperatively, to explore the effect of cataract on the results of FDT perimetry.

Materials and Methods

Patients ≥18 years old, diagnosed with visually significant cataract, and scheduled to undergo cataract surgery were prospectively identified by their attending ophthalmologists and referred to the study coordinator. Subjects were excluded if any ophthalmic disease processes other than cataract were present. Exclusion criteria included refractive error greater than ±6 diopters (D) sphere or ±3 D cylinder.

Best spectacle-corrected visual acuity (BSCVA) was assessed by the attending ophthalmologist during each patient's regularly scheduled clinical visits. Data regarding preoperative and postoperative visual acuity (VA) were obtained from the medical record during the study visits, which usually occurred on the same days as the clinical visits.

Within 1 month before cataract surgery, subjects underwent FDT perimetry with a commercially available instrument (Welch Allyn, Inc., Skaneateles Falls, NY; Carl Zeiss Meditec, Dublin, CA) for both eyes. After subjects were instructed regarding testing procedures, a practice session consisting of a screening mode FDT test was performed for one eye. After the patient demonstrated an adequate ability to perform the test, a full-threshold C-20 VF was performed for each eye, with the patient's glasses on, and with normal ambient room lighting. The mean deviation (MD) and pattern standard deviation (PSD) were reported on the FDT printout, and were entered in a database.

Frequency-doubling technology perimetry was repeated, as described above, including a practice session, between 3 weeks and 3 months after uncomplicated cataract surgery was performed. Subjects were excluded from the study if one or more VF tests were unreliable based on the presence of fixation losses or false-negative or false-positive response rates of ≥33%. Patients who underwent cataract surgery in the control eye before postoperative VF assessment were excluded from the study.

For each subject, the adjusted improvement in MD or PSD for the eye that underwent cataract surgery was calculated by subtracting the change (postoperative global index value − preoperative global index value) in each of those values in the control eye from the change for that value in the eye that underwent cataract surgery. This was done to correct for the learning effect that has previously been described for FDT perimetry.[21–23]

To determine if changes in threshold sensitivity varied, depending on the location of the areas of the VF tested, the 5 central targets were compared with the 12 peripheral targets. The mean threshold sensitivity among the 5 central targets was calculated for each eye of each subject, both before and after cataract surgery. The mean threshold sensitivity among the 12 peripheral targets was similarly calculated. Adjusted improvement in mean threshold sensitivity was then calculated for the group of 5 central targets and the group of 12 peripheral ones.

Each VF was classified as normal or abnormal. An abnormal VF was defined as one with ≥3 contiguous targets with threshold sensitivity at $P<5\%$, with at least one of those points being abnormal at the $P<2\%$ level.

Statistical comparisons were performed with 2-tailed, paired *t* tests. Correlations between baseline VA and baseline MD and between improvement in VA and adjusted improvement in MD in eyes that underwent cataract surgery were explored using regression analysis with the Pearson product moment correlation coefficient and the Spearman rank correlation coefficient. $P<0.05$ was considered significant.

This study was reviewed and approved by the Northwestern University Office for the Protection of Research Subjects. Each participant provided written informed consent before enrollment in this study. This work is compliant with the Health Insurance Portability and Accountability Act of 1996.

Results

Fifty-two patients completed the study. Among these, at least one unreliable VF test was obtained for 8 subjects. These patients were excluded from the study, leaving 44 patients for analysis. The median age was 67 years (range, 42–89). Twenty-five right eyes and 19 left eyes underwent cataract surgery. There were no surgical complications in this cohort. The median preoperative BSCVA was 20/60 (range, 20/30–20/800). The median postoperative BSCVA was 20/30 (range, 20/20–20/70).

The mean MD, PSD, and adjusted MD and PSD are summarized in Table 1. The mean preoperative and postoperative MDs in eyes that underwent cataract surgery were −4.00±3.72 decibels (dB) and −0.26±3.09 dB, respectively ($P<0.001$). The mean preoperative and postoperative MDs in control eyes were −1.74±3.71 dB and −0.94±3.85 dB, respectively ($P = 0.019$). Of the control eyes, some were already pseudophakic, and some others had cataract; however, none underwent surgery during the study period. The mean adjusted improvement in MD among the eyes that underwent cataract surgery was 2.94±3.44 dB ($P<0.001$).

The Pearson product moment correlation coefficient between the baseline VA and the baseline MD in the eyes that subsequently underwent cataract surgery was $r = 0.39$ ($P = 0.01$). The Spearman rank correlation coefficient was $r_s = 0.29$ ($P = 0.06$). The Pearson product moment correlation coefficient between improvement in VA and adjusted improvement in MD was $r = 0.38$ ($P = 0.01$) (for the Spearman, $r_s = 0.37$, $P = 0.01$).

There was no significant difference in adjusted improvement of threshold sensitivity between the mean of the 5 central targets (4.30±4.60 dB) and the mean of the 12 peripheral targets (3.82±4.92 dB) ($P = 0.39$). Among the control eyes, there was also no difference in improvement between the mean of the 5 central targets (0.77±3.55 dB) and the mean of the 12 peripheral targets (1.18±3.71 dB) ($P = 0.40$).

Among eyes that underwent cataract surgery, 58.5% had an abnormal VF before surgery, compared with 14.6% after cataract surgery. Among the control eyes, 29.3% were abnormal before surgery in the fellow eye, compared with 24.4% after cataract surgery.

Discussion

It has been demonstrated that the presence of visually significant lens opacity is associated with a loss of sensitivity, as assessed by standard achromatic automated static perim-

Table 1. Mean Deviation (MD), Pattern Standard Deviation (PSD), and Adjusted MD and PSD

Preoperative		Postoperative		Change (Postoperative − Preoperative)				Adjusted Change* (Postoperative − Preoperative)			
MD	*PSD*	*MD*	*PSD*	*MD*	P	*PSD*	P	*MD*	P	*PSD*	P
Surgical eyes (n = 44)											
−4.00 (±3.72)	4.96 (±2.13)	−0.26 (±3.09)	4.53 (±1.67)	3.74 (±3.31)	<0.001	−0.43 (±2.02)	0.167	2.94 (±3.44)	<0.001	−0.31 (±3.25)	0.53
Control eyes (n = 44)											
−1.74 (±3.71)	5.03 (±2.43)	−0.94 (±3.85)	4.91 (±2.33)	0.80 (±2.17)	0.019	−0.12 (±2.40)	0.75				

Units for MD and PSD are decibels. All values are listed as mean (standard deviation).
*Adjusted changes in MD and PSD were calculated for each subject by subtracting the change in each of those values in control eyes from the change in the same value for the eye that underwent surgery.

etry; however, to our knowledge, this has not been previously reported using FDT perimetry. In this study using FDT perimetry, our findings were similar to those previously reported for achromatic automated static perimetry.[12,13] We found that surgery for visually significant cataract is associated with a significant improvement in MD but not PSD. We also found a significant improvement in MD in the control eyes, presumably due to the previously described learning phenomenon with FDT perimetry.[21–23] Even adjusting for the magnitude of improvement in MD in the control eyes, the eyes that underwent cataract surgery experienced a significant improvement in MD. The absence of significant change in PSD was as expected because the influence of cataract on visual sensitivity diffusely impacts the entire field, whereas PSD increases in the setting of focal deficits in visual sensitivity. This was further corroborated by the fact that the magnitudes of the adjusted improvement in threshold sensitivity were similar in both the central and the peripheral portions of the VF area tested by FDT perimetry. The MD is the mean of the difference between the measured threshold sensitivity of all targets tested. The PSD is the mean of the difference between each sensitivity value and the normal value, adjusted for the MD. The PSD is an index of the bumpiness of the visual sensitivity map.

Although the methods utilized in providing routine clinical care for the study subjects likely provided a reasonable estimate of BSCVA and refractive status, a limitation of this study is the lack of a standardized technique to determine these measurements. Errors in the determination of BSCVA would only impact the analyses to correlate VA with MD and changes in VA with adjusted changes in MD. With the use of the low–spatial frequency targets used in the commercially available FDT device, as in this study, errors in refractive status (up to 6 D) are not likely to have a substantial impact on MD or PSD.[24,25]

The hypothesis that the FDT stimulus may be resistant to the effect of cataract was based largely on evidence that refractive blur does not result in a dramatic decline in sensitivity to the FDT stimulus.[19,20] However, a low MD in eyes with cataract is not analogous to the effects of refractive blur, but instead is due to the effects of veiling glare, which has a more severe impact in contrast sensitivity.[26]

Frequency-doubling technology perimetry has been shown to be sensitive and specific in the detection of glaucomatous VF deficits[27–34] and may be more sensitive than conventional achromatic automated static perimetry.[31] Therefore, FDT perimetry may ultimately prove valuable in the serial observation of patients with glaucoma, particularly if the testing algorithms are refined. As has been shown with standard perimetry, the effect of progressive cataract may prove to be a confounding variable in the detection of progressive glaucomatous VF loss using FDT perimetry.

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