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Effects of Cataract Extraction on the Outcomes of Automated Perimetry and Retinal Nerve Fiber Layer Thickness Measurements by Optical Coherence Tomography in Primary Angle Closure Glaucoma

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Abstract

Objective: To evaluate the effect of cataract extraction on both visual field and retinal nerve fiber layer thickness measurements in primary angle closure glaucoma (PACG) eyes.

Methods: Retrospective cohort study on 30 PACG eyes underwent cataract extraction. Changes in RNFL thickness and visual field parameters including mean deviation (MD), visual field index (VFI) and pattern standard deviation (PSD) were analyzed within 6 months before and after cataract extraction.

Results: Overall, MD (p=0.003) and VFI (p=0.004) improved significantly after cataract extraction, whereas PSD showed no significant change (p=0.6). In the 10 eyes with MD worse than -20 dB, mean MD improved by 3.4 ± 3.56 dB (from -24.36 ± 3.06 dB to -20.96 ± 5.06 dB, p=0.01) and mean VFI improved by 16.25 ± 15.66% (from 23.38 ± 9.65% to 39.63 ± 20.83%, p=0.02). PSD showed no significant change after cataract extraction (p=0.07). In the 20 eyes with MD better than -20 dB, MD and VFI also improved postoperatively, but the changes did not reach statistical significance: mean MD improved by 1.64 ± 3.65 dB (from -11.57 ± 5.57 dB to -9.92 ± 5.36 dB, p=0.05) whilst mean VFI improved by 4.57 ± 12.29% (from 74.95 ± 17.95% to 79.52 ± 17.26%, p=0.07). RNFL thickness did not show any significant changes after cataract extraction (p=0.13).

Conclusions: Both MD and VFI improved after cataract extraction, especially in eyes with pre-operative MD worse than -20 dB. PSD and RNFL thickness showed no significant change after cataract extraction.

Keywords: Perimetry, Visual field, Optical coherence tomography, Retinal nerve fiber layer thickness, Primary angle closure glaucoma, Cataract; Extraction

Introduction

In primary angle-closure glaucoma (PACG), iridotrabecular contact developing from predisposing anterior segment anatomy, blocks the outflow of aqueous humor, thus potentially leads to elevated intraocular pressure (IOP) and progressive irreversible optic neuropathy. PACG has a higher prevalence in Asia and it is a leading cause of irreversible blindness in the Chinese population [1-3].

The evaluation of glaucoma progression is highly dependent on perimetric visual field (VF) assessment and retinal nerve fiber layer (RNFL) thickness measurements by optical coherence tomography (OCT). More recently, cataract extraction has been considered as one of the treatments for PACG particularly in patients with co-existing cataract [4,5], which might affect the assessment of visual field and retinal nerve fiber layer (RNFL) thickness, thus functional and structural assessment of glaucoma progression.

Previous studies [2,6-11] on open angle or mixed glaucomatous eyes have shown statistically significant changes in visual field parameters after cataract extraction. Similarly, cataract extraction was found to have significant impact on RNFL thickness measurements [12-15]. As most PACG subjects are more advanced in age and are more prone to receive cataract extraction during their follow-up duration, evaluating visual field and RNFL progression in glaucomatous eyes following cataract extraction is a common challenge. However, there has been no study reported that specifically analyzed the effect of cataract extraction on visual field and RNFL thickness measurements in PACG patients. The aim of this study is to analyze the effect of cataract extraction on VF and RNFL thickness measurement therefore providing evidence for clinical decision-making and future interpretation of long term VF and RNFL changes in these patients.

Materials and Methods

This was a prospective cohort study in which patients diagnosed with PACG at the Hong Kong Eye Hospital were enrolled between June 2009 to February 2013; according to the inclusion and exclusion criteria, same as one of our previous study [16]. 397 PACG patients were recruited and 665 eyes were followed up regularly every 3 months. The following parameters were recorded at every follow up visit: best-corrected visual acuity, spherical refractive error, intraocular pressure (IOP) measured with a Goldmann applanation tonometer on a slit-lamp biomicroscope, number and type of IOP-lowering medications, gonioscopic examination of angle structures and Shaffer grading. Visual field by automated perimetry and RNFL thickness measurements by OCT were documented every 6 months.

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Of this cohort, those who underwent cataract extraction by phacoemulsification with intraocular lens implantation during the follow-up period (between June 2009 and February 2013) were identified. Those with automated perimetry and OCT RNFL being performed within 6 months before and within 6 months after cataract extraction were included in the retrospective analysis. A total of 30 PACG eyes of 30 patients were included in this study.

Static automated white-on-white threshold perimetry was performed using the Humphrey Field Analyzer II (Carl Zeiss Meditec, California, USA) (central 24-2 threshold test, Swedish Interactive Thresholding Algorithm (SITA)-standard strategy, size III white stimulus, with the fovea threshold test turned on). A visual field is defined as reliable when fixation losses are less than 33% and false positive and false negative rates are less than 25%. Only reliable tests were included in the analysis. From the automated perimetry, the following visual field parameters were documented: Mean Deviation (MD), Pattern Standard Deviation (PSD) and Visual Field Index (VFI).

RNFL thickness was measured by spectral-domain optical coherence tomography (SD-OCT) imaging system (Spectralis HRA+OCT; software version 3.1. Heidelberg Engineering, Heidelberg, Germany) and expressed as μm. The mean RNFL thickness as well as sectoral RNFL thickness (nasal, temporal, nasal-superior, nasal-inferior, temporal-superior, temporal-inferior) was measured at recruitment (baseline) and then at each 6-month follow up visit during the study period.

The outcome of the study was the mean changes of VF parameters and RNFL thickness measured within 6 months before and after cataract extraction during the study period.

The study complied with the Declaration of Helsinki and the International Conference on Harmonization of technical requirements for registration of pharmaceuticals for human use - Guideline for Good Clinical Practice (ICH-GCP) guidelines (Version E6, 1996). Informed consent was obtained from all patients prior to enrollment.

Statistical analysis

Statistical analyses were performed using Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, Washington, USA) and IBM Statistics 20 (IBM Corporation, Armonk, New York, USA). Continuous variables were expressed as mean ± standard deviation, whilst categorical variables were expressed as individual counts and proportions. Data were first tested for normality assumption with the Shapiro-Wilk test. If the data were normally distributed, continuous data were compared using Independent-Samples T Test for independent samples and Paired-Samples T Test for paired samples. If the data set were not normally distributed, non-parametric method Kruskal–Wallis Test was used for comparing more than two samples that were independent; Wilcoxon Signed Rank Test was used for the comparison of paired samples and Spearman's correlation analysis was used for the correlation between two parameters. A p value of <0.05 was considered statistically significant.

Results

30 eyes of 30 PACG patients who received cataract extraction by phacoemulsification during follow-up were included. Mean age of the patients was 74.11 years old, ranged from 47.7 years old to 89.5 years old. 11 patients were male and 19 patients were female.

After cataract extraction, MD and VFI significantly improved, moreover, the change in MD and the change in VFI were in a very close relationship (Figure 1); whereas, PSD and mean RNFL thickness did not show any statistically significant changes. Sub-group analysis was performed using MD of -20 dB as a cut-off. In the 10 eyes with MD worse than -20 dB, improvement in MD and VFI were of greater magnitude compared to those of the rest of the study eyes. In the 20 eyes with MD better than -20dB, improvement in MD was of smaller magnitude compared with the whole cohort, and the improvement in VFI became statistically insignificant (Table 1).

For the RNFL thickness, neither average nor each sectorial part showed any significant change before and after cataract extraction (Figure 2).

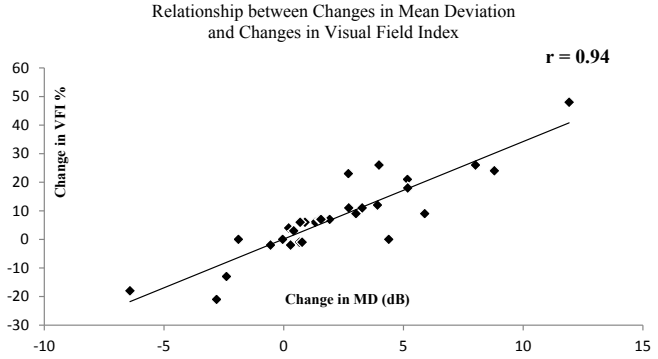

Figure 1: Scatter plot showing a very close relationship between changes in Mean Deviation (MD) and changes in Visual Field Index (VFI).

N=30	Before CE Mean ± SD (range)	After CE Mean ± SD (range)	Value of Change Mean ± SD (range)	*P* Value
MD dB	-15.41 ± 7.71 (-29.44- -1.77)	-13.23 ± 7.30 (-29.67- -1.11)	2.17 ± 3.65 (-6.42-11.92)	0.003*
PSD dB	6.41 ± 3.15 (1.29-12.32)	6.61 ± 3.51 (1.32-14.45)	0.20 ± 2.04 (-3.71-5.19)	0.60*
VFI%	60.72 ± 28.34 (9-99)	68.52 ± 25.50 (7-99)	7.53 ± 13.89 (- 21-48)	0.004#
RNFL μm	73.67 ± 22.21 (33-116)	68.84 ± 22.64 (31-106)	-1.96 ± 6.17 (-16-7)	0.13*
In eyes with MD better than –20 dB (n = 20)				
MD dB	-11.57 ± 5.57 (-19.90 - -1.77)	-9.92 ± 5.36 (-20.54- -1.11)	1.64 ± 3.65 (-6.42-8.80)	0.05*
PSD dB	5.88 ± 3.32 (1.29-12.32)	5.59 ± 3.37 (1.32-12.55)	-0.28 ± 1.97 (-3.71-3.6)	0.52*
VFI%	74.95 ± 17.95 (45-99)	79.52 ± 17.26 (33-99)	4.57 ± 12.29 (-21-26)	0.07#
In eyes with MD worse than –20 dB (n = 10)				
MD dB	-24.36 ± 3.06 (-29.44- - 21.58)	-20.96 ± 5.06 (-29.67- -12.95)	3.41 ± 3.56 (-0.55-11.92)	0.01#
PSD dB	7.67 ± 2.47 (4.49-11.84)	8.99 ± 2.67 (5.39 - 14.45)	1.31 ± 1.85 (-0.78-5.19)	0.07*
VFI%	23.38 ± 9.65 (9-34)	39.63 ± 20.83 (7-68)	14.44 ± 15.66 (-2-48)	0.02*

MD: Mean Deviation; PSD: Pattern Standard Deviation; VFI: Visual Field Index; SD-OCT: Spectral-Domain Optical Coherence Tomography; RNFL: Retinal Nerve Fiber Layer; *Paired-samples T test; #Wilcoxon signed Rank test.

Table 1: Comparison of visual field parameters before and after cataract extraction by phacoemulsification in PACG eyes.

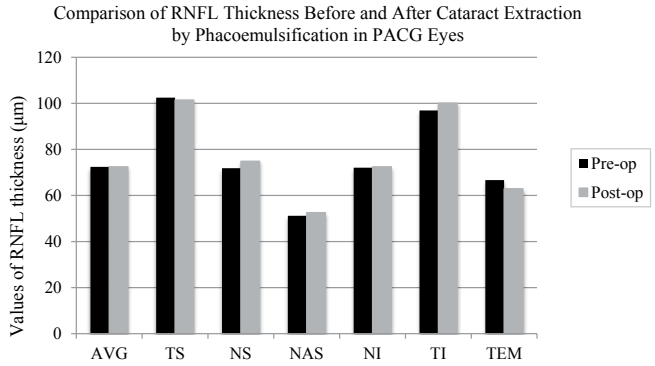

Figure 2: The mean average and sectorial peripapillary RNFL thickness showed no significant difference before and after cataract extraction. AVG: Average; TS: Temporal Superior; NS: Nasal Superior; NAS: Nasal; NI: Nasal Inferior; TI: Temporal Inferior; TEM: Temporal.

Discussion

This is the first study demonstrating the effect of cataract extraction on both functional and structural changes in primary angle closure glaucoma.

Our findings showed that in PACG patients, there was significant improvement in MD and VFI after cataract extraction, whereas PSD and RNFL thickness did not show any significant change.

Effect of cataract extraction on visual field

MD is one of the most useful global visual field indices, as it represents the average difference between normal age-corrected sensitivity values and the measured threshold values at all test locations. As MD is calculated based on the total deviation map, it is believed that its inherent limitation is the compound effect of diffuse depression caused by coexisting cataract. Therefore, the significant improvement in MD after cataract extraction is not a surprising result, and this has been proven in other studies [6-11].

However, changes in PSD after cataract extraction have been variable in different studies. PSD measures the standard deviation of each point from the age-corrected normal value. A higher PSD reflects a more irregular visual field pattern. It increases during the initial stages of glaucoma progression, reaches a peak during the advanced stage of glaucoma and then decreases again as the visual field becomes severely constricted and uniformly depressed. Thus, focal visual field defects will produce a high PSD; whereas near-normal and severely constricted visual fields will both have a low PSD [17]. Previous studies have had variable results in terms of change in PSD: some showed improvement [9,18], some showed deterioration [8,11,19] and some showed no significant change [6,10,14]. One hypothesis to explain these conflicting results is that cataracts are not of uniform density and therefore its effect on PSD is variable in different patients. In our study, PSD decreased in 11 patients, increased in 13 patients and remained almost the same in 6 patients after cataract extraction. PSD showed no significant changes even after stratification by MD.

VFI is an index developed by Bengtsson and Heijl for the Humphrey perimetry, which is expressed as a percentage, where 0% represents a blind field and 100% represents a normal field [20]. VFI is less affected by cataract and cataract extraction than the traditional MD index. It utilizes the age-corrected pattern deviation probability map for the identification of depressed visual field points, and the sensitivity at each point is scored with a percentage. However, if the MD is worse than -20 dB, which was the estimated valid operating range for pattern deviation analysis, it then utilizes the total deviation map instead to identify significantly depressed points.

In our study, VFI showed significant improvement after cataract extraction in patients with MD worse than -20 dB, but was not affected by cataract extraction in patients with MD better than -20 dB. This can be explained by the fact that for patients with MD worse than -20 dB, VFI is based on total deviation analysis, whereas for patients with MD better than -20 dB, VFI is based on pattern deviation analysis. These findings are in agreement with those from another study done by Rao et al. [9].

Effect of cataract extraction on rnfl thickness measured by OCT

Optical coherence tomography (OCT) is a non-invasive imaging modality that can obtain high-resolution cross-sectional images of the retina, optic nerve head and anterior segment by measuring light reflected from various structures at different depths in the eye [21,22]. Previous studies have shown that cataracts could cause a reduction in both signal strength and measurements of RNFL thickness [12-14,23]. However, results from our study showed no significant change in RNFL thickness after cataract extraction. This may be explained by the use of a different OCT device in our study. The various commercially available OCT devices differ in wavelength of their light source, scanning speed, axial resolution and segmentation algorithm software. The OCT device used in our study, Spectralis HRA+OCT, is the only device has a long wavelength of 870 nm allowing a better penetration through existing cataract. And together with other enhancement such as a coefficient variance of less than 1.0, a faster scanning speed of 40000 A scans/sec, better axial resolution of 7 um and an eye-tracking system to account for eye movement, this probably explain why the RNFL thickness measurements by Spectalis HRA+OCT is less susceptible to the effect of media opacity as compared to previous literature using other OCT devices [24,25].

Conclusions

We analyzed the effect of cataract extraction on visual field and RNFL thickness in patients with PACG and co-existing cataract. We found that MD and VFI on 24-2 SITA standard perimetry improved significantly after cataract extraction, especially in eyes with MD worse than -20 dB, whereas PSD showed no significant change. Peripapillary RNFL thickness measured by Spectralis HRA+OCT was not affected by cataract extraction. From these findings, it can be inferred that cataracts cause a reduction in MD and VFI. Therefore, when evaluating PACG progression in patients with co-existing cataract, visual field should be interpreted with caution. Furthermore, in PACG patients who have undergone cataract extraction, baseline perimetry may need to be repeated after cataract extraction. On the other hand, OCT RNFL measured by Spectralis OCT has shown to be a very useful surrogate in monitoring disease progression in PACG eyes with cataract.

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Conflict Interest

The authors have no conflict interests to declare.

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