

Evaluation of computerized image analysis system for quantification of posterior capsular opacification

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Abstract

• **AIM:** To set up and evaluate a computerized image scoring system for quantification of posterior capsular opacification (PCO) that is independent of examinee.

• **METHODS:** The PCO model was made in rabbits. Following dilation of the pupil (>6.5mm), standardized digital images of the PCO were obtained using slit-lamp photographic system (digital camera, computer included). PCO was scored by evaluating retroillumination photographs. The PCO score was calculated by the formula: $PCO\ score = \sum (OD \times AI\ in\ CR) \times 2 + \sum (OD \times AI\ in\ OR)$, in which OD is opacity density (class 0 to 4), AI is the opacity area fraction, CR is the central region (diameter=3mm), OR is the outer region (3-6mm ring region). To evaluate the reliability of the scoring system, 6 examiners scored the pictures of 5 same eyes (interindividual reliability), and one examiner scored the pictures of 5 eyes on five different days (intraindividual reliability).

• **RESULTS:** The PCO scoring system was very reliable. With PCO score range from 0 to 1.5, the interindividual reliability showed standard deviation between 0.05-0.087. Kruskal-Wallis analysis showed no significant difference ($H=0.314, P=0.9726$). The intraindividual reliability showed standard deviation between 0.041-0.067, no significant difference either ($H=0.613, P=0.9616$).

• **CONCLUSION:** This PCO quantification analysis system evaluates the central area (diameter=6mm) of posterior capsule which is larger than visual acuity or other objective testing. The system revealed high reliability and insignificant investigator-dependent difference. With a standardized photographic setup, systematic errors by the photographic technique were not relevant. This system was proved to be an easy

and useful tool to accurately evaluate PCO.

• **KEYWORDS:** posterior capsular opacification; digital image; quantification analysis

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INTRODUCTION

Cataract is the number one cause of blindness in China. Extracapsular cataract extraction with intraocular lens implantation is the most effective way for vision rehabilitation in cataract patients. The most important problem postoperatively is the opacification of the posterior capsule (after cataract). The incidence of posterior capsular opacification (PCO) has been reported to vary from 18% to 50% within 5 years postoperatively, while it was almost 100% in adolescence^[1].

At present, the diagnosis for after cataract is mainly based on the clinical observation, including visual acuity, contrast sensitivity, or slit-lamp findings, which are subjective. It is quite valuable and important to be able to analyze the PCO quantitatively, to define the severity and range of it. Quantification of PCO is important in the clinic and research field. At clinic, it can help the doctor to decide when to treat the PCO; in research, it can help the study of PCO etiology, monitoring its development, evaluating the surgery outcome, and the influence of risk factors such as intraocular lens material, design or other factors which may lead to PCO.

With the fast development of computer technology, several softwares for evaluation of PCO quantification were developed recently. In which, the EAS-10000 (Nidek, Japan) and EPCO software were relatively well used. However, the images analyzed in EAS-10000 system were slit images, which cannot reflect the true and whole situation of after cataract. The EPCO software outcome may be influenced by the examiner. What is more, all these instruments and softwares were quite expensive, not affordable in China.

There is a large number of cataract patients in China, and the incidence of after cataract is quite high. It will be helpful to many practicing/research-oriented ophthalmologists if an

affordable software is available to quantify the severity of posterior capsular opacification. Therefore, the objective of this research project was to develop a software of our own and to analyze the severity of posterior capsular opacification.

MATERIALS AND METHODS

Materials Thirty healthy white rabbits, 8 weeks old, 1.0±0.2kg weight; phaco machine (NIDEK CV-8000, Japan); slit-lamp camera (YZ5FI, Suzhou Medical Instruments Company).

Methods

Rabbit PCO animal models Under general anesthesia, biocular extracapsular lens extraction with phacoemulsification was performed in 30 rabbits. The continuous circular capsulorhexis was 6mm. Postoperatively, the pupil was dilated with Mydrin-P, and topical Tobrex was administered twice a day.

Development of PCO-CAAS software In collaboration with software engineers, a set of digital image collecting method and PCO qualification analysis software -PCO-CAAS (PCO-Computer-aided Analysis System) were set up.

Observation and documentation of PCO With general anesthesia and pupil dilation (pupil diameter >6.5mm), the digital image of PCO was taken at 15, 30 and 60 days postoperatively. 5 eyes were randomly chosen to take pictures on 5 successive days (60-64d). Photograph condition: image under dispersive light: slit angle 45°, slit width 3.5mm, slit height 9mm, magnification ×16; retroillumination image: coaxial slit width 2-3mm, slit height 9mm, magnification ×16. The quality of image can be observed on the computer screen. Photographs were made repetitively until satisfying image was gained, and saved as JPGE/BMP files. Images under dispersive light were used to record the general condition of PCO, and retroillumination images were used for PCO evaluation.

PCO evaluation The retroillumination images were stored in the computer and analyzed by the PCO-CAAS software. Region of interest (ROI): 6mm-diameter posterior capsule centered by visual axis. Evaluating method: the opacity density (OD) of posterior capsule was divided into five grades: Grade 0: no opacity; Grade 1: mild opacity, but fundus examination and red reflex were unaffected; Grade 2: mild opacity, fundus examination was limited, and the red reflex of fundus decreased; Grade 3: moderate opacity, fundus blurred, and no red reflex; Grade 4: severe opacity, fundus examination was blocked. The ROI was divided into 2 parts: center region (CR), the 3mm diameter posterior capsule centered by vision axis; Outer region (OR): the 3mm-6mm ring region. The area index (AI) of each grade of posterior capsular opacity, which was the area percentage of each grade opacity in ROI, can be calculated by computer directly. PCO Score (PS)=Σ (OD×AI in CR)×2 +Σ (OD×AI in OR) (Figure 1).

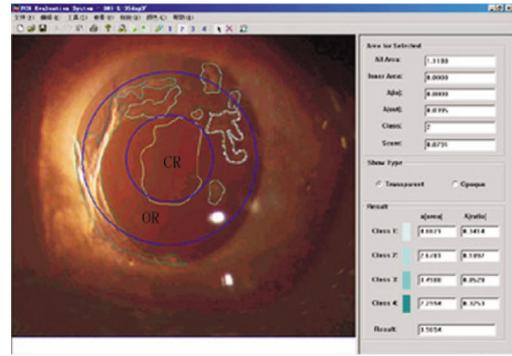


Figure 1 The working screen of PCO-CAAS system. The blue circles represent the region of interest (ROI) i.e center region (CR) and outer region (OR) respectively. The PCO score is given on the right side of the screen directly

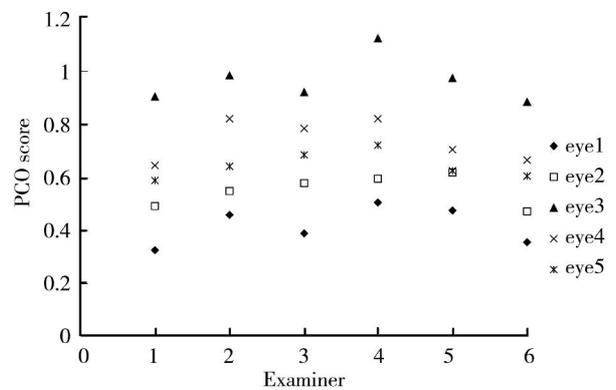


Figure 2 showing posterior capsular opacification (PCO) scores between the six examiners

Evaluation of the reliability of PCO-CAAS software

Interindividual difference: 5 pictures were analyzed with PCO-CAAS software by 6 examiners. The results were compared for similarity. All the 6 examiners have to be trained to use the PCO-CAAS software before entering this study. **Intraindividual difference:** the pictures of 5 eyes in 5 successive days were analyzed by same examiner, and the results of each eye were compared for similarity. These 25 pictures were mixed, so the examiner was unaware of the arrangement to reduce the individual bias.

Statistical Analysis Non-parameter test, Kruskal-Wallis analysis, software EPI-Info (WHO, Version 6.0) were used.

RESULTS

By Kruskal-Wallis analysis, the interindividual difference between the 6 examiners was not statistically significant (Kruskal-Wallis $H=0.314, P=0.972618$). The standard variation was only 0.05-0.087, far less than the range of the PCO score (0-1.5) (Figure 2), which showed that there was reliability between the 6 examiners. The intraindividual difference was also not statistically significant, the standard variation was 0.041-0.067(Kruskal-Wallis $H=0.613, P=0.961617$, Figure 3), which was consistent and reproducible by the same examiner.

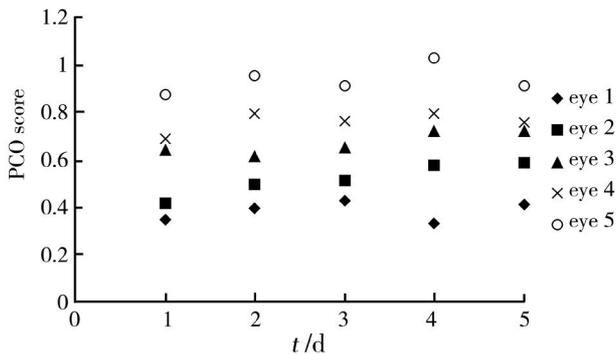


Figure 3 showing the posterior capsular opacification (PCO) scores by the same examiner on different days

DISCUSSION

With the improvement in extracapsular cataract extraction surgical techniques, the biomaterial reform and designing of intraocular lens, the outcome of cataract surgery is more perfect day by day. The PCO, the long-term complication, which can lead to the impairment of postoperative vision, is the main concern of cataract surgeons. The incidence of PCO was quite variable in the published reports, probably because the objectives of various studies were different, and the diagnosis criteria of PCO in these studies were different, such as the change in visual acuity, decrease in contrast sensitivity, the percentage of posterior capsule opening with YAG laser, or the subjective findings with slit-lamp [1-3]. However, the change in postoperative visual acuity and contrast sensitivity may be caused by factors other than PCO. For example, opacity in cornea or intraocular lens, pathological changes in retina [1-4]. The percentage of posterior capsule opening with YAG laser depended not only on the severity of PCO, but on the complaint of patients, medical condition, even economic factors [1-3]. Besides, it usually takes years for PCO to cause severe visual impairment, which means that long-term follow-up will be needed to evaluate the effect of certain factor on PCO if the percentage of posterior capsule opening with YAG laser was used as the diagnosis criteria. Schamberg [3] suggested that a standardized, acceptable and relatively objective method should be used to evaluate the severity and progress of PCO.

The PCO-CAAS software developed in this study used the digital images of PCO to analyze its severity. This procedure can be used in animal experiment and in the clinics as well. The results showed that the PCO-CAAS system was of high accuracy and reproducibility. The interindividual difference was not significant when used by different examiners. The standardized photography has significantly decreased the systemic bias. The most significant characteristics of

PCO-CAAS system was that the PCO evaluation area was 6mm-diameter round area centered by visual axis, which was region of interest (ROI). And the ROI was divided into the middle 3mm diameter central region (CR) and the outer 3-6mm ring region (OR). Under normal light illumination, the mean diameter of human pupil was 3mm. PCO in this area can affect the vision more than that in peripheral area, so the PCO in center 3mm region was weigh with coefficient 2; according to the report of Holladay [5], under dark illumination, the pupil size was 4.5-6mm, meanwhile the diameter of the IOL optics usually less than 6mm, so the center 6mm region was taken as the region of interest to evaluate the severity of PCO. The PCO located in the outer ring may be responsible for the postoperative complaint of glare and halo [6].

To judge the effectiveness of many procedures aiming at reducing PCO, such as intraoperative medication, improvement in surgical techniques, new IOL designing [1-3], many PCO qualification analysis system have been developed in recent years. The most commonly used software was EAS-1000 ocular anterior segment analysis system (Nidek, Gamagori, Japan). In this system, Scheimpflug principle was used to get a clear slit image of all the components of anterior segment. The design purpose of this system was to analyze the structure of anterior segment, and can be used for PCO evaluation too. The PCO severity was indicated by the density of scattered light of posterior capsule, which was computer compatible tapes (CCT). The relevant study showed that 4 slit images were collected on the meridian of 0, 45, 90, 135° to represent the PCO on the whole posterior capsule. For the digital image collected by EAS-1000 system was slit image, the evaluation result cannot represent the real situation of whole posterior capsule. And there was no confirmed conclusion whether EAS-1000 system can monitor the progress of PCO [7,8]. Wang *et al* [9] used digital images taken with an EAS anterior segment analysis system. Brightness of different points on the digital image was graded with 0 to 255 brightness units. A threshold of transparency was picked at 167 units and the computer then calculated the percentage level of transparency in a particular area, with any pixel being above that value considered as transparent. The advantage of this system is that it is objective in the sense that observers are not grading the opacification of posterior capsule. However, there are many possible sources of bias with this approach, such as the pupil size, fundus pigmentation, illumination condition, position of IOLs; all these factors may lead to the changes in the brightness of certain point. In general, this system is little

used in clinics because of abundant error sources.

Friedman *et al*^[10] and Findl *et al*^[11] used the texture of each pixel in the digital image to analyze PCO. The texture was based on the smoothness of certain point, no matter it was opaque or transparent, so the system has a pre-processing procedure to make the texture difference significant. This system included a set of complex photographing instruments and analysis software. The system is the most objective one at present, while part of the picture was adjusted during pre-processing which may lead to the errors in evaluating results.

In the systems mentioned above, there were limitations no matter which of the brightness of pixels, grey value or texture was used as criteria in evaluation. For special type of PCO, such as folds in posterior capsule, and pigmentation in posterior capsule, these systems can not get correct results. There is no system that can recognize the distinction between fibrosis and pearls till today^[12]. In the reports of these systems application, the evaluating results were compared with the clinical findings by experienced doctors, to prove the accuracy of computerized analysis.

To simplify the procedure, reduce equipment, increase practical value, we include the clinical PCO slit-lamp grading into our system, combined with computerized analysis of density boundaries. So the evaluation results of our system are semi-objective. With standard training procedure, cataract surgeons can easily master the usage of our system. PCO-CAAS is an easy, convenient system for PCO evaluation, and this can be used both in clinics and for research purpose.

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