Use of Photographic Techniques to Grade Nuclear Cataracts

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Methods for objectively documenting and grading different varieties of lens opacities are needed in order to conduct research on risk factors for cataracts. This study tested the feasibility and reliability of using two different photographic methods to grade nuclear opacities. Photographs were taken of 41 eyes using a regular Topcon SL-5D photo slit lamp, and using a Topcon SL-45 (Scheimpflug) camera. The photographs were graded against a set of four standard photographs of increasing nuclear opacification. Densitometric analyses were also performed on both sets of photographs. The clinical grade, on examination, of the nucleus was compared to the examiner's grade of each photograph. Agreement was fair between the examination results and the grading of the photographs. Inter-observer reliability was high (kappa = 0.71) with photographs taken using the photo slit lamp. Moreover, the severity grading of the photographs showed a good correlation with the severity of opacity as determined by densitometric analyses. On the basis of these data, and on the field experience, the use of photographs of the nucleus obtained by photo slit lamp may be used in epidemiological surveys.

Epidemiological studies have a high priority as part of a multidisciplinary effort to reduce the prevalence of cataracts by preventive measures.1 Epidemiological studies in populations yield important information on factors that increase the risk of cataracts and on potential intervention strategies. However, field research on risk factors has been hampered by a lack of standardized methods for determining the presence and severity of the lens opacity. To date, field surveys have relied solely on clinical examination to detect cataracts.

Well conducted studies have included trials of inter-observer agreement, where the same patient was examined by different ophthalmologists to insure that standardized training of personnel resulted in uniformity of diagnosis.2,3 However, large inter-observer trials, while necessary for documenting the degree of reliability in detecting cataracts, are expensive to conduct in the field, and time-consuming for patients as well as field staff. The results of the trials provide equivocal results on the inter-observer reliability for detecting and grading cataracts; the reliability for grading nuclear opacities was particularly poor.2,4 This problem may be partially alleviated by taking a photograph of the cataract, thereby obtaining objective documentation of the opacity which can be graded for severity using expert graders or densitometric analyses.

Epidemiological studies have moved towards distinguishing between the different anatomical types of lens opacities, based on data that suggest each type has unique biochemical properties and are probably initiated by different factors.2,5,6 Therefore, any alternative method of objectively detecting and grading cataract severity must differentiate at least the three common types of cataracts: nuclear, cortical and posterior subcapsular. Several photographic techniques have the potential to document and quantify the severity of the different types.9

MacLean and Taylor describe a system using a standard photo slit lamp camera to document cortical opacities on retroillumination photographs.10 Kawara and Obazawa refined the technique using polarizing filters to remove the flash artifact.11 Hockwin and Dragomirescu describe using a Topcon SL-45 Scheimpflug camera to document nuclear opacities, with severity graded using a microdensitometer;12 they have extended the system to classify other opacities as well, although there is disagreement that cortical cataracts can be well documented using this system.6,13 There is also concern that the camera system and densitometer would not be useful for large-scale epidemiological research.9

The purpose of this study was to test the feasibility,
Fig. 1. Scheimpflug photograph of nuclear opacity.

Fig. 2. Standard photographs of lens nucleus. Standard photograph 1 (top left): Faint opaque crescents can be seen in the nucleus but a clear central sulcus separates them. The opacities do not extend to the edges of the nuclear zone and are clearly demarcated. Standard photograph 2 (top right): Mild flocculant opacification with at least some opacity extending throughout most but not all of the nuclear zone. The opacities reach edges of the nuclear zone in some areas. Standard photograph 3 (bottom left): Increasing density of nuclear opacity with a uniform opacification of the whole nuclear zone which has no clear areas. The nucleus is clearly delineated from the rest of the lens. Standard photograph 4 (bottom right): Dense uniform nuclear opacity. Scheimpflug photograph of same opacity as seen in Figure 1.

reliability, and validity of two methods for photographing in vivo nuclear opacities. The specific issues addressed were to determine the inter-observer reli-

ability using a set of photographs to grade the severity of nuclear opacities seen on the photographs, and to assess how well the grading of nuclear opacities on photographs correlated with the clinical examination.

Materials and Methods

Photographs of the nucleus were taken with two camera systems using the following settings:

A. Topcon (Tokyo, Japan) SL-5D photo slit lamp (referred to as the "photo slit lamp") with power unit was used. The slit beam was 0.3 mm wide × 9 mm long angled at 30° to the visual axis and focused in the center of the nucleus. Magnification was ×16, the flash intensity was set at 5, equivalent to 200 watt seconds, and the film used was Kodak Ektachrome, ASA 200.

B. Topcon SL-45 camera built on the "Scheimpflug" principle (referred to as the "Scheimpflug" camera) was used with slit width of 0.08 mm; height of 10 mm, magnification setting of 0.5. Kodak Tri-X ASA 400 film was used. The picture was taken only when the audible signal indicated the light beam was in focus. The Scheimpflug camera has been regarded as the best system to use for anterior segment photographs because of its depth of focus and standard illumination (see Fig. 1).

Efforts were made in this study to reduce any variation in the photographs by using the same cameras, the same film from the same batch, and using only one photographer. Furthermore, aperture setting and shutter speed was the same for all photographs. In all cases, film was developed using identical procedures.

A set of four photographs taken with the photo slit lamp of increasingly severe nuclear opacities was selected from photographs of over 600 patients (see Fig. 2). The selection was based on the impact of the density of the nuclear opacity on visual acuity. The set of standard photographs was used to grade the nuclear portion of the lens in the photographs using the definitions as shown in Table 1.

Twenty-four adults (41 eyes with intact lens) presenting at Wilmer Eye Clinic for evaluation of cataract were entered into the study to compare the feasibility of the two photographic methods. Each patient received mydriatic drops and was examined with a slit lamp; the presence and severity of nuclear opacities were uniformly recorded on a form. The grading was performed without use of the standard photographs, and the ophthalmologist relied on a written description of the severity grade of nuclear opacity. The presence of nuclear cataract was documented by the assessment of the optical density rather than the color change which is seen in aging lenses. Clinically, nuclear opacities were graded from
1 to 4 according to the estimated impact on visual acuity. Grade 1 opacities were opacities that were definitely present but not thought to reduce visual acuity. Grade 2 opacities were consistent with a visual acuity between 20/20 and 20/30. Grade 3 opacities were consistent with vision between 20/40 and 20/100. Grade 4 opacities were consistent with vision of 20/200 or less.

Pictures were taken of each eye using each camera system. Pictures were not obtained because of poor dilation, or not usable for four eyes; clinical information on the severity of nuclear cataracts was inadvertently not recorded on two eyes.

To assess reliability of grading, all photo slit lamp photographs were graded by two ophthalmologists, using the photographic standards. All Scheimpflug photographs were also graded by each examiner using the grey scale that appears on each negative as a standard. Although one of the ophthalmologists conducted the clinical examination, each one was unaware of the original clinical examination findings and of the other’s grading while reviewing the photographs.

For purposes of assessing validity, densitometric analyses using an Optronics PI700 scanning densitometer were performed on 42 hand-masked photographs (21 randomly selected pairs of photo slit lamp and Scheimpflug photographs). Each photograph was first hand-masked to expose only the adult nucleus of the lens. Scans of this region were performed with a pixel size of 0.04 mm². Corresponding to each pixel was a density reading on an increasing scale of 0 to 255 (0–3 optical density range). A program was developed to calculate the minimum, maximum, mean and median density, the standard deviation and coefficient of variation for the unmasked nuclear portion of each photograph. Replicate densitometric analyses were done on four photographs to assure consistency in the readings. There were no differences in the median values from time 1 to time 2, so differences in the mean values were analyzed. There were no significant differences in the mean values between the replications, as measured by a paired t-test. The values for the differences in the two means for the Scheimpflug photographs were closer together (means 115.0 versus 113.0, and 143.7 versus 145.0) compared to the values for the photo slit lamp photographs (means 101.0 versus 110.0, and 79.7 versus 81.0). The distribution of densities was not normal, and we selected the median density value to represent the center of the distribution of pixel densities.

The weighted kappa statistic was used to assess the level of agreement among graders using the standard photographs to assess five categories of severity. Arbitrary values of weights were chosen at 1, 0.67, 0.33, and 0 to weigh the importance of perfect agreement to maximal disagreement.

Table 1. Nuclear opacity grading definitions*

<table>
<thead>
<tr>
<th>Nuclear Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No opacity. Less dense or less extensive than standard photograph 1.</td>
</tr>
<tr>
<td>1</td>
<td>Nuclear opacity present but consistent with 20/20 vision.</td>
</tr>
<tr>
<td>2</td>
<td>Nuclear opacity consistent with vision in the range 20/25 to 20/30.</td>
</tr>
<tr>
<td>3</td>
<td>Nuclear opacity consistent with vision 20/40 to 20/100.</td>
</tr>
<tr>
<td>4</td>
<td>Nuclear opacity consistent with vision less than 20/100.</td>
</tr>
</tbody>
</table>

* In the presence of cortical opacities which may cause intense light scatter, care must be taken not to overcall the density of the nuclear opacity. In these cases, particular attention must be directed to the uniformity and distribution of the nuclear opacity. The yellow-brown discoloration of the lens should be disregarded while grading.

Results

To assess inter-observer reliability, two examiners independently graded all photographs against the set of photographic standards (Table 2). High inter-observer reliability was seen with the grade of nuclear opacities in photographs taken with the photo slit lamp; the weighted kappa value of 0.71 indicates good reproducibility among graders. Fair reproducibility was seen with the grade of photographs taken with the Scheimpflug camera; the weighted kappa was 0.55.

The clinical grade of nuclear opacity was compared to the grade of the photographs taken with each camera system. Agreement was fair between the clinical examination findings and the gradings by the clinical examiner of the photographs taken with the photo slit lamp (Table 3). This agreement was better than that observed when the clinical examination results were

Table 2. Interobserver agreement between two readers grading nuclear opacities in photographs taken with the photo slit lamp and the Scheimpflug camera

<table>
<thead>
<tr>
<th>Camera</th>
<th>Percent agreement</th>
<th>Weighted kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo slit lamp</td>
<td>79%</td>
<td>0.71</td>
</tr>
<tr>
<td>Scheimpflug</td>
<td>59%</td>
<td>0.55</td>
</tr>
</tbody>
</table>
Table 3. Agreement between the grade of nuclear opacity by clinical examination with grade of photo slit lamp photographs for 36 eyes

<table>
<thead>
<tr>
<th>Clinical grade</th>
<th>Photograph grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity of opacity</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
</tr>
</tbody>
</table>

Weighted kappa = 0.41

* See text for description of severity categories.

Table 4. Agreement between the grade of nuclear opacity by clinical examination with the grade of the Scheimpflug photographs for 37 eyes

<table>
<thead>
<tr>
<th>Clinical grade</th>
<th>Photograph grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity of opacity</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Weighted kappa = 0.25

* See text for description of severity categories.

ASSOCIATION OF THE GRADING OF THE SCHEIMPFLUG PHOTOGRAPH WITH THE MEDIAN DENSITY OF THE NUCLEUS, MEASURED BY DENSITOMETRIC ANALYSES

ASSOCIATION OF THE GRADING OF THE PHOTO SLIT-LAMP PHOTOGRAPH WITH THE MEDIAN DENSITY OF THE NUCLEUS, MEASURED BY DENSITOMETRIC ANALYSES

Discussion

In general, these data suggest that photodocumentation of nuclear opacities, with subsequent grading by readers using standard photographs or by densitometric analyses, is a feasible and reliable alternative compared with the grade by the clinical examiner of Scheimpflug photographs (Table 4).

Twenty-one of the photographs were subjected to densitometric analyses of the nucleus, and the median density compared to the clinical grade of the photographs (Figs. 3, 4). Although the numbers are small in each category of severity, it is clear for both sets of pictures that the clinical grade generally “tracked” the densitometric analysis. In fact, the slope of the relationship is reversed, as expected with the two different types of photographs. The inverse association of density readings and positive photographs taken with the photo slit lamp reflects the fact that clear lens reflects no light and thus appears as “black” or most dense. The Scheimpflug camera produces a negative, so a clear lens appears white.

In terms of utility under field survey conditions, the Scheimpflug camera was found to be too light-sensitive and too delicate a system to use in other than a virtually dark photographic laboratory; the audible signal system for focusing properly reacted to even dim light from under doorways. In contrast, the regular photo slit lamp proved robust and relatively insensitive to less than ideal conditions encountered in field surveys.
to clinical examination alone for field surveys of cataracts.

The inter-observer reliability, as measured by two ophthalmologists independently grading each set of photographs against a standard set of photographs, was good, especially for photographs taken with the photo slit lamp. Because the standard set of color photographs was taken with the photo slit lamp, we expected more difficulty in using these standards to grade the black and white, negative photographs taken with the Scheimpflug camera. In fact, the weighted kappa for inter-observer agreement in grading the "Scheimpflug" photographs was acceptable, and could be expected to be higher if specific photographic standards for this camera were developed. For our purposes, a single set of standards was needed that could be used to grade severity for all aspects of a major field survey, including the clinical examination and photographs.

The grade of the photographs, using either camera system, showed only fair association with the clinical examination findings. An important contribution to the disparity was the fact that the actual photographic standards were not used during the clinical examination. The high inter-observer agreement seen with the grading of photo slit lamp photographs when photographic standards were used suggests that this is a much more reliable and reproducible method than clinical examination, especially when the clinical examination relies on a written description and does not use photographic standards.

The significantly poorer association of clinical grading with the gradings of the Scheimpflug photographs was thought to be due, in part, to a tendency to grade yellow lens as having more severe opacities during the clinical examination. The black and white photographs using the Scheimpflug camera obscured any bias due to color of the lens. In fact, the data suggest that most of the disagreement was due to assigning the Scheimpflug photographs to a less severe category than the grade assigned by clinical examination. Thus, the impact of the color of the lens on grading appeared to explain, in part, the poorer association.

The validity of using photographs of the nucleus and grading them according to a set of standard photographs was assessed in part by comparing the density of the nucleus on the photograph as measured by the densitometer with the severity as graded against the standards. While small numbers in some of the categories limited the association of densitometric data with the clinical grading, the change in the objective determinations of median density with the subjective grade of nuclear opacity reinforces the validity of using this grading scheme to interpret the photographs.

On the basis of these data and our field experience, the use of photographs of the nucleus of the lens obtained by photo slit lamp appears to be a realistic, reproducible and robust system for use in epidemiological field surveys of cataracts. The standard set of photographs of nuclear opacity that have been developed can be used reliably to grade the severity of nuclear opacity in such photographs.

Key words: cataracts, nuclear opacities, photograding, photo slit lamp, Scheimpflug camera

References

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