*Reprinted from the Archives of Ophthalmology*
*June 1993, Volume 111*


# The Lens Opacities Classification System III

Leo T. Chylack, Jr, MD; John K. Wolfe, PhD; David M. Singer; M. Cristina Leske, MD, MPH; Mark A. Bullimore, OD, PhD; Ian L. Bailey, OD, MS; Judith Friend, MA; Daniel McCarthy; Suh-Yuh Wu, MA; for the Longitudinal Study of Cataract Study Group

**• *Objective.*—To develop the Lens Opacities Classification System III (LOCS III) to overcome the limitations inherent in lens classification using LOCS II. These limitations include unequal intervals between standards, only one standard for color grading, use of integer grading, and wide 95% tolerance limits.**

***Design and Results.*—The LOCS III contains an expanded set of standards that were selected from the Longitudinal Study of Cataract slide library at the Center for Clinical Cataract Research, Boston, Mass. It consists of six slit-lamp images for grading nuclear color (NC) and nuclear opalescence (NO), five retroillumination images for grading cortical cataract (C), and five retroillumination images for grading posterior subcapsular (P) cataract. Cataract severity is graded on a decimal scale, and the standards have regularly spaced intervals on a decimal scale. The 95% tolerance limits are reduced from 2.0 for each class with LOCS II to 0.7 for nuclear opalescence, 0.7 for nuclear color, 0.5 for cortical cataract, and 1.0 for posterior subcapsular cataract with the LOCS III, with excellent interobserver agreement.**

***Conclusion.*—The LOCS III is an improved LOCS system for grading slit-lamp and retroillumination images of age-related cataract.**

**(*Arch Ophthalmol.* 1993;111:831-836)**

The Lens Opacities Classification System II (LOCS II) was introduced in 1989,[1] was validated by other investigators in 1989 and 1991,[2-3] and has been used in epidemiologic studies of the natural history of age-related cataract. It has also been compared with objective means of measuring cataract type and cataract growth,[4-6] used to evaluate the effects of cataract on visual function,[7-9] adopted in clinical trials of anticataract and potentially cataractogenic[10] drugs or diseases,[11] and compared with other systems of cataract classification.[12,13] The LOCS II is a simple classification system based on a set of standard color photographic transparencies of cortical cataract (C), nuclear opalescence (NO), posterior subcapsular cataract (P), and nuclear color (NC) that can be used as references to classify lens opacities at the slit-lamp or in standardized lens photographs.

Although LOCS II has proven valuable in several clinical research applications, it does have several limitations: (1) The scale for NC grading is small and coarse. (2) The guidelines for color grading are not linked to parameters of color (ie, hue, purity, and luminance) and have been difficult to teach to others. (3) The early stages of nuclear cataract (NO in theLOCS II system) are underrepresented. (4) The scaling intervals on all scales are unequal, only indirectly related to objective measurements, and often too broad to allow delineation of small changes in cataract severity. (5) The scale for P grading underrepresents early P change, and the extent of the cataract in two of the standards is difficult to define. (6) The 95% tolerance limits are large because LOCS II grading employs an integer scale.

We have attempted to rectify these deficiencies in the LOCS II by developing LOCS III. We have (1) expanded the scale for NC grading from three steps (using one standard reference) to six steps (with five standards); (2) linked the subjective scaling of NC to two objective measures of color (purity and the Commission Internationale l'Eclairage [CIE] X chromaticity coordinate [1931 scale[14]]) and confirmed that the ranking by eye and by fast spectral scanning colorimetry are concordant; (3) expanded the scale for NO so that the early stages of nuclear cataract are better represented; (4) established objective bases for the selection of the interval steps for the grading of different cataract features; (5) used equal scaling intervals for measuring NO and NC and intervals between the reference standards for the grading of C and P that are based on a monotonic function; (6) expanded the lower end of the P scale to better represent the early stages of P formation; and (7) used decimalized rather than integer grading to reduce the size of the 95% tolerance limits.

Recently, Bailey et al[15] and others[16,17] have shown that adopting a finer grading system can have substantial advantages. Grading in finer incremental steps lowers the observed concordance (ie, the frequency of perfect agreement between independent observers), but it can dramatically increase the sensitivity to change in the parameter or characteristics being assessed. Finer scales may be easily adopted in cataract grading by decimalizing the scale so that the observer interpolates in 0.1-unit steps between the standard photographic reference images that represent integer values. This type of grading system has been incorporated into LOCS III.

We believe the LOCS III will find useful application in long-term studies of age-related changes and short-term clinical trials of anticataract drugs and drugs with cataractogenic potential. The purpose of this article is to describe LOCS III and to illustrate some of its features.

## MATERIALS AND METHODS

### Selection of LOCS III Standard Images

**For NO and NC.**—From the large library of Lens Opacities Case-Control Study[18] photographs at the Center for Clinical Cataract Research, Boston, Mass, we selected 5×5-cm color transparencies (Ektachrome ASA 200,

Accepted for publication February 12, 1993.

From the Center for Clinical Cataract Research, Brigham and Women's Hospital (Drs Chylack, Wolfe, Singer, Friend, and McCarthy, and the Longitudinal Study of Cataract [LSC] Study Group) and Harvard Medical School (Drs Chylack, Wolfe, and Friend, and the LSC Study Group), Boston, Mass; Department of Preventive Medicine, State University of New York at Stony Brook (Drs Leske and Wu and the LSC Study Group), and School of Optometry, University of California, Berkeley (Drs Bullimore and Bailey).

Reprint requests to the Center for Clinical Cataract Research, 221 Longwood Ave, Boston, MA 02115 (Dr Chylack).

Eastman Kodak, Rochester, NY) of eyes with NO or NC but minimal C (LOCS II scores: NO=0 through 4; NC=0, 1, or 2; and C≤1). We eliminated technically unsatisfactory slides and subjected each of the others to objective measurement of NO and NC. We assessed NO with a specially developed nuclear mean density program that measures the mean density of the nuclear zone,[19,20] and we assessed NC objectively by measuring purity and the CIE × chromaticity coordinate with fast spectral scanning colorimetry[14,21,22] of slit-lamp images of the lens obtained with a conventional slit lamp with photographic abilities (Carl Zeiss, Oberköchen, Germany).

The X, Y, and Z chromaticity coordinates were defined by the CIE in 1931 and were the bases of one method of defining color. Application of these numbers to the CIE chromaticity diagram of 1931, which is a commonly accepted norm for color definition, provides an exact definition of color. This system is used in parallel with the more familiar system involving dominant wavelength (hue) and purity.[14] From several hundred images, we selected six standard images, each separated by nearly equal intervals in nuclear mean density, purity, and the CIE × chromaticity coordinate (Figs 1 and 2). This sequence of photographs is used as the reference standard for independently grading NO and NC in LOCS III.

**Standards for C.**—For LOCS III, we elected not to increase or decrease the number of standard images used to grade C in LOCS II since these standards spanned a wide range of cortical changes (up to 75% of the area opacified) in convenient intervals. Each of the cortical standards was analyzed with opacity (OPAC),[23] a computerized, objective method of measuring the area of C or P in retroillumination images taken with a retroillumination camera. With OPAC, the percentage of pupillary area that is opacified is measured. The LOCS II standard images for C showed a simple monotonic relationship to the objective measures (Fig 3). These images are also used in LOCS III.

**Standards for PC.**—From the photographs for the Lens Opacities Case-Control Study,[18] we selected all those showing evidence of P but no significant C (LOCS II scores: P≥1 and C, none or only a trace). We obtained OPAC measurements for all photographs and ranked them according to OPAC score, the objective measure of severity of P. We selected six images yielding a monotonic increase from very small P to very pronounced P. Figure 4 shows the relationship between the P grading and the percentage of area with opacity using OPAC for the LOCS III standard images for P.

## Rules for Grading With the LOCS III System

The following grading guidelines should be followed when evaluating slit-lamp and retroillumination images of cataracts. The photographs are taken exactly as specified in the original LOCS II publication.[1] The LOCS III standards are presented in Figure 5.

**General Rules.**—(1) All of the standards are boundaries of scaling intervals. There are no 0 standards or grades in LOCS III. (2) The grader decides in which interval the unknown image falls; the severity of the opacity must be more than that in the lower standard and less than or equal to that in the next higher standard. Each interval between adjacent reference standards is imagined to be divided into 10 equal parts, each being 0.1 of an interval unit. For each cataract type or for NC, higher grading scores indicate greater severity. The scale ranges from 0.1 (clear or colorless) to 5.9 (very opaque [in cases of C and P]) or 6.9 (very opaque or brunescent [in cases of NO and NC]). (3) A decimal grade, using 0.1-unit intervals, is then assigned to the opacity. The decimal grade should reflect the position of the unknown in the standard interval; for example a grade of 2.5 would mean that the severity of the cataract was judged to be midway between standards 2 and 3. If the severity of the cataract is equal to that in standard image 3, the grade is 3.0. If it is less than that shown in standard image 3 but more than midway through the interval, the score would range from 2.6 to 2.9. Similarly, a score of 1.1 to 2.0 is assigned if the cataract is greater than that in standard 1, but less than or equal to that shown in standard 2. The most severe cataract shown in the reference standards is 5 for C and P and 6 for NC and NO. The highest score for each would be 5.9 and 6.9, respectively. Thus, the assigned score ranges from 0.1 to 5.9 or 6.9.

**To Grade NO.**—Nuclear opalescence is graded by comparing the colored slit-lamp image to be graded with the standard nuclear images (standards 1 through 6). The average opalescence of the *entire* nucleus in the lens being evaluated is compared with that of the opalescence in each of the standards. The grader then assigns a decimal grade to reflect the position of the unknown within the appropriate standard interval. For example, if the average opalescence of the unknown is slightly greater than standard 1 but definitely less than standard 2, the grader might assign a grade of 1.2. For grading purposes, the nuclear area extends between the anterior and posterior supranuclear zones of scatter and comprises anatomic zones of increased scatter from the embryonal nucleus and both its outer shells (together called *the figure*) and background regions that may be clear or hazy (called *the ground*). In lenses of very young patients, the ground is perfectly clear and the figure is very faint. In very early nuclear opacification, the background remains clear and the figure becomes more pronounced. Such reductions in contrast of the figure may be misinterpreted as a reduction in cataract severity when in fact they are due to increased opalescence of the ground. In very advanced nuclear cataracts, the components of the figure merge and form an oval zone of markedly enhanced scatter that may have a defined perimeter. The outermost zone of the nucleus usually remains clear even in very advanced nuclear cataracts.

**To Grade NC.**—Nuclear color is graded by comparing the color of the lens to be graded with that in NC standards 1 through 6 (which are the same as NO standards 1 through 6). Nuclear color grading requires the grader to focus on two regions of the nucleus: the entire cross-sectional view of the nucleus and the posterior subcapsular reflex. This

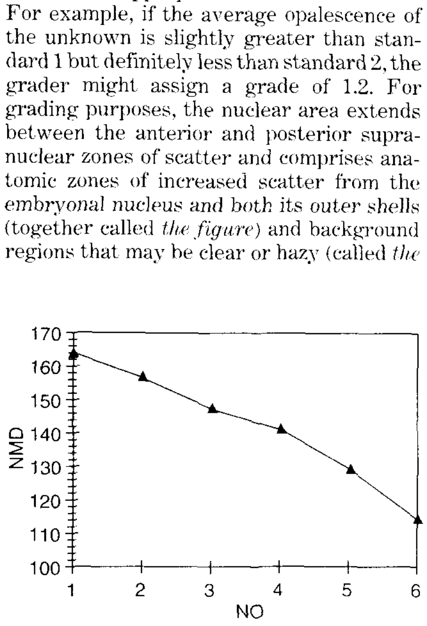


Fig 1.—Relationship between nuclear opalescence (NO) with the subjective Lens Opacities Classification System III and an objective measure of nuclear mean density (NMD). The relationship between the objective and subjective measures is linear.

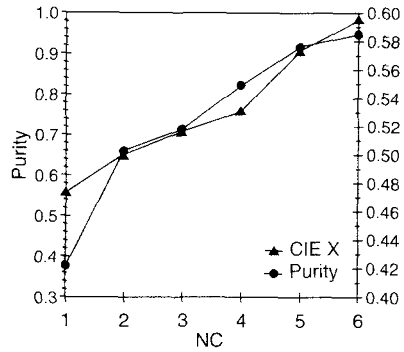


Fig 2.—Relationship between grades of nuclear color (NC) with the subjective Lens Opacities Classification System III and two objective measures: purity and the X chromaticity coordinate of the 1931 Commission Internationale l'Eclairage (CIE). The relationship between the subjective measure and the two objective measures is almost linear.

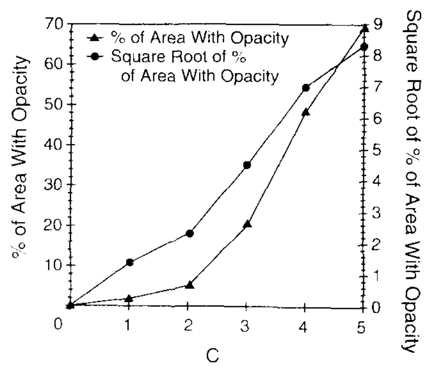


Fig 3.—Relationship between grades of cortical cataract (C) with the subjective Lens Opacities Classification System III and the objective measure of percentage of area with opacity. The relationship between percentage of area with opacity and the subjective grade is monotonic. The square root of the percentage of area with opacity is linearly related to the subjective grade.

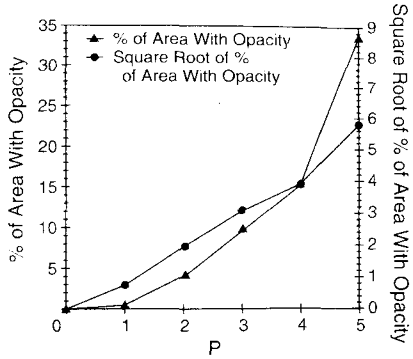


Fig 4.—Relationship between grades of posterior subcapsular cataract (P) with the subjective Lens Opacities Classification System III and the objective measure of percentage of area with opacity. The relationship between percentage of area with opacity and the subjective grade is monotonic. The square root of the percentage of area with opacity is linearly related to the subjective grade.

is slightly different from the rules used in the LOCS II in that attention is being directed to the color of the entire nucleus, not just to that of the posterior reflex. This is done to avoid overestimating the severity of the brunescent change, such as occurs occasionally when the reflex alone is used. The overall view indicates whether there is significant brunescence of the nucleus, and the posterior reflex is the best location to judge the quality of the brunescent color. The color in the observed lens should be compared with the color in NC standards 1 through 6 and the grade assigned by using decimals to interpolate between the integer values of the reference standards. The assigned score for NC may range from 0.1 to 6.9. In LOCS III, the color standards are boundaries, unlike in LOCS II where there are no color boundaries. In LOCS III, the grader is asked to do the simpler task of deciding if the color is more than or less than or equal to that in a standard image.

**To Grade C.**—Cortical cataract is visualized in retroillumination images focused either anteriorly (at the plane of the iris) or posteriorly (at the plane of the posterior capsule). Small opacities are graded in LOCS III. To decide whether a small opacity is gradable, its size is compared with the size of the small dot opacity located at the 6 o'clock position in C standard 1. Any opacities that size or larger are included. The grader compares the aggregate area of the opacity in the image being graded with that in standards 1 through 6 and selects an interval that brackets the amount of C in the unknown. In estimating the severity or aggregate extent of C, the observer should mentally compress the three-dimensional information into a two-dimensional image and compare the aggregate area of the opacity in the unknown with that in the standard C images. Again, decimalization should be used to interpolate the integer values depicted in the sequence of standard C images. The assigned score may range from 0.1 to 5.9. Opacities visible *only* in the posteriorly focused image are graded as cortical if they are closer to the periphery than to the center of the pupil unless they are connected to a central opacity; in that case, the entire opacity is graded as P. Isolated water clefts, vacuoles, retrodots, lamellar separations, and sutural opacities are ignored (not graded). If, however, such irregularities are clustered and organized into discrete arrays, they should be graded as C. In many retroillumination images, the peripheral portions of the image manifest soft, radially oriented areas of variable contrast—almost like very soft opacities; these zones lack the sharp, discrete edges of most cortical opacities. These soft hazy zones should be ignored. We have not been able to grade these areas consistently.

**To Grade P.**—Only posteriorly focused retroillumination images are used in grading P. The area of the opacity in the lens being graded is compared with that in standards 1 through 5. The standard interval selected should bracket the opacity of the ungraded image. The assigned decimal grade should reflect the location of the cataract in the interval; the assigned score may range from 0.1 to 5.9. Opacities visible only in the posteriorly focused image are graded as P if they are closer to the center than to the periphery of the area.

### Evaluating the LOCS III System

**Selection of Photographs to Test LOCS III.**—One hundred sixty sets of cataract images were identified from the slide library of Longitudinal Study of Cataract at the Center for Clinical Cataract Research to represent the full range of cataract types and severities based on their LOCS II classification. Each set included three photographs: one 35-mm color slit-lamp transparency of a cross-sectional view of the nuclear region of the lens and two black-and-white retroillumination images, one focused on the anterior lens at the pupillary plane and one on the posterior lens capsule. For the black-and-white photographs, a flash intensity of 3, illumination aperture of 8 mm, and lens aperture of 3 are used. These images are used to grade C and P. For the color transparency, the beam of the slit lamp is oriented 45° to the line of vision, and the camera is focused in the center of the nucleus. The illumination aperture is set at 4 mm; the slit-lamp width at 0.2 mm; and the flash intensity at 3. The beam is tall enough to just overlap the margins of the pupil. One takes the film using an ASA speed of 200. The color images are used to grade NO and NC. A slit-lamp image is also useful in identifying the anteroposterior location of opacities seen in retroillumination photographs.

**Grading of Test Photographs.**—The slides were coded by a technician, arranged in random sequence, placed into slide carousels, and projected onto a large screen for grading. For grading NO and NC, the color slit-lamp image was projected; for grading C and P, the two retroillumination images and a slit-lamp image were projected. Between experimental sessions a technician rearranged the slide sequence into a new random order. In each experimental session, either NO and NC or C and P were graded. The relevant LOCS III standard images were continuously projected onto the same large screen and were maintained at the same magnification as the slide being graded. Six sessions were needed for conducting the test and retest sessions for NO/NC and C/P groups of slides. Grading sessions were typically separated by 1 to 2 weeks.

Each set of slides was graded by the same two experienced graders. Each grader wrote a score on a separate standardized form; the two graders then compared scores and arrived at a consensus score that was recorded on a third standardized form.

**Method of Analysis.**—We analyzed the repeatability of LOCS III gradings and estimated the 95% tolerance limits for defining change. For each photograph and for each characteristic, two grades may be compared (either grades from each observer in the same session or grades from different sessions determined by the same observer). The discrepancy or difference between the two scores can be simply calculated. The distribution of these discrepancies is then plotted, and the SD of the discrepancy distribution provides a measure of the reproducibility of the grading. We defined change as a difference greater than a specified distribution of grading errors. The approximate 95% tolerance limits[15,24] are a useful specification of the distribution of grading errors. They were calculated as the next highest increment above the 95th percentile of discrepancy values. These limits become clinically useful as the established tolerance limits for defining change. If the difference between sequential observations exceeds these 95% tolerance limits, it is assumed that a change has occurred. If the discrepancy between sequential measures does not exceed the tolerance limits, it is assumed there has been no significant change in the condition. Assuming no bias (the tendency to obtain consistently higher or consistently lower values, either between observers or between sessions), the distribution of discrepancies should have a mean of 0, about which there should be a relatively symmetrical distribution of discrepancies.

## RESULTS

The results are presented in the Table. For each of the four cataract types, the table shows the mean difference, the median difference, the SD of difference, and the 95% tolerance limits for the five different comparisons: for observers 1 and 2, values obtained at session 1 were compared with those obtained at session 2. For consensus, values determined by both observers were averaged and then compared for the two sessions. For sessions 1 and 2, values obtained by observer 1 were compared with those obtained by observer 2.

For NO, the between-sessions 95% tolerance limits were 0.7 for observer 1 and 1.0 for observer 2, and the between-observer tolerance limits were 0.7 and 0.8 at sessions 1 and 2, respectively. For

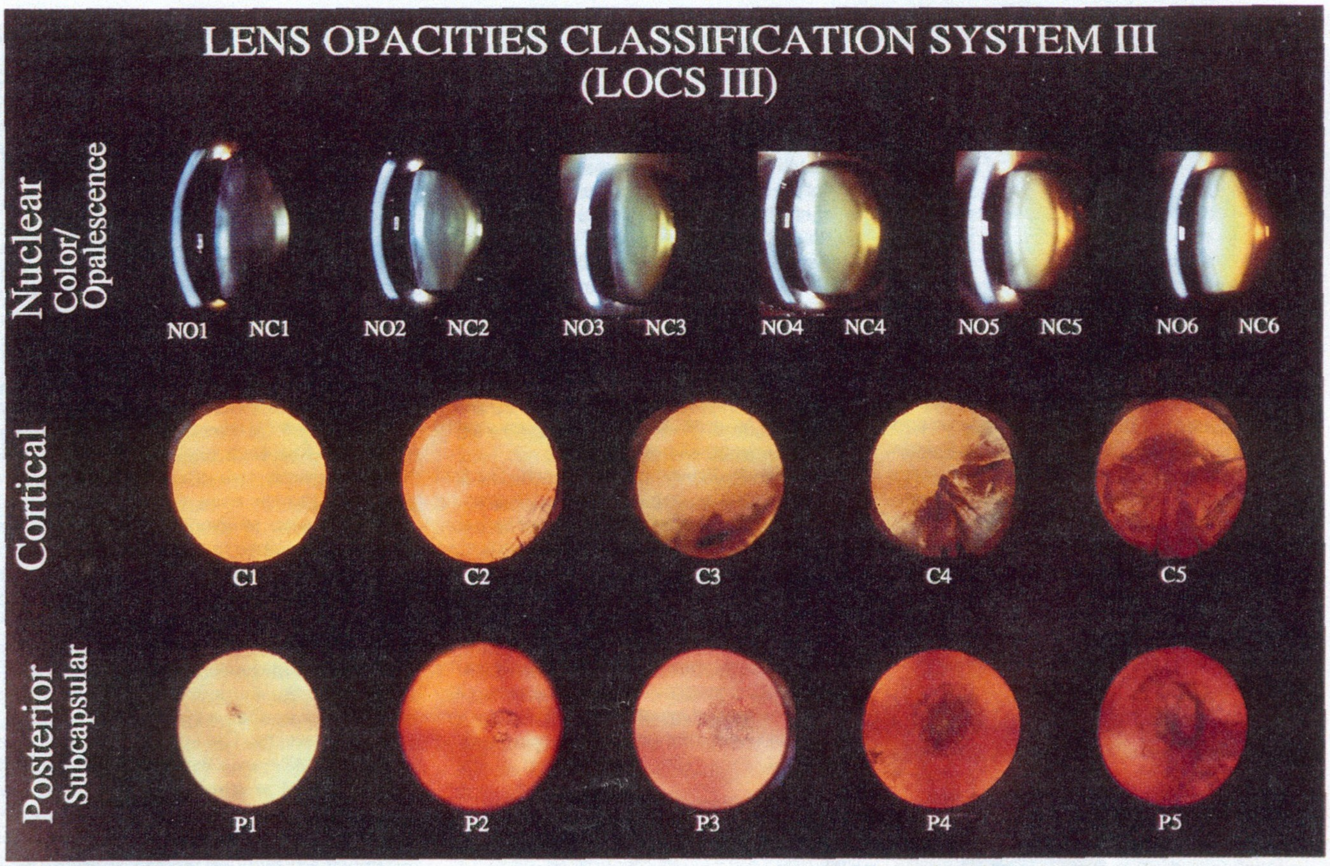


Fig 5.—The LOCS III standards. This set of standards is prepared as a set of slides for grading standardized photographic images of opacity. The five or six individual standard slides for the cataract type or nuclear color being graded are projected at the same size as the slides of unknown opacity. NO1 to NO6 and NC1 to NC6 are the standards for nuclear opalescence and nuclear color, respectively. C1 to C5 are the standards for cortical cataract, and P1 to P5 are the standards for posterior subcapsular cataract.

NC, the between-session limits were 0.7 and 0.8 for observers 1 and 2, respectively, and the between-observers tolerance limits were 0.6 at both sessions 1 and 2. For C, the between-sessions tolerance limits were 0.7 for observers 1 and 2, and the between-observers tolerance limits were 0.6 for session 1 and 0.5 at session 2. Finally, for P, the between-sessions tolerance limits were 0.9 for observers 1 and 2, and the between-observers tolerance limits were 0.4 for both sessions 1 and 2.

## COMMENT

The LOCS III, with its expanded sets of reference photographs and decimalized grading, is easier to use and provides more sensitive grading than LOCS II when applied to photographic images of cataracts. A fuller analysis of the benefits of decimalizing grading systems has been presented elsewhere,[15] but the 95% tolerance limits for all of the LOCS III classes are much smaller (0.4 to 1.0) than the 95% tolerance limits for LOCS II, which uses integer increments only. For each category of cataract or for NC, the LOCS II tolerance limits are at best 2.0. Because sequential observations do not show 95% concordance, the level of concordance required for the 95% tolerance limit would be 1.0.[15]

For each category (NO, NC, C, and P) LOCS III has some specific advantages over LOCS II. For grading NO, the rescaling has achieved approximately equal intervals between each reference standard, and there are more standards for evaluation of the early stages of NO. Removal of inconsistent variations in color over the range of NO standards makes judgments about the severity of NO much more straightforward. Improved opalescence grading may offer opportunities to assess in vivo basic age-related biochemical processes such as protein aggregation, and there is evidence that NO, as judged using LOCS II, is correlated to some aspects of visual dysfunction (eg, contrast sensitivity loss).[7,11]

In LOCS II, there was only one reference standard for NC, making assessment of NC the most subjective of all the judgments in LOCS II. A much broader array of standard reference images in LOCS III greatly facilitates the assignment of NC grades. In the past, grading brunescence has not always been considered important. However, there is evidence that increased NC may be related to contrast sensitivity dysfunction.[11] In addition, grading NC is necessary if one is to assess the protective effect of lens pigments against short-wavelength visible and long-wavelength UV light. There is also a well-known but poorly quantified clinical relationship between NC and ease of nuclear phacoemulsification.

Nuclear opalescence and NC are correlated.[9,11,21] In one analysis,[25] 33% of the variability in NO grading (using LOCS II) was due to variations in NC. If one is to isolate the effect of opalescence on visual function and define the relationship between NO and other biologic phenomena, one must be able to isolate and eliminate the variability in opalescence grading due to color in statistical analyses using regression models. Therefore, it is important to grade NC as well as NO.

For grading C, the reference standards in LOCS III are the same as those used in LOCS II. The standards are separated by intervals that increase

Results of Photograding Using LOCS III*

| Grade Determination† | Mean Difference | Median Difference | SD of Difference | 95% Tolerance Limits |
|---|---|---|---|---|
| **Nuclear Opalescence** | | | | |
| Observer 1 | −0.02 | 0 | ±0.30 | ±0.7 |
| Observer 2 | +0.02 | 0 | ±0.41 | ±1.0 |
| Consensus | +0.01 | 0 | ±0.30 | ±0.7 |
| Session 1 | −0.06 | −0.1 | ±0.29 | ±0.7 |
| Session 2 | −0.02 | 0 | ±0.33 | ±0.8 |
| **Nuclear Color** | | | | |
| Observer 1 | +0.02 | 0 | ±0.31 | ±0.7 |
| Observer 2 | −0.01 | 0 | ±0.35 | ±0.8 |
| Consensus | +0.02 | 0 | ±0.27 | ±0.7 |
| Session 1 | +0.02 | 0 | ±0.26 | ±0.6 |
| Session 2 | −0.01 | 0 | ±0.30 | ±0.6 |
| **Cortical Cataract** | | | | |
| Observer 1 | +0.03 | 0 | ±0.22 | ±0.7 |
| Observer 2 | +0.01 | 0 | ±0.27 | ±0.7 |
| Consensus | +0.02 | 0 | ±0.22 | ±0.5 |
| Session 1 | +0.03 | 0 | ±0.23 | ±0.6 |
| Session 2 | +-0.01 | 0 | ±0.20 | ±0.5 |
| **Posterior Subcapsular Cataract** | | | | |
| Observer 1 | −0.01 | 0 | ±0.38 | ±0.9 |
| Observer 2 | −0.03 | 0 | ±0.39 | ±0.9 |
| Consensus | −0.01 | 0 | ±0.36 | ±1.0 |
| Session 1 | +0.02 | 0 | ±0.17 | ±0.4 |
| Session 2 | 0 | 0 | ±0.16 | ±0.4 |

*LOCS indicates Lens Opacities Classification System.

†For observers 1 and 2, values obtained at session 1 were compared with values obtained at session 2. For consensus, values determined by both observers were averaged and then compared for the two sessions. For sessions 1 and 2, values obtained by observer 1 were compared with those obtained from observer 2.

monotonically when measured with the computerized objective method of assessing cataract area, OPAC, and are easy to use. We have changed the instructions for using cortical standards in LOCS III to reduce between-session variability. We have determined that much of the variability is due to variability in the contrast of the peripheral parts of the cortical region in nearly clear lenses. The areas of variable contrast are sometimes graded as opacity and at other times graded as clear. The instructions for LOCS III specify that only sharply defined areas of cortical opacity are to be graded; the soft hazy areas should be ignored.

With respect to grading P, LOCS III standards are considerably improved from those of LOCS II. Standards illustrating early P have clearly defined, sharp borders that make estimation of area more straightforward. Furthermore, the number of standards has increased, with a systematic increase in the area of P between standards; these features contribute to improved P grading. Irregular and stellate opacities would be assessed by estimating the area of a circle that would be occupied by the cataract, much in the same way that we form a mental aggregate of multicentric cortical opacities, and the circular surrogate would be compared with the discoid opacities in the P standards. The outliers in P grading occurred when large Ps with very vague borders coexisted with advanced NO or C. Inevitably, some portions of mixed cataracts will not be clearly imaged and delineation of the extent of each portion of the cataract will not be clear to the grader. We doubt that a new approach to grading will alter this situation.

We have investigated the use of grids and templates to measure Cs and Ps and demonstrated that results with these tools are similar to results obtained using OPAC. We continue to use OPAC regularly for objective analysis of C and P. However, we believe that there is still a place for the use of subjective systems in evaluating cataract because much of the hardware and software required for objective analysis is expensive and not readily available.

Alternative methods of grading involve adjustment of beam width of the slit lamp to measure the vertical and horizontal limits of P[26]; consideration of the circumferential extent of C, which is advocated in the Wilmer system[27]; and a percentage/grid approach, which is used in the Wisconsin system.[28] We chose to adopt decimal grading so that the assessment approach would be the same for all cataract types. This facilitates the use of consistent analysis techniques.

For these reasons, we believe that LOCS III represents substantial improvement from LOCS II for grading standardized lens photographs and is superior to LOCS II as a means of accurately specifying the type and severity of cataract. However, we have not presented data regarding the use of LOCS III for grading cataract type and severity at the slit lamp. The LOCS II has been validated in both cross-sectional and longitudinal in vivo studies, and experiments assessing this for LOCS III are under way. Therefore, for those studies in which in vivo slit-lamp classification is used to generate classification data, LOCS II should be used until we have tested LOCS III.

In general, and in an ideal world, photograph-derived classification of cataract type and severity is preferable to patient-derived classification because a photographic record is not affected by variations due to staffing changes or "drift" in the manner in which a grader applies the classification system. *Drift* refers to systematic inconsistency in a grader's application of classification criteria with time. There is no easy way to correct for this drift when it occurs in patient-derived classification data. One can easily correct for it in photo-derived classification data by presenting images from several visits at one classification session. The impact of drift is greater when grading scales are coarse or reference standards are few. Furthermore, in our experience, it is easier to train properly a new lens/cataract photographer with the photographic techniques needed for LOCS II or III than it is to train, certify, and periodically retest the performance of slit-lamp graders. Also, it is our experience that it is easier to grade photographs than to grade at the slit lamp. It is essential, however, that when photograding is used strict protocols for photographic procedures be followed and photographs meet LOCS III standards.

In the "real" world, however, the cost or inefficiency of photograding may be too high, especially when screening large numbers of patients rapidly in field conditions. In this situation, patient-derived subjective grading with LOCS II offers a simple and effective alternative to photograph-derived grading. The larger number of patients may enable investigators to shorten the length of the protocol, thereby limiting the effects of drift.

The LOCS III is unique among cataract classification systems in that its intervals have been determined by objective measures of cataract applied to a vast array of candidate images. When the images were ranked according to their objective measurements, no subjective inconsistencies in ranking were apparent. In other words, objective methods ably rank a series of images in a manner perfectly acceptable to the eye. It should not be surprising, therefore, to find a high correlation between the subjective grades and corresponding objective scores derived from the same photographs. The LOCS II standards were selected using subjective criteria alone, and although recent analyses indicate that increasing LOCS II grades of NO, NC, C, and P are associated with increasing corresponding objective scores, there is considerable overlap. Few have sought to make direct correlations between frequently used cataract classification systems[27-33] and objective measures of cataract. One study by Adamsons et al[16] demonstrated good correlation between clinical gradings and digital analysis of NO and C. With LOCS III, we have a subjective system that gives results comparable to the objective systems in NC and the three cataract types (NO, C, and P). Thus, we believe LOCS III is a subjective system that gives results comparable to those of objective methods. There may be concern that objective and subjective systems for quantifying cataract measure completely different features of the cataractogenic process. Our results with the subjective and objective aspects of LOCS III suggest that the grader's eye and the objective sensors are assessing essentially the same features in an image. Thus, LOCS III may be useful also in evaluating new objective systems of cataract quantification.

CELEBRATING VISION RESEARCH 25TH ANNIVERSARY NATIONAL EYE INSTITUTE

This work was supported in part by research grants R01 EY-8291 (Dr Leske) and R01 EY-06365 (Dr Bailey) from the National Eye Institute and the Brigham Surgical Group Foundation. We thank Roy Milton, MD, and Robert Sperduto, MD, for helpful suggestions in the developmental stages of LOCS III.

Additional members of the Longitudinal Study of Cataract study group include Margarett Baker and Laura Bury from the Center for Clinical Cataract Research and Elinor Schoenfeld, PhD, from the State University of New York, Stony Brook.

## References

1. Chylack LT Jr, Leske MC, McCarthy D, Khu PM, Kashiwagi T, Sperduto, R. Lens Opacities Classification System II (LOCS II). *Arch Ophthalmol.* 1989;107:991-997.

2. Maraini G, Pasquini P, Tomba MC, et al. An independent evaluation of the Lens Opacities Classification System II (LOCS II). *Ophthalmology.* 1989;96:611-615.

3. Maraini G, Pasquini P, Sperduto RD, et al. The effect of cataract severity and morphology on the reliability of the Lens Opacities Classification System II (LOCS II). *Invest Ophthalmol Vis Sci.* 1991;32:2400-2403.

4. Khu PM, Chylack LT Jr, Leske MC, McCarthy D, Wu S-Y. Measuring the rate of age-related cataract formation in vivo using LOCS II standard photographs. *Invest Ophthalmol Vis Sci.* 1989;30 (ARVO suppl):164. Abstract.

5. Leske MC, Chylack LT Jr, Wu S-Y, McCarthy D, Grimson R, the LSC Group. Longitudinal changes in lens photographs with the LOCS II method. *Invest Ophthalmol Vis Sci.* 1991;32 (ARVO suppl):1244. Abstract.

6. Wolfe JK, Chylack LT Jr, Leske MC, et al. Nuclear lens changes with image analysis and LOCS II photograding. *Invest Ophthalmol Vis Sci.* 1991;32(ARVO suppl):1991. Abstract.

7. Drews-Bankiewicz MA, Caruso RD, Datiles MB, Kaiser-Kupfer MI. Contrast sensitivity in patients with nuclear cataracts. *Arch Ophthalmol.* 1992;110:953-959.

8. Chylack LT Jr, Wolfe JK, McCarthy D. Cross-sectional and longitudinal correspondence between LOCS II (subjective) and various objective measures of human cataract and nuclear color. *Invest Ophthalmol Vis Sci.* 1990;31(ARVO suppl):374. Abstract.

9. Chylack LT Jr, Jakubicz G, Rosner B, et al. Contrast sensitivity and visual acuity as functions of cataract type and extent. *J Cataract Refract Surg.* In press.

10. Chylack LT Jr, McCarthy D, Wolfe JK, et al. Monitoring cataracts with LOCS II and counterpart objective methods: lovastatin and the human lens: results of a 2-year study. *Optom Vis Sci.* In press.

11. Chylack LT Jr, Padhye N, Khu PM, et al. Loss of contrast sensitivity in diabetic patients with LOCS II classified cataracts. *Br J Ophthalmol.* 1993;77:7-11.

12. Sparrow JM. Methods of clinical cataract grading: two systems compared. *Arch Ophthalmol.* 1990;108:1209.

13. Taylor HR, Lee JA, Wang F, Muñoz B. A comparison of two photographic systems for grading cataract. *Invest Ophthalmol Vis Sci.* 1991;32: 529-532.

14. Agoston GA. *Color Theory and Its Application in Art and Design.* New York, NY: Springer-Verlag NY Inc: 1987:53-62.

15. Bailey IL, Bullimore MA, Raasch TW, Taylor HR. Clinical grading and the effects of scaling. *Invest Ophthalmol Vis Sci.* 1991;32:422-432.

16. Adamsons I, Taylor KI, Enger C, Taylor HR. A new method for documenting lens opacities. *Am J Ophthalmol.* 1991;111:65-70.

17. Muñoz B, West S, Wang F, Taylor HR. Measuring cataract progression for longitudinal studies. *Invest Ophthalmol Vis Sci.* 1991;32(ARVO suppl):1243. Abstract.

18. Leske MC, Chylack LT Jr, Wu S-Y, the Lens Opacities Case-Control Study Group. The Lens Opacities Case-Control Study: risk factors for cataract. *Arch Ophthalmol.* 1991;109:244-251.

19. Chylack LT Jr, Rosner B, Cheng H-M, McCarthy D, Pennett M. Sources of variance in the objective documentation of human cataractous change with Topcon SL-45 and Neitz-CTR retroillumination photography and computerized image analysis. *Curr Eye Res.* 1987;6:1381-1390.

20. Wolfe J, Chylack LT Jr, Leske MC, et al. Nuclear lens changes with image analysis and LOCS II photograding. *Invest Ophthalmol Vis Sci.* 1991;32(ARVO suppl):1244. Abstract.

21. McCarthy D, Chylack LT Jr, Rosner, B. Quantification of nuclear yellowing and its effect on visual function. *Invest Ophthalmol Vis Sci.* 1989;30 (ARVO suppl):497. Abstract.

22. Herzberg S, McCarthy D, Kansupada K, Wolfe JK, Chylack LT Jr. Positional dependence of objective measures of nuclear color in the lens: correlation with LOCS II score. *Invest Ophthalmol Vis Sci.* 1990;31(ARVO suppl):352. Abstract.

23. Wolfe JK, Chylack LT Jr. Objective measurement of cortical and subcapsular opacification in retroillumination photographs. *Ophthalmic Res.* 1990;22(suppl 1):62-67.

24. Rosner B. *Fundamentals of Biostatistics.* 2nd ed. Boston, Mass: Duxbury Press; 1986:106.

25. Chylack LT Jr. How successfully can we measure cataract growth rate? Presented at the Sixth Annual Cooperative Cataract Research Group Meeting; December 3, 1991; Kona, Hawaii.

26. Datiles MB, Podgor MJ, Sperduto RD, Kashima K, Edwards P, Hiller R. Measurement errors in assessing the size of posterior subcapsular cataracts from retroillumination photographs. *Invest Ophthalmol Vis Sci.* 1989;30:1848-1854.

27. Taylor HR, West S. A simple system for the clinical grading of lens opacities. *Lens Res.* 1988;5: 175-181.

28. Klein BEK, Magli YL, Neider MW, Klein R. *Wisconsin System for Classification of Cataracts From Photographs.* Springfield, Va: National Technical Information Service; 1989. Accession No. PB 90-138306.

29. Sparrow JM, Bron AJ, Brown NAP, Ayliffe W, Hill AR. The Oxford clinical cataract classification system. *Intl Ophthalmol.* 1986;9:207-225.

30. Sparrow JM, Ayliffe W, Bron AJ, Brown NP, Hill AR. Inter-observer and intra-observer variability of the Oxford clinical cataract classification and grading system. *Intl Ophthalmol.* 1988;11:151-157.

31. Laties AM, Keates E, Lippa E, et al. Field test reliability of a new lens opacity rating system utilizing slit-lamp examination. *Lens Eye Toxicol Res.* 1989;6:443-464.

32. Sasaki K, Shibata T, Obazawa H. Classification system for cataracts: application by the Japanese Cooperative Cataract Epidemiology Study Group. *Ophthalmic Res.* 1990;22(suppl 1): 46-50.

33. Khu PM, Chylack LT Jr. Subjective classification and objective quantitation of human cataract. In: Jakobiec FA, Albert DM, eds. *The Principles and Practice of Ophthalmology: The Harvard System.* Philadelphia, Pa: WB Saunders Co. In press.



*Printed and Published in the United States of America*