Lens Opacities in a Rural Population of Southern India: The Aravind Comprehensive Eye Study

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OBJECTIVES. To determine the prevalence of lens opacities in an older population in rural southern India.

METHODS. A cross-sectional study of 5150 persons aged 40 years and more who were selected as part of a representative sample from three southern districts of the state of Tamil Nadu in southern India. All lenses were graded and classified for opacities and other disorders by slit lamp after pupillary dilation, using the Lens Opacification Classification System (LOCS) III and standard photographs. Definite cataract was defined as either LOCS III nuclear opalescence of grade 3.0 or more and/or cortical cataract of grade 3.0 or more and/or posterior subcapsular cataract (PSC) of grade 2.0 or more.

RESULTS. Definite cataract was present in one or both eyes in 2499 (47.5%) of 5150 subjects. The age-adjusted prevalence (adjusted to U.S. population estimates for 2000) of definite cataract in this population was 61.9% (95% CI, 60.6–63.5%). The prevalence was significantly lower in men (P = 0.0002). In those eyes with cataracts, nuclear cataract (59.7%) was most common, and cortical cataract was present in 20.0% and PSC in 24.3%. Cataract surgery had been performed in 9.4% persons, including 3.0% who had bilateral surgery for cataracts. Best corrected visual acuity was less than 6/60 in 3.7% of aphakic eyes and in 0.8% of pseudophakic eyes.

CONCLUSIONS. The higher age-adjusted prevalence and relatively early onset of age-related cataract in this population suggest that the cataract-centered approach to minimizing preventable blindness, adopted by the National Program for Prevention of Blindness in India, is appropriate. (Invest Ophthalmol Vis Sci. 2003;44:4639–4645) DOI:10.1167/iovs.03-0011

Almost 80% of blindness and nearly all treatable blindness in India have been attributed to cataract, a disease that is far less common a cause of blindness in developed nations. This finding has been the justification for the Indian Government-initiated, World Bank-assisted Cataract Control Program that has primarily focused on age-related cataract. Even after more than a decade of sustained emphasis on cataract eradication, age-related cataract remains the most common cause of blindness in India. A recent population-based study from the state of Andhra Pradesh in southern India reported cataract, a condition that can be relatively quickly and inexpensively reversed, as the cause of nearly 45% of current blindness. Epidemiologic details on this disease of high prevalence in India, especially in rural areas where most of the population lives, are limited and inadequate. Reports on cataract from the Indian subcontinent are also limited by the lack of standardized lens grading, observations to detect pseudoxfoliation (PXF) of the lens, and evaluations of risk factors for age-related cataracts.7,8 We report herein on the prevalence of lens abnormalities and cataract, in a rural population aged 40 years and above in southern India.

METHODS

The study design and methods have been described in greater detail in a previous publication. The Aravind Comprehensive Eye Survey (ACES) is a population-based prevalence study of glaucoma and other visually impairing ocular disorders conducted among a rural population aged 40 years or more from three districts—Madurai, Tirunelveli and Tuticorin—of the state of Tamil Nadu in southern India.

The sampling frame for this study consisted of a sample of typical rural districts (equivalent to a county in the United States) that have access to the Aravind Eye Hospitals located in Madurai and Tirunelveli to best reflect the rural population in the southern part of India. These areas are representative of southern India in age, gender, and socioeconomic status. These districts are representative in standard demographic and health-care utilization in south India, but may or may not be representative of northern or other Indian states. A total of 14 rural blocks (the administrative unit directly below a district) were chosen at random in the three districts mentioned to identify 5000 subjects aged more than 40 years. Tirunelveli and Tuticorin were combined for the purposes of this study into one study district, because they were originally two districts that were geographically combined into one district during the time course of the study. Lists of villages for these blocks were obtained based on data from the 1991 Indian national census. Villages with population below 350 were excluded, because a minimum of 100 persons aged 40 or more years were needed from each selected village and these smaller villages were not representative of the catchment area. Twenty-five villages from each of the two study districts were selected from the list of sectors with probability proportionate to size and stratified by district.

Data collection in the field started from November 1995 and was completed by February 1997. A detailed map was prepared for each village noting the location of all households in each sector and other important landmarks. Each village was divided into sectors of approximately 100 households and for those villages with more than one sector, one sector was randomly chosen, so that only one sector in any village was included in the sample. This provided a final sample of 50 sectors—25 from each of the two study districts. Within the geographic boundaries of each selected sector, all residential dwelling units were screened to identify eligible subjects. Each household received a census, and a brief interview was conducted with the head of the household regarding demographic and
socioeconomic characteristics. All personnel used for the study were certified after standardization procedures.

A project field worker and an ophthalmologist's assistant conducted a basic screening examination on all members of each household. Visual acuity was measured separately in each eye, under standardized conditions at 4 m with the subject's current correction in place. A logarithm of the minimum angle of resolution (logMAR) E chart, originally developed for use in the Baltimore Eye Survey and equivalent to the letter charts developed for the Early Treatment Diabetic Retinopathy Study, was placed in full daylight and protected from glare and shadow. Subjects were given credit for a line on the chart if they correctly read three or more of the five letters on that line. Pinhole visual acuity was measured in those eyes with presenting visual acuity worse than 6/18.

All subjects aged 40 years or more were transported to the Aravind Eye Hospitals in either Madurai or Tirunelveli for a comprehensive ophthalmic examination. This examination consisted of the following: subjective retinoscopic refraction, measurements of presenting and best corrected visual acuity, automated full-threshold visual fields for subjects with best corrected visual acuity better than 6/60 using the C-24-2 full-threshold program on the Humphrey Visual Field Analyzer (model 650; Carl Zeiss Meditec, Dublin, CA), evaluation of pupillary response, external and anterior segment examination by slit lamp biomicroscope, measurement of intraocular pressure with a Goldmann applanation tonometer (three independent readings in each eye), and gonioscopy with a Goldmann lens.

Lens Grading

After pupillary dilation with 1% tropicamide and/or 10% phenylephrine, grading of the lens was conducted using the Lens Opacification Classification System (LOCS) III. This clinical grading was performed with a standard set of photographs mounted next to the slit lamp. The presence and degree of nuclear opalescence and color and of cortical or posterior subcapsular cataract (PSC) were recorded. We graded nuclear cataracts with reference to standard photographs on a decimal scale of 0.1 to 6.9, based on optical density, without reference to lens color. Although we recorded lens color, we did not use the color to grade the lens. Cortical opacity was graded on a decimal scale of 0.1 to 5.9 according to the opacity that obscured the light reflex on retroillumination. PSC was graded according to the estimated area of posterior capsule involved. Measurements of the greatest vertical and horizontal dimensions of the PSC were made and graded on a decimal scale of 0.1 to 5.9.

Ophthalmologists for the study were standardized to the lens grading on three separate occasions: once immediately before the onset of the study, and at 6 and 12 months into data collection. The ophthalmologists were standardized between themselves as well as to a senior ophthalmologist whose grading was considered the gold standard. A weighted χ score of less than 0.75 prompted restandardization of the ophthalmologists with respect to lens grading. For this analysis, definite cataract was defined as nuclear opalescence of grade 3.0 or more and/or cortical cataract of 3.0 or more and/or PSC of 2.0 or more.

The anterior lens surface was examined with narrow slit lamp beam under full illumination and high magnification. PXF was diagnosed by the presence of typical white deposits on the iris and/or anterior lens surface. Additional sites where we found PXF included the cornea, anterior vitreous face, posterior capsule, and even the intraocular lens in pseudophakic eyes. We also looked for changes in the angle by using gonioscopy including increased pigmentation, PXF deposition, and PXF material within the angle.

For the purpose of this study, a lens that was completely dislocated into either the vitreous or the anterior chamber was considered a dislocated lens. Lenses that were partially dislocated from their normal positions were considered subluxated lenses. Lenses that had cataract changes secondary to other systemic or ophthalmic causes including ocular inflammations were considered “complicated” cataracts.

Stereoscopic examination of the vitreous, retina, and optic nerve was performed by slit lamp with a 78-D lens. We examined the retinal periphery with an indirect ophthalmoscope and a 20-D lens.

After the completion of the examinations, all opthalmic diagnoses were recorded and coded according to the International Classification of Diseases, 9th revision (ICD-9). Three visual acuity measures are reported herein. Presenting visual acuity was defined, both in the village and the clinic, as the visual acuity in the better eye with whatever correction was worn by the subject to the examination. Best village-based visual acuity was defined as the better of presenting and pinhole visual acuities, as measured during the screening examination. Best corrected visual acuity was defined as the best visual acuity recorded in the clinic (including that measured with full refractive correction) in the better eye. As a part of the examination process for all persons with best corrected visual acuity of worse than 6/18 in either eye, an assessment of the principal cause(s) of vision loss was determined and recorded for each affected eye.

Definitions of blindness and visual impairment vary widely throughout the world, although an international standard proposed by the World Health Organization (WHO) has been widely accepted and incorporated into the ICD-9. All standardized definitions of blindness and/or visual impairment include both visual acuity and visual field criteria, although most investigators report results based solely on visual acuity criteria, because visual field data are not available for all study participants. To provide comparability with previous studies, we have chosen to follow this approach and present data using visual acuity criteria alone.

Three levels of informed consent were used in this study: community, household, and individual. Meetings were held with community leaders and all health-related personnel in the area to explain the purpose of the study. Once approval was obtained at these meetings, the study was fully explained to all adults in the household to address any concerns and to secure consent for the household to participate. Before both screening and definitive examinations, the study was explained in detail to all potential participants, and their voluntary consent was solicited. All informed consent was verbally obtained, as a significant proportion of this population was illiterate. The study and this method of obtaining informed consent was approved by the Committee on Human Research at the Johns Hopkins Bloomberg School of Public Health and by the Ethics Review Committee of the Aravind Eye and Children’s Hospitals. This project adhered to the tenets of the Declaration of Helsinki.

Statistical Analysis

We used statistical software on computer (Stata, ver. 7.0; College Station, TX) to perform the analyses. The prevalence of the various lens opacities, cataract, and other lens disorders were estimated, and confidence intervals of prevalence estimates calculated using a normal approximation of the binomial distribution.

RESULTS

We enumerated 5539 eligible persons aged 40 years or more. Among subjects 40 years or older, 5373 (96.4%) persons received the village-based screening examination, whereas 202 (3.6%) persons refused screening but provided demographic data. Data on 38 (0.7%) individuals were incomplete. Of those enumerated, 5150 were examined—a response rate of 93.0%. The median age of those examined was 51.0 years, and 55.1% were women. The response rate to examination was high, both in the field and in the hospital, and there was no association of response to examination with age, gender, religion, caste, occupation, or literacy.

The distribution of the different lens disorders included definite age-related cataract in 2499 (47.5%) persons, PXF on the lens in 197 (3.5%), complicated cataract in 13 (0.3%), traumatic cataract in 19 (0.4%), dislocated lens in 5 (0.1%), and
subluxated lens in 18 (0.4%). The age-adjusted prevalence (adjusted to U.S. population estimates for 2000) of definite cataract in this population was 61.9% (95% CI: 60.6–63.3).

The prevalence of definite cataracts increased significantly ($P < 0.001$) with age, from 15.7% among those aged 40 to 49 years to 79.4% among those aged 70 or more years (Table 1). After adjustment for age, men had lower odds (odds ratio [OR], 0.76; 95% CI: 0.64–0.86) for cataract than women.

### Nuclear Lens Opacity

After excluding persons with bilateral previous cataract surgeries, definite nuclear cataract (grade 3.0 or higher) was present in 2236 (44.7%) persons and showed a significant increase in prevalence with age ($P < 0.001$). The prevalence of all grades of nuclear lens opacities and the variation by age and gender is found in Table 2. There was no significant difference in the mean grades between sexes. The mean grade showed a significant increase with increasing age groups for both genders from 0.34 ± 0.74 among those aged 40 to 49 years to 2.02 ± 1.94 for those aged 70 or more years ($P < 0.001$). Definite nuclear cataract was present in 717 (13.9%) persons. Men were less likely to have cortical cataracts after adjusting for age (OR: 0.76, 95% CI: 0.64–0.90). The prevalence of cortical cataracts increased significantly with age ($P < 0.001$), after adjusting for sex.

### Cortical Lens Opacities

Cortical lens opacities were present in 1398 (27.1%) persons: 767 (27.3%) of women and 631 (26.9%) of men. The mean grade of cortical opacities is found in Table 2. There was no significant difference in the mean grades between sexes. There was a significant increase in mean grade with increasing age for both sexes, from 0.34 ± 0.74 among those aged 40 to 49 years to 2.02 ± 1.94 for those aged 70 or more years ($P < 0.001$). Definite cortical cataract was present in 717 (13.9%) persons. Men were less likely to have cortical cataracts after adjusting for age (OR: 0.76, 95% CI: 0.64–0.90). The prevalence of cortical cataracts increased significantly with age ($P < 0.001$), after adjusting for sex.

### Posterior Subcapsular Opacities

Posterior subcapsular opacities were present in 1178 (22.9%) persons: 616 (21.9%) women and 562 (24.0%) men. The mean grades of PSC by age are found in Table 2. There was no

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**Table 1. Prevalence of Age-Related Cataract among Subjects Aged 40 Years or More, by Age and Sex**

<table>
<thead>
<tr>
<th>Type of Cataract</th>
<th>40–49</th>
<th>50–59</th>
<th>60–69</th>
<th>≥70</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Cataract</td>
<td>325 (15.7)</td>
<td>817 (55.7)</td>
<td>976 (81.3)</td>
<td>331 (79.4)</td>
<td>2449 (47.5)</td>
</tr>
<tr>
<td>Mixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>61 (9.9)</td>
<td>181 (29.3)</td>
<td>298 (48.3)</td>
<td>77 (12.5)</td>
<td>617 (21.7)</td>
</tr>
<tr>
<td>Female</td>
<td>43 (7.8)</td>
<td>145 (26.4)</td>
<td>225 (40.9)</td>
<td>157 (24.9)</td>
<td>550 (23.7)</td>
</tr>
<tr>
<td>Only nuclear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>120 (19.1)</td>
<td>267 (42.5)</td>
<td>197 (31.4)</td>
<td>44 (7.0)</td>
<td>628 (22.1)</td>
</tr>
<tr>
<td>Male</td>
<td>49 (9.4)</td>
<td>179 (34.4)</td>
<td>230 (44.2)</td>
<td>63 (12.1)</td>
<td>521 (22.5)</td>
</tr>
<tr>
<td>Only cortical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>12 (1.7)</td>
<td>10 (1.3)</td>
<td>5 (0.8)</td>
<td>4 (2.6)</td>
<td>31 (1.1)</td>
</tr>
<tr>
<td>Male</td>
<td>12 (1.5)</td>
<td>14 (2.1)</td>
<td>6 (1.0)</td>
<td>2 (0.8)</td>
<td>34 (1.5)</td>
</tr>
<tr>
<td>Only PSC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>16 (1.5)</td>
<td>13 (1.6)</td>
<td>7 (1.2)</td>
<td>2 (1.3)</td>
<td>38 (1.3)</td>
</tr>
<tr>
<td>Male</td>
<td>12 (1.5)</td>
<td>8 (1.2)</td>
<td>8 (1.4)</td>
<td>2 (0.8)</td>
<td>30 (1.3)</td>
</tr>
<tr>
<td>Population sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1280 (100.0)</td>
<td>795 (100.0)</td>
<td>607 (100.0)</td>
<td>154 (100.0)</td>
<td>2856 (100.0)</td>
</tr>
<tr>
<td>Male</td>
<td>786 (100.0)</td>
<td>671 (100.0)</td>
<td>594 (100.0)</td>
<td>263 (100.0)</td>
<td>2314 (100.0)</td>
</tr>
</tbody>
</table>

Data presented as number of persons (%). Subjects who underwent surgery for cataract in both eyes were not considered in the analysis.

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**Table 2. Prevalence of Lens Opacities among Subjects Aged 40 Years or More, by Age**

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Nuclear</th>
<th>Cortical</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>330 (16.0)</td>
<td>512 (24.8)</td>
<td>61 (0.5)</td>
</tr>
<tr>
<td>50–59</td>
<td>69 (4.8)</td>
<td>194 (13.4)</td>
<td>24 (1.6)</td>
</tr>
<tr>
<td>60–69</td>
<td>42 (3.7)</td>
<td>128 (11.4)</td>
<td>55 (4.9)</td>
</tr>
<tr>
<td>≥70</td>
<td>35 (9.6)</td>
<td>18 (1.8)</td>
<td>22 (2.1)</td>
</tr>
<tr>
<td>Total</td>
<td>476 (9.5)</td>
<td>729 (14.6)</td>
<td>245 (4.7)</td>
</tr>
</tbody>
</table>

Data are presented as number of persons (%); the higher score of both eyes was assigned to the person for grading cataracts. Subjects ($n = 153$) who underwent surgery for cataract in both eyes were not included in this analysis for type of opacity; an additional 5 subjects had no cataract grading.
significant difference in the mean grades between men and women. The mean grade showed a significant increase with increasing age for both genders (P < 0.001). Definite posterior subcapsular cataract was determined to be present in 1024 (19.9%) and showed a significant increase in prevalence with age (P < 0.001).

### History of Cataract Surgery

Evidence for previous cataract surgery in one or both eyes, either aphakia or pseudophakia, was present in 482 (9.4%) persons, including 252 (52.3%) women and 230 (47.7%) men. The prevalence of cataract surgery in either eye increased with increasing age (P < 0.001). Bilateral cataract surgery had been performed for 153 (3.0%) persons (31.7% of all subjects having had cataract surgery), including 72 (47.1%) women and 81 (52.9%) men (Table 3). The prevalence of cataract surgery in both eyes increased significantly with age (P < 0.001). Of 640 eyes of 482 persons who had surgery for cataract, 521 (81.4%) were aphakic and 119 (18.6%) pseudophakic.

After best correction, 19 (3.7%) eyes with previous aphakic cataract surgery had visual acuity less than 6/60, including 4 (0.8%) with visual acuity less than 3/60. Only one eye (0.8%) that had undergone pseudophakic cataract surgery had visual acuity less than 6/60 (Table 4).

### Discussion

Age-related cataracts remain the predominant lens disorder and cause of treatable blindness in India, despite concerted efforts by the Indian National Program for Control of Blindness. We found that PXF of the lens was not uncommon. The prevalence and characteristics of PXF in this population have been described elsewhere. An increase in the prevalence of lens changes, with increasing age, and a predominance of nuclear lens changes is similar to that previously described in other populations.

Data from our study suggest there may be differences in the type of lens opacities and cataracts in this southern Indian population compared with other populations. The age-adjusted prevalence across all age groups is higher in our population than is found elsewhere. We cannot explain these differences, but they do not appear likely to be due to differences in methodology or lens classification.

It has been reported that age-related cataracts occur at an earlier age in persons from the Indian subcontinent as individuals age, increasing life expectancies coupled with an earlier development of cataract will probably add to the burden of cataract-related blindness, unless radical changes in surgical training and healthcare policies are made. More individuals with cataract may be opting for surgery earlier because of advancements in surgical technology, and a consequent improvement in quality of life. This increased desire for earlier surgery may increase the burden on the existing healthcare delivery systems.

The prevalence of cataract surgery in this population is higher than that reported in other developing and developed populations. There have been reports on the poor quality of cataract surgery in India, with variable and less than desirable postoperative visual acuity. Using best corrected visual acuity as a criterion, we found good postoperative visual outcomes in those whose eyes were pseudophakic. We believe these better outcomes may be due to intense training programs emphasizing high quality of care in this area of southern India. Postoperative visual outcomes in aphakic eyes are dependent on the use of spectacles with adequate refractive power. The use of spectacles is often determined by some nonmedical reasons including but not limited to affordability, distortion, and willingness to wear spectacles. The use of aphakic spectacles may affect blindness rates and impairment categories if we had used presenting vision as a basis for classification in post- cataract-surgery eyes. This may not have accurately reflected the visual potential after cataract surgery but may in turn have reflected on the quality of surgery. We therefore preferred using best corrected visual acuity to assess the quality of visual outcomes. The proportion of individuals with pseudophakic and aphakic eyes having good postoperative best corrected visual acuity is similar to the results reported in a controlled clinical trial performed in a hospital environment. This suggests that outcomes similar to those obtained in a controlled hospital environment are possible on a population basis.

The potential for misclassification between cataracts and refractive errors has to be borne in mind while assigning a principal cause of blindness. It may not always be clear in a cross-sectional study whether the myopia on examination can be attributed to a primary refractive error or lens changes. This is important in populations with a low utilization of eye care services, where it may not be possible to ascertain the history

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**Table 4.** Best Corrected Visual Acuity for Eyes with Cataract Surgery

<table>
<thead>
<tr>
<th>Acuity</th>
<th>Aphakia*</th>
<th>Pseudophakia</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥6/18</td>
<td>445 (86.2)</td>
<td>108 (90.7)</td>
</tr>
<tr>
<td>6/24–6/60</td>
<td>52 (10.1)</td>
<td>10 (8.4)</td>
</tr>
<tr>
<td>&lt;6/60–3/60</td>
<td>15 (2.9)</td>
<td>1 (0.8)</td>
</tr>
<tr>
<td>&lt;3/60</td>
<td>4 (0.8)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Total</td>
<td>516 (100.0)</td>
<td>119 (100.0)</td>
</tr>
</tbody>
</table>

* Best corrected visual acuity was not available for five aphakic eyes.
of spectacle use to determine prior refractive error. Over half of the nuclear opacities in the age group 40 to 60 were grade 2 and 3 opacities. Their mean spherical equivalents were 2 to 3 D of myopia. This possible myopic shift underscores the potential for misclassification and possible over- or underestimation. However, clinically, almost all these nuclear cataracts may require surgery at some time.

The absence of lens photographs is a limitation of our study. However, the possible effects of this limitation were minimized by performing multiple standardizations before and both 6 and 12 months into data collection and by strictly adhering to the methodology specified in the LOCS III protocol. Lens grading was attempted after full dilation was achieved at the slit lamp under full illumination and adequate magnification in a darkened room and using standard lens photographs.

Data from our study suggest that the cataract-centric approach adopted by the National Program for Prevention of Blindness in India was not misplaced and is still appropriate, considering the high prevalence of cataract and the early onset of cataract in this population. Age-related cataracts remain a major reversible public healthcare problem in southern India, requiring sustained focus. Although the exact quantum of blindness attributable to cataract may be debatable, adequate control of cataract in India depends on a better understanding of risk factors and continuous estimation of magnitude leading to strategies that focus on curative, preventive, and social aspects.24,25

References