WORLD VIEW

A population based eye survey of older adults in Tirunelveli district of south India: blindness, cataract surgery, and visual outcomes

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Aims: To assess the prevalence of vision impairment, blindness, and cataract surgery and to evaluate visual acuity outcomes after cataract surgery in a south Indian population.

Methods: Cluster sampling was used to randomly select a cross sectional sample of people ⩾50 years of age living in the Tirunelveli district of south India. Eligible subjects in 28 clusters were enumerated through a door to door household survey. Visual acuity measurements and ocular examinations were performed at a selected site within each of the clusters in early 2000. The principal cause of visual impairment was identified for eyes with presenting visual acuity <6/18. Independent replicate testing for quality assurance monitoring was performed in subjects with reduced vision and in a sample of those with normal vision for six of the study clusters.

Results: A total of 5795 people in 3986 households were enumerated and 5411 (93.37%) were examined. The prevalence of presenting and best corrected visual acuity ⩾6/18 in both eyes was 59.4% and 75.7%, respectively. Presenting vision <6/60 in both eyes (the definition of blindness in India) was found in 11.0%, and in 4.6% with best correction. Presenting blindness was associated with older age, female sex, and illiteracy. Cataract was the principal cause of blindness in at least one eye in 70.6% of blind people. The prevalence of cataract surgery was 11.8%—with an estimated 56.5% of the cataract blind already operated on. Surgical coverage was inversely associated with illiteracy and with female sex in rural areas. Within the cataract operated sample, 31.7% had presenting visual acuity ⩾6/18 in both eyes and 11.8% were <6/60; 40% were bilaterally operated on, with 63% pseudophakic. Presenting vision was <6/60 in 40.7% of aphakic eyes and in 5.1% of pseudophakic eyes; with best correction the percentages were 17.6% and 3.7%, respectively. Refractive error, including uncorrected aphakia, was the main cause of visual impairment in cataract operated eyes. Vision <6/18 was associated with cataract surgery in government, as opposed to that in non-governmental/private facilities. Age, sex, literacy, and area of residence were not predictors of visual outcomes.

Conclusion: Treatable blindness, particularly that associated with cataract and refractive error, remains a significant problem among older adults in south Indian populations, especially in females, the illiterate, and those living in rural areas. Further study is needed to better understand why a significant proportion of the cataract blind are not taking advantage of free of charge eye care services offered by the Aravind Eye Hospital and others in the district. While continuing to increase cataract surgical volume to reduce blindness, emphasis must also be placed on improving postoperative visual acuity outcomes.

Recent surveys in India, and elsewhere, have demonstrated that cataract blindness continues as the leading cause of blindness in developing countries.[1–7] Accordingly, blindness control programmes in India have focused primarily on cataract.[8 9] Although such programmes have improved the coverage of cataract surgery,[1 4 10] they have not always resulted in good postoperative vision outcomes. Reports from population based studies in Nepal,[11] China,[12 13] and recently from three in India[14–16] underscore the unmet need to fully realise the sight restoring potential of cataract surgery.

This article reports on the prevalence of vision impairment, blindness, and cataract surgery, as well as postoperative visual acuity status, among people 50 years of age and older and living in the Tirunelveli district of Tamil Nadu, the southern most state of India. Tirunelveli, in the southern part of Tamil Nadu, has an economy based primarily on agriculture. The 1991 population of the district was 2 501 832, with 49.2% males.[17] Among males, 16.7% were of age 50 years or older, and 16.4% among females. Literacy was 66.5% in males and 46.9% in females (all ages). Sixty eight per cent of the population resides in rural areas.

The district is served by the Aravind Eye Hospital in Tirunelveli, with 11 ophthalmologists currently on staff, and by approximately 100 other ophthalmologists practising in the district, including those at a government medical college hospital. The Aravind Eye Hospital, established in Tirunelveli in 1988 as part of the Aravind Eye Hospitals network based in Madurai (also in Tamil Nadu), is the largest provider of eye care services. (In 1999, 23 897 cataract surgeries were performed at the hospital, with 72% being free of charge to the patient—about half were for patients living outside of Tirunelveli district.)

MATERIALS AND METHODS

The survey population was selected by cluster sampling. To construct a sampling frame of approximately equally sized clusters, small villages were grouped together and large villages were segmented, resulting in 1983 clusters with population ranging from 854 to 1635. A sample size requirement of 5498 people was based on estimating with 95% confidence a cataract blindness prevalence of 8% (plus or minus 1.0%), including an anticipated 90% examination response rate among enumerated subjects and cluster sampling design effects of 1.75. Twenty eight clusters—21 rural and seven urban—were randomly selected with equal probability, with an estimated 1991 census population of 34 435, and approximately 5700 people ⩾50 years of age.

Fieldwork took place over an 8 week period starting in mid-March 2000. Four enumeration teams performed door to door enumeration of residents within the selected clusters. Residency was defined as having lived in the cluster for the last 6 months, including those temporarily absent. Age, literacy, years of formal schooling, and occupation were elicited by face to face interviews—or from a responsible member of the family when this was not possible. Those 50 years of age or older were invited to a site within the village for visual acuity measurement and ocular examination during a 2 day period immediately following the enumeration process. Two teams conducted clinical assessments—working independently at different sites. Each team consisted of one ophthalmologist and two ophthalmic assistants.

Verbal informed consent was obtained from all participants at the examination site. The World Health Organization (WHO) Secretariat Committee on Research Involving Human Subjects and the Indian Council for Medical Research cleared the examination protocol, which was also used in earlier surveys in India,[1 4] Nepal,[5] and China.[6 7] The protocol was also approved by the institutional review board of the Aravind Eye Hospitals and Post Graduate Institute of Ophthalmology.

Ophthalmic assistants measured presenting distance visual acuity using retroilluminated logMAR tumbling E charts—with spectacles if the subject was using them—and best corrected visual acuity after refraction using streak retinoscopy. Visual acuity measured separately for each eye was recorded as the smallest line read with one or no errors. Visual acuity was assessed at 4 metres, and those unable to read the top line of the chart were tested at 1 metre. When necessary, testing included the ability to count fingers, to detect hand movements, or to perceive light. "No light perception" was assigned to absent/phthisical eyes. All people who had previous cataract surgery and all people with visual acuity <6/18 at presentation were refracted. Subjects were queried regarding the date and place of surgery for each cataract operated eye.

Detailed examination of the external eye, anterior segment, and fundus, including evidence of cataract surgery complications, was performed using slit lamp biomicroscopy and direct ophthalmoscopy by the team ophthalmologist. For cataract operated eyes, the extraction procedure employed—intracapsular (ICCE) or extracapsular (ECCE)—and whether an intraocular lens was implanted, were recorded. Pupils were dilated in all operated on eyes and in those eyes where lens or retinal status, including optic disc characteristics, could not be evaluated otherwise. The presence of cataract was defined as partial or complete obscuration of red reflex with lens changes evident on slit lamp examination. Intraocular pressure was measured by applanation tonometry for those cases suspected as having glaucoma based either on the anterior chamber depth, optic nerve characteristics, or previous surgery for glaucoma. All eyes with presenting visual acuity <6/18 were assigned a principal cause of visual impairment/blindness by the examining ophthalmologist using a 20 item list. Refractive error was assigned as the cause for eyes improving to at least 6/18 with best correction.

Those physically unable to attend the examination site and those failing to come after follow up contact were offered the ocular examination at home. Those not willing to be examined either at home or the examination site after a minimum of six follow up contacts were considered refusals. Eligible residents not present during the examination period were recorded as absent.

Treatment for minor ophthalmic problems was provided free of charge at the examination site. Those with previous cataract surgery or visual acuity <6/60 improving with refraction were provided spectacles free of charge. Individuals requiring cataract surgery or further diagnostic assessment were referred to the Aravind Eye Hospital in Tirunelveli for free treatment.

Staff training at the Aravind Eye Hospital in Tirunelveli preceded the fieldwork. The two study ophthalmologists were standardised to each other with regard to lens status, cataract surgery procedure, incision type, iridectomy status, and cause of vision impairment. In 100 test subjects, interobserver agreement was present in all but one case with disagreement regarding the cataract surgery procedure. The two pairs of ophthalmic assistants were standardised to each other in the measurement of visual acuity, and to a senior optometrist considered the gold standard; agreement was checked in a masked fashion on three separate occasions during the training.

After the 2 week training period, a pilot study was conducted in two non-study clusters—one urban and the other rural. Because participation in the examination among enumerated subjects was less than 85%, a second pilot was conducted in two additional non-study clusters—where 271 subjects were enumerated and 254 (93.7%) examined. The pilot studies provided an opportunity for all aspects of the study protocol to be tested and team performance evaluated in a setting similar to that which would be experienced in the full study.

Interobserver agreement for visual acuity measurement between ophthalmic assistants was monitored during the course of the study in six preselected clusters. All people with presenting visual acuity <6/18 in either eye, all people with previous cataract surgery, and 10% of those with normal vision were tested twice, independently by two ophthalmic assistants in a masked fashion. Interobserver agreement was evaluated for 474 right eyes and 474 left eyes—72.6% of eyes had presenting visual acuity worse than 6/18 on the first measurement. Exact line by line agreement was achieved in 93.9% of right eyes and 94.1% of left eyes, with kappa statistics of 0.93 and 0.94, respectively.

For reporting of vision status, subjects were placed in one of five categories: (1) NN: normal or near normal vision, ⩾6/18 in both eyes; (2) VI: unilateral or bilateral visual impairment, <6/18 to ⩾6/60 in the worse eye and ⩾ 6/60 in the better eye; (3) UL: unilateral blindness, <6/60 in the worse eye and ⩾6/60 in the better eye; (4) MB: moderate bilateral blindness, visual acuity <6/60 in the worse eye and <6/60 to ⩾3/60 in the better eye; (5) SB: severe bilateral blindness, visual acuity <3/60 in both eyes.

The cause of blindness was tabulated for affected eyes. Those blind with cataract as the cause in one or both eyes were defined as cataract blind. (These individuals would no longer be bilaterally blind after successful cataract surgery.) The cataract blind included those who had previous cataract surgery in one eye, but were currently blind in that eye as well as in the unoperated, fellow eye. In defining a never operated cataract blind group, previously operated cases were excluded.

Cataract blindness burden was defined as the sum of all the never operated cataract blind plus those already operated cases who were possibly bilaterally blind when initially operated on for cataract. Because preoperative status was not available, already operated cases were presumed to have been bilaterally blind at the time of initial cataract surgery if both eyes were operated on, or if only one eye was operated on and the fellow eye was currently blind from cataract. Surgical coverage within the cataract blind cohort was taken as the proportion already operated on for cataract.

Table 1 Prevalence of vision impairment and blindness based on presenting and best corrected visual acuity*

Worse eye visual acuity	Better eye visual acuity: ≥6/18	<6/18 to ≥6/60	<6/60 to ≥3/60	<3/60	All
≥6/18	NN 3216 (59.5) 4095 (75.8)				3216 (59.5) 4095 (75.8)
<6/18 To ≥6/60	VI	1013 (18.7) 541 (10.0)			1013 (18.7) 541 (10.0)
<6/60 To ≥3/60	UL 584 (10.8, 9.9 to 11.7) 521 (9.6, 8.8 to 10.4)		MB 370 (6.8, 5.4 to 8.3) 85 (1.6, 1.1 to 2.0)		434 (8.0) 103 (1.9)
<3/60				SB 222 (4.1, 3.3 to 5.0) 163 (3.0, 2.3 to 3.7)	742 (13.7) 666 (12.3)
All	3744 (69.3) 4695 (86.9)	1069 (19.8) 462 (8.5)	370 (6.8) 85 (1.6)	222 (4.1) 163 (3.0)	5405 (100.0) 5405 (100.0)

NN = normal/near normal; VI = unilateral or bilateral vision impairment; UL = unilateral blindness; MB = moderate bilateral blindness; SB = severe bilateral blindness.
*Data are given as number of people (percentage prevalence, 95% confidence interval). For each pair of numbers, presenting visual acuity is on the top and best corrected visual acuity on the bottom.

The prevalences of blindness, blindness due to cataract, and cataract surgery were estimated, and multiple logistic regression modelling was used to investigate associations with age, sex, literacy, and area of residence (urban/rural). Differences in the cataract blindness burden and in surgical coverage across age, sex, literacy, and residence were also investigated with logistic regression. For cataract operated eyes, time period and place of surgery, sex, literacy, and area of residence as possible predictors of good vision (visual acuity ≥6/18) were investigated with logistic regression models. These later models used only the first operated eye in bilaterally operated people. (Independence among eyes would not have been maintained if second operated eyes had been included—compromising the calculation of confidence intervals for odds ratios.)

Confidence intervals (CI) for prevalence estimates and for odds ratios from the regression analyses were calculated taking design effects (deff) associated with the cluster sampling design into account. Design effects reflect the relative inefficiency of cluster sampling compared to a simple random sampling plan, and can become large when within cluster variance is small compared to between cluster variance for the parameter being estimated. Pairwise interactions between variables in the multiple regression models were assessed simultaneously using the adjusted Wald F test, and considered significant at the p <0.100 level. Missing values were ignored in all analyses and, thus, were assumed to be distributed the same as available data. Statistical analyses were performed using STATA statistical software.[18]

Table 2 Prevalence of presenting bilateral blindness (visual acuity <6/60) by age, sex, literacy, and residence

	Number examined*	Blindness prevalence No (%)	Adjusted odds ratio (95% CI)
Age (years)			
50–59	2681	155 (5.8)	1.0
60–69	1718	218 (12.7)	2.4 (1.9 to 2.9)†
≥70	1006	219 (21.8)	4.5 (3.5 to 5.7)†
Sex			
Male	2420	193 (8.0)	1.0
Female	2985	399 (13.4)	1.4 (1.1 to 1.8)‡
Literacy			
Literate	2119	115 (5.4)	1.0
Illiterate	3286	477 (14.5)	2.2 (1.6 to 3.1)†
Residence			
Urban	1306	97 (7.4)	1.0
Rural	4099	495 (12.1)	1.5 (0.8 to 2.8)
All	5405	592 (11.0)	

*Not including six people with missing visual acuity measurements; †p ≤0.001; ‡p≤0.010.

RESULTS

A total of 3986 households with at least one eligible person ≥50 years of age were identified. A total of 5795 eligible people were enumerated: 50% were 50–59 years of age, 32% were 60–69 years, and 18% were ≥70 years. Their mean age was 61.0 years, and 45.7% were males. Sixty per cent of enumerated people had no formal schooling, and 76% were living in rural villages.

Examinations were performed on 5411 participants—an overall response rate of 93.4%. Eighty seven participants (1.6%) were examined in their homes. Of the 384 people enumerated but not examined, 306 (79.7%) were unavailable because of temporary absence and 78 (20.3%) refused to participate. Enumerated females were somewhat more likely to be examined than males (94.9% versus 91.5%; χ^2 test, p <0.001), as were those living in urban areas (94.8% versus 92.9% for rural areas; p = 0.016). Age and schooling were not associated with examination response. The mean age of the examined population was 61.0 years—61.3 for males and 60.8 for females. On average, males had 4.2 years of schooling, and females 1.4 years.

Table 1 shows the prevalence of vision impairment and blindness based on both presenting and best corrected visual acuity using the five previously defined vision categories. This table also shows the distribution of vision based on better eye and worse eye visual acuity. Visual acuity could not be measured in six individuals because of their inability to cooperate. The 87 cases examined at home had poorer vision than those examined at the village site (Kolmogorov-Smirnov test, p = 0.004). The difference between males and females in the distribution of both presenting and best corrected vision was

Table 3 Principal causes of presenting blindness in eyes

Principal cause	Eyes of bilaterally blind person No (%)	Eyes of unilaterally blind people No (%)	All blind eyes No (%)
Cataract	762 (64.4)	355 (60.8)	1117 (63.2)
Refractive error	276 (23.3)	72 (12.3)	348 (19.7)
ARMD	34 (2.9)	18 (3.1)	52 (2.9)
Corneal opacity	19 (1.6)	31 (5.3)	50 (2.8)
Globe disorders*	19 (1.6)	31 (5.3)	50 (2.8)
Glaucoma	27 (2.3)	14 (2.4)	41 (2.3)
Optic atrophy	11 (0.9)	17 (2.9)	28 (1.6)
Retinal detachment	6 (0.5)	13 (2.2)	19 (1.1)
PCO	6 (0.5)	6 (1.0)	12 (0.7)
Amblyopia	2 (0.2)	6 (1.0)	8 (0.5)
Other/surgical complications	6 (0.5)	9 (1.5)	15 (0.9)
Other	16 (1.4)	12 (2.1)	28 (1.6)
All causes	1184 (1.4)	584 (100.0)	1768 (100.0)

*Phthisical/disorganised/absent globe.

statistically significant (p <0.001), with females having more impairment.

Spectacles were worn by 536 (9.9%) of the examined population. Of these, 246 (45.9%) had presenting vision ≥6/18 in both eyes. Blindness (<6/60) with presenting vision was 11.0% (95% CI: 8.8% to 13.1%, deff 5.943). With best correction, the prevalence was reduced to 4.6 % (95% CI: 3.7% to 5.5%, deff 2.328)—indicating that more than half of those who presented blind would not be if they had had adequate corrective lenses. Further, the percentage of cases with better eye visual acuity ≥6/18 increased from 69.3% to 86.9% with best correction (Table 1).

Presenting blindness was associated with older age, female sex, and illiteracy (Table 2). (The illiterate population coincided with those reporting no formal schooling plus two cases with schooling.) Area of residence was not an independent predictor of blindness.

Principal causes of presenting blindness in the 592 bilaterally blind people and the 584 unilaterally blind are shown in Table 3. Including the 355 eyes of those unilaterally blind because of cataract, cataract accounted for 63.2% of all eyes presenting blind, representing a prevalence of 10.3% (1117/10 810) among examined eyes. Among the bilaterally blind, 344 (58.1%) were blind because of cataract in both eyes and another 74 (12.5%) in only one eye, for a total of 762 cataract blind eyes affecting 418 (70.6%) of the bilaterally blind people, and representing a cataract blindness prevalence of 7.7% (95% CI: 6.1% to 9.3%, deff=4.494).

Uncorrected refractive error, correctable to at least 6/18, was the next major cause of presenting blindness—accounting for 19.7% of blind eyes, and affecting 158 bilaterally blind people (26.7%) in one or both eyes and 72 unilaterally blind people (12.3%). Together, 545 (92.1%) of the bilaterally blind people had cataract or correctable refractive error in one or both eyes, along with 427 (73.1%) of the unilaterally blind. Age related macular degeneration (ARMD) and glaucoma were the next most frequently identified causes in those presenting bilaterally blind, while corneal opacities and globe disorders (phthisical, disorganised, or absent) were more frequent in those unilaterally blind. The other/surgical complications category includes eyes where the principal cause of blindness was taken to be cataract surgery, and not represented by any of the specific causes itemised in Table 3.

Seventy five of the 592 presenting bilaterally blind (12.7%) had already been operated on for cataract. This included 43 of the 418 bilaterally blind with unoperated cataract in at least one eye—leaving 375 of the cataract blind as having never been operated on. The distribution of the never operated cataract blind by age, sex, literacy, and residence is shown in Table 4. In investigating the association of cataract blindness with age, sex, literacy, and area of residence, it was necessary to fit a multiple logistic regression model for those from urban areas separate from rural residents because of statistically significant interactions between place of residence and other model variables. Never operated cataract blindness was associated with increasing age and illiteracy in both models, and with female sex in the rural model (Table 5).

A total of 638 people had been already operated on for cataract—including the 75 who were still bilaterally blind—representing a cataract surgery prevalence of 11.8% (95% CI: 9.9% to 13.6%, deff = 4.188). Statistically significant interactions between model variables again necessitated separate regression models for urban and rural residents. Cataract surgery was associated with older age in both models, and inversely with illiteracy among rural residents (Table 5).

The burden of cataract blindness affected 861 (15.9%) of those examined—the 373 never operated cataract blind plus 486 of the 638 already operated who were presumed to have been blind when first operated on for cataract (Table 4). Interactions between variables in the regression model were not significant, allowing for a composite model encompassing both urban and rural residents. Cataract blindness burden was associated with increasing age, female sex, and illiteracy (Table 5). Area of residence was not significant.

Table 4 Presenting cataract blindness and cataract surgery by age, sex, literacy, and residence*

	Examined population	Never operated cataract blind		All cataract operated		Cataract blindness burden		% surgical coverage
		No	Prevalence	No	Prevalence	No	Prevalence	
Age (years)								
50–59	2683	89	3.3	128	4.8	176	6.6	49.4
60–69	1718	128	7.5	248	14.4	310	18.0	58.7
≥70	1010	158	15.6	262	26.0	375	37.1	57.9
Sex								
Male	2424	96	4.0	290	12.0	310	12.8	69.0
Female	2987	279	9.3	348	11.7	551	18.4	49.4
Literacy								
Literate	2122	63	2.96	266	12.5	251	11.8	74.9
Illiterate	3289	312	9.49	372	11.3	610	18.5	48.9
Residence								
Urban	1307	50	3.8	211	16.1	216	16.5	76.9
Rural	4104	325	7.9	427	10.4	645	15.7	49.6
All	5411	375	6.9	638	11.8	861	15.9	56.5

*Prevalence estimates are crude prevalence per 100 examined subjects.

Table 5 Relation of age, sex, and literacy to cataract blindness and surgery for people from urban and rural areas*

	Never operated cataract blindness		All cataract operated		Cataract blindness burden§	Surgical coverage	
	Urban residence	Rural residence	Urban residence	Rural residence		Urban residence	Rural residence
Age (years)							
50–59	1.0	1.0	1.0	1.0	1.0	1.0	1.0
60–69	4.2 (2.0 to 8.5)†	2.2 (1.5 to 3.1)†	3.0 (2.2 to 4.2)†	3.6 (2.8 to 4.7)†	3.2 (2.6 to 3.8)†	0.6 (0.2 to 1.4)	1.7 (1.0 to 2.6)‡
⩾70	6.5 (2.7 to 15.5)†	5.5 (4.0 to 7.6)†	7.6 (3.7 to 15.5)†	7.0 (5.4 to 9.1)†	8.5 (6.9 to 10.4)†	0.9 (0.4 to 2.2)	1.3 (0.9 to 2.1)
Sex							
Male	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Female	1.0 (0.8 to 1.3)	2.3 (1.8 to 3.1)†	1.1 (0.8 to 1.7)	1.1 (0.8 to 1.5)	1.5 (1.3 to 1.8)†	1.1 (0.8 to 1.5)	0.5 (0.3 to 0.8)‡
Literacy							
Literate	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Illiterate	3.6 (1.5 to 8.7)‡	1.8 (1.3 to 2.5)†	1.0 (0.7 to 1.6)	0.7 (0.5 to 0.9)‡	1.3 (1.1 to 1.6)†	0.3 (0.1 to 0.8)‡	0.5 (0.3 to 0.9)‡

*Data are given as adjusted odds ratios (95% confidence intervals), obtained by multiple logistic regression models with age category, sex, literacy, and residence as covariates; †p⩽0.010; ‡p⩽0.050; §the adjusted odds ratio for rural/urban in this model was 0.9 (95% CI: 0.6 to 1.3).

Surgical coverage among those affected by cataract blindness was calculated as 56.5% (Table 4). Relatively low coverage was observed among rural residents, the illiterate, and females. Again, because of interactions between area of residence and other variables, two separate logistic regression models were used. Illiteracy was inversely associated with surgical coverage among both urban and rural residents, as was female sex among rural residents. An overall lower surgical coverage was observed among females, which was entirely attributable to the sex disparity in the rural population. Those 60–69 years old and living in rural areas had higher surgical coverage than those in the 50–59 year group. For urban residents, surgical coverage among the cataract blind was higher in the 50–59 year group, but not at a statistically significant level.

The cross sectional sample of 638 people operated on for cataract had a median age of 67 years, and 45.5% were males. Forty per cent had cataract surgery in both eyes (893 operated eyes). Thirty seven per cent were aphakic and 63.0% pseudophakic, including 4.7% who were aphakic in one eye and pseudophakic in the fellow eye (Table 6). Thirty five per cent of the cataract operated were wearing glasses, including 67.8% of aphakic people. There were 386 aphakic eyes—237 were operated with conventional ICCE, 130 with ECCE without an IOL implant, and for 19 aphakic eyes the examining ophthalmologist could not determine which procedure was used (for example, because of a disorganised globe or corneal abnormalities).

Presenting and best corrected visual acuity for cataract operated eyes is shown in Table 7.

Table 8 identifies the principal causes of presenting impairment/blindness. Of the 169 eyes where refractive error was specified as the cause by the examining ophthalmologist, all improved to ⩾6/18 with best correction. Additionally, one of the AMD cases improved to ⩾6/18 with best correction. The other/surgical complications category includes 18 cases where the principal cause of impairment was cataract surgery related, and not represented by the specific itemised causes, such as optic atrophy and retinal detachment, where it may have been a contributing factor. Surgical complications were

Table 6 Lens status of both eyes for cataract operated people by presenting visual acuity*

Presenting vision category	Bilateral aphakic	Unilateral aphakic	Pseudophakic aphakic	Bilateral pseudophakic	Unilateral pseudophakic	
	No (%)	No (%)	No (%)	No (%)	No (%)	All
NN	60 (50.0)	0 (0.0)	2 (6.7)	80 (76.2)	60 (22.5)	202 (31.7)
VI	20 (16.7)	2 (1.7)	0 (0.0)	17 (16.2)	57 (21.3)	96 (15.1)
UL	22 (18.3)	66 (56.9)	28 (93.3)	6 (5.7)	142 (53.2)	264 (41.4)
BB	18 (0.15)	48 (41.3)	0 (0.0)	1 (0.9)	8 (3.0)	75 (11.8)
All	120 (18.8)	116 (18.2)	30 (4.7)	105† (16.5)	267 (41.8)	638† (100)

NN = normal/near normal vision, ⩾6/18 in both eyes; VI = unilateral or bilateral vision impairment, ⩾6/60 in the better eye and <6/18 to ⩾6/60 in the worse eye; UL = unilateral blindness, ⩾6/60 in the better eye and <6/60 in the worse eye; BB = bilateral blindness <6/60 in both eyes.
*Data are given as number (%) of people; †includes one pseudophakic person with no visual acuity measurement in either eye.

Table 7 Presenting and best corrected visual acuity outcomes in aphakic and pseudophakic eyes*

	⩾6/18	<6/18–⩾6/60	<6/60	
	No (%)	No (%)	No (%)	All
Presenting vision				
Aphakic eyes	182 (47.2)	47 (12.2)	157 (40.7)	386 (100)
Pseudophakic eyes	388 (76.8)	91 (18.0)	26 (5.1)	505 (100)
Best corrected vision				
Aphakic eyes	279 (72.3)	39 (10.1)	68 (17.6)	386 (100)
Pseudophakic eyes	461 (91.3)	25 (4.9)	19 (3.8)	505† (100)

*Data are given as number (%) of eyes; †does not include two pseudophakic eyes in one person where neither presenting nor best corrected visual acuity could be measured.

Table 8 Principal cause of impaired vision/blindness in cataract operated eyes by presenting visual acuity*

Principal cause	<6/18–≥6/60 Aphakic	<6/18–≥6/60 Pseudophakic	<6/60 Aphakic	<6/60 Pseudophakic	Total
Refractive error/uncorrected aphakia	30 (63.8)	71 (78.0)	67 (42.7)	1 (3.9)	169 (52.7)
Glaucoma	0 (0.0)	0 (0.0)	5 (3.2)	4 (15.4)	9 (2.8)
Optic atrophy	0 (0.0)	0 (0.0)	12 (7.6)	1 (3.9)	13 (4.1)
AMD	12 (25.5)	12 (13.2)	27 (17.2)	4 (15.4)	55 (17.1)
Posterior capsule opacity	0 (0.0)	5 (5.5)	3 (1.9)	9 (34.6)	17 (5.3)
Phthisical/disorganised globe	0 (0.0)	0 (0.0)	9 (5.7)	0 (0.0)	9 (2.8)
Corneal opacity	2 (4.2)	0 (0.0)	5 (3.2)	1 (3.9)	8 (2.5)
Retinal detachment	0 (0.0)	0 (0.0)	13 (8.3)	1 (3.9)	14 (4.4)
Amblyopia	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	1 (0.3)
Other/surgical complications	1 (2.1)	2 (2.2)	10 (6.4)	5 (19.2)	18 (5.6)
Other	2 (4.3)	1 (1.1)	5 (3.2)	0 (0.0)	8 (2.5)
All causes	47 (100.0)	91 (100)	157 (100)	26 (100)	321 (100)

*Data are given as number (%) of eyes.

evident in 24 of the 303 eyes not included in the other/surgical complications category.

Overall, surgical complications were present in 49 (5.5%) of the 893 cataract operated eyes, including seven eyes without visual acuity impairment. Corneal decompensation was the most common complication, observed in 13 eyes (1.5%). Less common complications included papillary capture in 11 eyes (1.2%), postoperative uveitis in eight eyes (0.9%), vitreous loss in seven eyes (0.8%), cystoid macular oedema in six eyes (0.7%), iris prolapse in four eyes (0.4%), and endophthalmitis in two eyes (0.2%). Iridodialysis, epithelial in-growth, wound dehiscence, and retained cortex were each observed in one eye.

Although cataract surgery for the cross sectional sample of eyes was found to span several decades, 68% had been performed since 1995 (Table 9)—approximately half of the cases had been operated on within 3 years of the survey. Time intervals were categorised such that all cases operated on after the World Bank assisted cataract blindness control project[9] was initiated were grouped together (the ≥1995 period) and those operated on before the nationwide survey conducted by the national programme for control of blindness in 1986–9[8] were also grouped (≤1989). Two thirds of the cataract surgeries were performed by the Aravind Eye Hospital in Tirunelveli. Cases operated on in camps were few (3.6%). Two thirds of the operated on eyes were of patients living in rural areas. The majority of patients were illiterate. (Less than 5% of the patients travelled to facilities outside the district for cataract surgery.)

The association of time period and place of surgery, sex, literacy, and area of residence with visual acuity ≥6/18 was explored with logistic regression modelling using first operated eyes: 265 aphakic and 373 pseudophakic. Separate regression models were used for each of the two lens categories. Presenting vision in aphakic eyes was associated with place of surgery, with both the Aravind Eye Hospital and other NGO/private facilities producing better visual acuity outcomes than cases operated on in government facilities: adjusted odds ratios of 2.9 (95% CI: 1.4 to 5.7) and 3.3 (95% CI: 1.6 to 6.9), respectively. The better outcomes observed among those operated in earlier years, among males, among the literate, and among those from urban areas were not statistically significant. With best corrected visual acuity, the better outcomes for cases operated at the Aravind Eye Hospital remained statistically significant. Regression modelling for pseudophakic eyes was limited to those operated on since 1995. Except for the Aravind Eye Hospital, few IOL cases were operated before 1995 (thus, the exclusion of these cases from the regression model). Again, presenting visual acuity ≥6/18 was associated with surgery at the Aravind Eye Hospital and other NGO/private facilities: adjusted odds ratios of 3.8 (95% CI: 1.6 to 9.2) and 5.7 (95%CI: 1.8 to 18.2), respectively.

Table 9 Presenting and best corrected visual acuity of operated on eyes*

	Aphakic			Pseudophakic			
	No eyes	%PVA ≥6/18	%BCVA ≥6/18	No eyes	%PVA ≥6/18	%BCVA ≥6/18	Total eyes No (%)
Time period							
≥1995	161	36.7	72.7	448†	75.8	90.8	609 (68.2)
1990–4	135	51.9	75.6	55	83.6	94.6	190 (21.3)
≤1989	90	58.9	66.7	4	100.0	100.0	94 (10.5)
Place							
Government	110	28.2	63.6	52	59.6	76.9	162 (18.1)
NGO/private	59	61.0	71.2	56	83.9	96.4	115 (12.9)
Aravind Hospital	186	53.2	79.0	398†	78.3	92.4	584 (65.4)
Eye camp	31	51.6	64.5	1	0.0	100.0	32 (3.6)
Sex							
Male	164	51.8	72.6	238†	80.5	92.4	402 (45.0)
Female	222	43.7	72.1	269	73.6	90.3	491 (55.0)
Literacy							
Literate	141	58.9	78.0	233†	81.0	93.1	374 (41.9)
Illiterate	245	40.4	69.0	274	73.4	89.8	519 (58.1)
Residence							
Urban	127	56.7	74.0	166	78.9	92.2	293 (32.8)
Rural	259	42.5	71.4	341†	75.8	90.9	600 (67.2)
All	386	47.2	72.3	507†	76.8	91.3	893 (100.0)

*PVA = presenting visual acuity; BCVA = best corrected visual acuity; †presenting and best corrected vision was unknown for two pseudophakic eyes of one literate rural male operated on at Aravind Hospital in ≥1995.

The better outcomes at these facilities remained significant with best corrected vision.

Lens status was included as a covariate in multiple logistic regression modelling encompassing all (first operated) eyes from the ⩾1995 time period, which confirmed the superiority of IOL operated cases. The aphakia/pseudophakia odds ratio in the model for presenting visual acuity (⩾6/18) was 6.1 (95% CI: 3.2 to 11.4), and 3.5 (95% CI: 1.9 to 6.5) in the model for best corrected vision. In both models, surgery in non-government facilities was also a predictor of better outcomes.

DISCUSSION

Presenting bilateral blindness (<6/60) was found in 11.0% of this older adult population. In addition to advancing age, female sex and illiteracy were predictors of blindness. Cataract in one or both eyes accounted for over two thirds of the blindness, with a prevalence in the examined population of 7.7%. Correctable refractive error was also important as a principal cause of blindness—over one fourth of those presenting blind improved to normal/near normal vision (⩾6/18) in at least one eye with best corrected vision. Others did not achieve normal/near normal vision with best correction, but showed sufficient improvement so that they were no longer blind (⩾6/60)—these cases had something other than refractive error identified as the principal cause of presenting blindness, generally cataract. Overall, it was possible to reduce the prevalence of blindness to 4.6% with best corrected vision.

Although unoperated cataract remains as a major cause of blindness in Tirunelveli, nearly 12% of examined people had already received cataract surgery. Surgical coverage, which was higher in urban areas, was inversely associated with illiteracy and with female sex in rural areas. Better presenting and best corrected visual acuity outcomes in the cataract operated were associated with surgery at non-governmental facilities. Refractive errors, including uncorrected aphakia, accounted for more than half of presenting visual impairment/blindness—representing a substantial unmet need for aphakic and other prescription glasses. Age related macular degeneration was identified as the principal cause of impairment in 17% of cases. Surgical complications were evident in 13% of cases with impairment, including those where it may have been only a contributing factor.

This survey should be representative of the entire Tirunelveli district, from which the study sample was randomly drawn. The door to door enumeration process and high examination response rates produced the desired sample size. Nevertheless, because design effects associated with the cluster sampling plan were sometimes much greater than anticipated, the desired level of precision was not always obtained for some of the estimates. The prevalence of vision impairment/blindness may have been overestimated to the extent that those not examined may have been less likely to be suffering from vision impairment. They were relatively young and frequently unavailable because of work outside of the study area. On the other hand, because prevalence estimates were based only on central vision measurements, some impairment/blindness associated with visual field defects could have been missed—resulting in a potential underreporting of impairment/blindness associated with glaucoma, optic atrophy, and retinal disorders, such as retinitis pigmentosa. It is also possible that the causes of blindness would have been distributed somewhat differently (at the expense of cataract) if perimetry data had been available or if all fundus examinations had been performed with dilated pupils.[19]

The finding of a significantly higher cataract blindness burden among females and the illiterate is reflective of a higher incidence of cataract blindness, which in turn is the result of an increased risk of cataract development and/or a lower chance of surgery in the preblinding stages of cataract. (Without early surgery, cataract cases will ultimately reach the blindness stage, at which point they become part of the cataract blindness burden.) Because males did not receive cataract surgery at a significantly higher rate than females, it is unlikely that earlier surgery in males is responsible for this sex related disparity in cataract blindness burden. Thus, it reasonable to suspect that the higher burden in females is due, at least in part, to a greater risk of cataract development. Although the illiterate in urban areas had cataract surgery at rates comparable to their literate counterparts, this was not the situation with the illiterate from rural areas. Thus, a lower chance of early surgery is a probable reason for the higher cataract blindness burden among the illiterate, particularly those living in rural areas.

Although not at statistically significant levels, presenting vision appeared to be worse for aphakic eyes operated in the period since 1995. This may have been brought about by the changing case mix associated with the trend towards IOL surgery in India.[20] People who in the past might have received ICCE, and complied with use of aphakic spectacles because of a necessity for relatively good vision, may now be choosing IOL surgery—in effect leaving aphakic surgery for the less compliant and for those who may be satisfied with lower levels of vision. Increasingly, aphakic surgery may be an option primarily for individuals where implantation of an intraocular lens is contraindicated. Even though ECCE-IOL surgery is priced to make it affordable to virtually everyone, it is usually not offered entirely free of charge, which traditionally has been the case with aphakic surgery. Thus, wearing unattractive aphakic glasses today might be equated with the inability to afford the preferred IOL surgery, and aphakics might forego wearing spectacles for this reason. The rising costs of spectacles could also be a factor for those with lost or broken spectacles.

The apparently superiority of outcomes in IOL cases operated before 1995 (which were essentially all Aravind Eye Hospital cases) might have been influenced by a changing case mix as well. With increased patient demand for IOLs, eyes that previously might not have received an IOL, because of the risk of a less than completely successful visual acuity outcome, may now be receiving them—including eyes with mature cataract where effective preoperative posterior segment examination may not be possible. Difficulties during the transition of community surgeons experienced with ICCE to ECCE-IOL surgery may also have had a negative influence on cases operated in the post-1995 period.

The trend towards IOL surgery raises the issue of visual disability because of posterior capsular opacification (PCO) and the availability of laser treatment. We did not find this to be a major problem in Tirunelveli. PCO was the cause of impairment/blindness in only 14 of 507 pseudophakic eyes (2.8%), which is comparable to the 2.5% prevalence of untreated vision impairing PCO found in a 4 year follow up of patients originally enrolled in a clinical trial comparing the complications of ICCE versus ECCE-IOL surgery.[21 22]

A disparity in the prevalence of blindness was found between urban and rural areas of the district: 7.4% among those living in the urban areas and 12.1% among rural residents. This pattern is similar to the 6.7% and 12.8% found in urban and rural areas, respectively, in the Bharatpur district of Rajasthan, a state in northwest India,[1] but contrasts with findings from a recent population based survey in the Sivaganga district of Tamil Nadu, where a somewhat similar 5.0% blindness prevalence for those living in urban areas was accompanied by a much lower 6.2% prevalence for rural residents.[4] (Because the same survey and examination methods were used in all three studies, comparison of findings is straightforward.) Older age and illiteracy were independent predictors of blindness in these studies, as it was in Tirunelveli. Female sex was also significant in Bharatpur. As in Tirunelveli, blinding cataract in one or both eyes was the major cause of blindness in Bharatpur and Sivaganga, accounting for approximately 70% of blind cases. An increased risk of blindness (due to cataract) for those living in rural areas was also found in a recent population based survey in the Indian state of Andhra Pradesh—where among the 2300 participants ⩾50 years of age, 225 (9.8%) were found to be blind.[2] The odds of being blind increased with increasing age, decreasing socioeconomic status, and female sex.

Surgical coverage for cataract blindness in the urban areas of Tirunelveli district (77%) was comparable to the 75% found in the urban areas of Bharatpur district,[1] the 83% for urban areas of Sivaganga,[4] and the 85% reported from a 1997 survey in the urban district of Ahmedabad in western India.[10] The 50% coverage in the rural areas of Tirunelveli district was below the 64% and 76% for the rural areas of Bharatpur and Sivaganga, respectively, but it compares favourably with the 40% reported from a 1995 survey in the state of Karnataka in southern India.[3]

Approximately 40% of aphakics in Tirunelveli presented with visual acuity <6/60, in large measure because of the absence of any refractive correction. Similar conditions were found in Bharatpur[15] and Sivaganga,[16] and in an urban sample of cases from the Andra Pradesh survey.[14] The percentage of aphakic eyes remaining blind with best correction was reduced to 17.6% in Tirunelveli, 14.0% in Bharatput, and 11.7% in Sivaganga. Without the same necessity of spectacles, pseudophakic eyes presented with a much smaller blind percentage: 5.1% in Tirunelveli, 4.2% in Sivaganga, and 5.6% in Andra Pradesh. (Pseudophakic eyes were few in the Bharatpur survey.) Although IOL surgery produced better postoperative vision in these populations, some of the differences observed may have been the result of unrecognised demographic and other factors. Indeed, the previously referenced clinical trial of cataract surgery, the Madurai Intraocular Lens Study (MIOLS), showed that with adequately trained surgeons both ECCE-IOL and ICCE can produce satisfactory results in restoring visual acuity.[21] The study also demonstrated that a standard +10 dioptre lens is not an adequate correction for most aphakics and, likewise, that a third of those with IOL surgery require prescription glasses to obtain best corrected vision. Best corrected vision for psuedophakic eyes in Tirunelveli did not reach the levels obtained in a 4 year follow up of ECCE-IOL patients from the MIOLS trial, where 4.3% had visual acuity <6/18, including 1.2% <6/60.[22]

Findings from the Tirunelveli survey show that blindness remains a significant public health problem in the district, even though 90% of it is potentially unnecessary because it is associated with generally treatable cataract and correctable refractive error. Although findings suggest that institutions like the Aravind Eye Hospital are having an impact on the cataract blindness problem, further efforts are needed. In particular, targeting of rural females and the illiterate in community outreach programmes appears warranted. Further study is needed to obtain an up to date understanding of socioeconomic and other barriers that interfere with successfully reaching the blind, particularly those living in rural areas.[23–25] Although it is apparent that cataract and refractive error should remain high priority in prevention of blindness programmes in India, increased emphasis on surgical quality and postoperative monitoring to ensure good visual acuity outcomes is also necessary to eliminate needless impairment among the already operated.[26–28] Good postoperative visual outcomes may not be possible in all cases because of coexisting ocular pathologies, but meticulous preoperative examination could help to identify these high risk cases in advance. As life expectancies increase in India, the influence of age related pathologies on visual outcomes will become more marked, creating new challenges to achieving and maintaining good vision among the cataract operated.

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