Blindness in the Indian State of Andhra Pradesh

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Purpose. To determine the current prevalence and causes of blindness in the Indian state of Andhra Pradesh to assess if blindness has decreased since the last survey of 1986–1989.

Methods. A population-based epidemiology study, using a stratified, random, cluster, systematic sampling strategy, was conducted in the state of Andhra Pradesh in India. Participants of all ages ($n = 10,293$), 87.3% of the 11,786 eligible, from 94 clusters in one urban and three rural areas representative of the population of Andhra Pradesh, underwent interview and a detailed dilated ocular evaluation by trained professionals. Blindness was defined as presenting distance visual acuity < 6/60 or central visual field < 20° in the better eye.

Results. Two hundred seventy-five participants were blind, a prevalence of 1.84% (95% confidence interval, 1.49%–2.19%) when adjusted for the age, sex, and urban–rural distribution of the population in 2000. The causes of this blindness were easily treatable in 60.3% (cataract, 44%; refractive error, 16.3%). Preventable corneal disease, glaucoma, complications of cataract surgery, and amblyopia caused another 19% of the blindness. Blindness was more likely with increasing age and decreasing socioeconomic status, and in female subjects and in rural areas. Among the 76 million population of Andhra Pradesh, 714,400 are estimated to have cataract-related blindness (615,600 cataract, 53,200 cataract surgery-related complications, 45,600 aphakia), and 228,000 refractive error-related blindness (159,600 myopia, 22,800 hyperopia, 45,600 refractive error-related amblyopia). If 95% of the cataract and refractive error blindness in Andhra Pradesh had been treated effectively, 3.4 and 7.4 million blind-person-years, respectively, could have been prevented. If 90% of the blindness due to preventable corneal disease and glaucoma had been prevented, another 2.7 million blind-person-years could have been prevented.

Conclusions. The prevalence of blindness in this Indian state has increased from 1.5% in the late 1980s to 1.84% currently, as against the target of the National Program for Control of Blindness to reduce the prevalence to 0.3% by 2000. The number of people with cataract-related blindness has not reduced even with the eye care policy focus on cataract. Reduction of blindness in India will require strategies that are more effective than those that have been pursued so far. (*Invest Ophthalmol Vis Sci.* 2001;42:908–916)

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A global initiative for the elimination of avoidable blindness under the title "VISION 2020: The Right to Sight" was launched in 1999 by the World Health Organization in collaboration with a number of international nongovernmental organizations.[1] The objective of this initiative is to facilitate reduction of blindness worldwide by bringing together the resources needed to do so.[1–3] To be effective, this global initiative will have to be translated into practical action at the community level in each country through development of appropriate national plans to eliminate avoidable blindness.

To have the appropriate plan to eliminate avoidable blindness in India, current population-based data on the magnitude and causes of blindness in all age groups are a prerequisite. A national survey done during 1986–1989 reported that 1.5% of the population in India was blind, with presenting visual acuity < 6/60 in the better eye, and that 80% of this blindness was caused by cataract.[4] Consequently, in the 1990s the focus of the National Program for the Control of Blindness was almost exclusively on reducing cataract blindness,[5,6] which included large funding under a World Bank cataract project.[5] The original target of the National Program was to reduce the prevalence of blindness to 0.3% by 2000, though it was acknowledged by the mid-1990s that achievement of this target was unlikely.[5] The current prevalence of blindness in the entire age range of the population is not known for India.

Andhra Pradesh is a state in the southern part of India with a population of 76 million in 2000.[7] The prevalence of blindness in Andhra Pradesh was reported as 1.5% in the 1986–1989 survey.[4] From October 1996 to February 2000 we conducted the population-based Andhra Pradesh Eye Disease Study (APEDS) in one urban and three rural areas, representative of the population of Andhra Pradesh, to assess the prevalence and causes of blindness and other levels of visual impairment, risk factors for various eye diseases, effect of visual impairment on quality of life, and barriers to access to eye care services.[8] We reported earlier from the urban component of this study that the previous national survey likely overestimated the proportion of blindness attributed to cataract because detailed dilated eye examination was not done.[9] In this article, we report the combined results from the three rural and one urban components of APEDS to estimate the current prevalence and causes of blindness in Andhra Pradesh.

Methods

The Ethics Committee of the L.V. Prasad Eye Institute, Hyderabad, India, approved the study design of APEDS.[8] This study followed the tenets of the Declaration of Helsinki.

Study Sample

We calculated a sample size of 10,000 persons, 5000 each below and above 30 years of age. This was based on the assumption that a 0.5% prevalence of an eye disease in either of these age groups may be of public health significance. The planned sample would estimate this prevalence as 0.3% to 0.8% at the 95% confidence level.[8] A multistage sampling procedure was used to select the study sample. One urban and three rural areas from different parts of the southern Indian state of Andhra Pradesh were selected, with the aim of including approximately 2500 participants in each area, such that these would roughly

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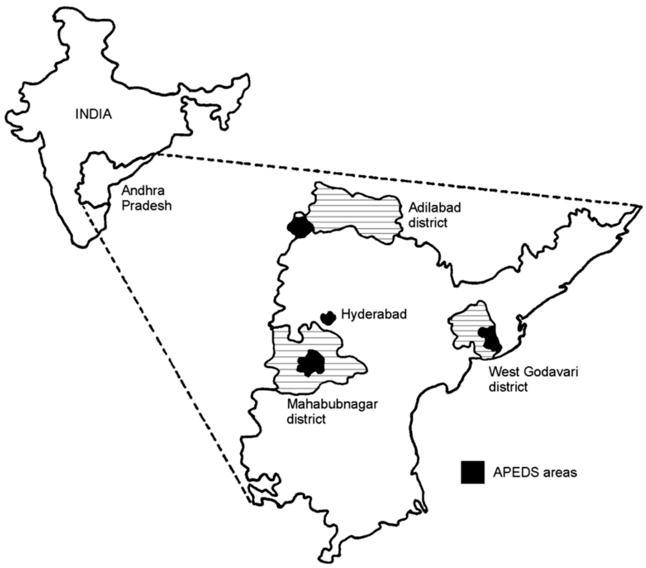

FIGURE 1. Areas where the Andhra Pradesh Eye Disease Study (APEDS) was conducted.

reflect the urban–rural and socioeconomic distribution of the population of this state. These four areas were located in Hyderabad (urban), West Godavari district (well-off rural), and Adilabad and Mahabubnagar districts (poor rural; Fig. 1). APEDS was conducted from October 1996 to June 1997 in Hyderabad, July 1997 to May 1998 in West Godavari, June 1998 to March 1999 in Adilabad, and April 1999 to February 2000 in Mahabubnagar.

The three rural areas selected for APEDS comprised of four to five mandals (administrative unit comprising of a number of villages) each, which had villages within 50 kilometers of an eye care facility associated with the L.V. Prasad Eye Institute that had been established just before the survey in each area; this was done for logistic support during the survey. The populations in the rural areas from which the samples were selected were 332,000 for West Godavari, 144,000 for Adilabad, and 248,000 for Mahabubnagar (estimated for the time of the study in each area using a growth rate of 1.8% per year[10] since the last census of 1991); though the areas covered were similar in size, the total population covered varied because of different population densities in these three areas. The proportion of the four different castes (forward caste, backward caste, schedule caste, and schedule tribe) in the population in each rural area was determined based on information obtained from the Census of India[11] and the Backward Class Welfare Office for each area. Because caste is a surrogate measure of socioeconomic status in our rural populations, we aimed to get a sample with a caste distribution similar to that in the population in each of the three rural areas. To achieve this, the two castes with the largest population in each eligible village in the sampling areas were noted, and the villages were stratified according to these castes. The two largest castes in each village were chosen to have a large enough number of subjects for each selected cluster. A total of 23 to 24 villages were selected in each of the three rural areas under the four caste strata using stratified random sampling with probability of selection proportionate to size, such that the proportion of each caste in the sample would be similar to that in the population in each of the three rural areas. In each selected village the section where the caste selected according to the sampling scheme lived (the different castes mostly live in homogenous clusters in Indian villages) was demarcated. These areas (clusters) were mapped and the number of households and members in each household was listed. Every second to fifth household was systematically selected in each cluster to obtain roughly equal number of households in each cluster. Approximately half the clusters in each of the three rural areas were randomly assigned to have persons of all ages in the selected households eligible for the study, and the other half to have only those ≥30 years of age eligible for the study. This was done to obtain a similar number of participants in the <30- and ≥30-years age groups.[8] Without this approach the desired approximately equal sample in these two age groups would not have been achieved because the population structure of India is pyramidal.[10] This oversampling of the ≥30-years age group was later adjusted in the calculations to obtain estimates of blindness for the entire population.

The sampling of the urban sample in Hyderabad has been described previously.[9] The major difference between the urban and rural sampling was that the former was selected from blocks stratified by socioeconomic status and religion, whereas the latter were selected from villages stratified by caste. Approximately 2950 persons were sampled in each of the four study areas such that at least 2500 participants would be recruited for each study area by aiming for a participation rate of at least 85%. Trained investigators interviewed the participants in the study, including information about income from all sources.[8]

Examination

The participants were brought for examination in a van to clinics specially set up for this study in Hyderabad and West Godavari, and to our rural eye center in Adilabad and Mahabubnagar where an area was assigned separately for the study. Written informed consent was obtained from the participants before examination. For participants ≤15 years of age, consent was obtained from the parent or accompanying guardian. The illiterate participants gave thumbprint as consent after the content of the consent form was explained to them. The examinations were done by four ophthalmologists and four optometrists who had received special training in the procedures of this study for standardization of the documentation of the findings. Distance and near visual acuity, both presenting and best corrected after refraction, were measured for each eye separately using logMAR (logarithm of minimum angle of resolution) charts.[12] Presenting visual acuity was measured with currently used refractive correction, or no correction if none was being used by the participant. English alphabet logMAR chart was used for those who could read the English alphabet, and E-type logMAR chart for those who could not read the English alphabet. Distance visual acuity was measured in a standardized manner using illumination of at least 200 lux,[8] which was checked with a photometer. Initially, the distance acuity was measured at a distance of 3.8 m. The logMAR equivalent of the number of letters read correctly was recorded as the visual acuity. If no letter was read at this distance, indicating acuity worse than 1.0 logMAR units or 6/60, the distance was reduced to 1.9 m and the logMAR scale adjusted accordingly. If no letter was read even at this distance, indicating acuity worse than 1.3 logMAR units or 3/60, finger counting at 1 m, hand motion close to face, projection of light, and perception of light, were assessed in that order. If presenting visual acuity was worse than 6/6 (0.0 logMAR units), objective refraction was performed with a streak retinoscope, followed by subjective acceptance with which the best-corrected acuity was measured and recorded.

External eye and anterior segment examination were done with slitlamp biomicroscope. Intraocular pressure was measured with Goldmann applanation tonometer. Gonioscopy was attempted on all participants with NMR-K two-mirror goniolens (Ocular Instruments Inc., Bellevue, WA) and the angle was graded as open, occludable, or occluded based on the classification of Scheie.[13] If the participant could not cooperate with gonioscopy, the angle was graded with the slitlamp using van Herick technique.[14] All participants had their pupils dilated unless contraindicated because of risk of angle closure. After dilatation, the lens was examined with the slitlamp and nuclear cataract was graded according to the Lens Opacities Classification System III,[15] and cortical and posterior subcapsular cataracts were graded using the Wilmer classification.[16] If the crystalline (natural) lens was not present, the absence of any lens (aphakia) or the presence of intraocular lens (pseudophakia) was documented. Stereoscopic fundus examination, including assessment of the vitreous, retina, and optic disc, was done at the slitlamp using 78 diopter lens and with the indirect ophthalmoscope using 20 diopter lens.

Automated visual fields were done with the Humphrey visual field analyzer[17] using the central 24-2 threshold strategy in those participants assessed to have any suspicion of glaucoma or other optic nerve pathology or higher visual pathway lesion, and in those with significant macular/retinal pathology (such as retinitis pigmentosa), according to uniform predefined criteria. If the visual field was abnormal or unreliable, it was repeated on another day. Anterior segment pathology was photographed with Nikon photograph-slitlamp (Nikon Corporation, Tokyo, Japan), and optic disc, macular or other retinal pathology with a Zeiss fundus camera (Carl Zeiss, Jena, Germany).

Those participants who were physically debilitated and unable to come to the clinic were examined at home with portable equipment. This examination was similar to the one at the clinic except that gonioscopy, examination with 78 diopter lens, automated visual fields, and photography could not be done.

Definition of Blindness

Various definitions of blindness are used worldwide. We assessed blindness with two definitions: (1) presenting distance visual acuity < 6/60 or central visual field < 20° in the better eye, and (2) presenting distance visual acuity < 3/60 or central visual field < 10° in the better eye. Definition one is similar to the definition of economic blindness used previously in India.[4,9] Definition two is similar to that recommended by WHO,[18] except that instead of best-corrected visual acuity in the WHO definition we used presenting visual acuity so that blindness due to refractive error would not be missed.[9] A uniform method of scoring visual field constriction with automated perimetry was used.[19]

Cause of Blindness

The cause of blindness in each eye was initially documented by the ophthalmologist examining the participant. This was later discussed with the principal investigator (LD) and coinvestigator (RD), along with the visual fields and photographs obtained according to the study protocol, and the final decision on the cause of blindness was made. If the information available to make this decision for a particular participant was thought to be unsatisfactory, that participant was reexamined by the principal investigator.

If cataract and a posterior-segment lesion of the optic nerve or retina coexisted, and removal of cataract would not restore vision, the cause of blindness was considered to be the posterior-segment lesion. If dense cataract was present that prevented any view of the posterior segment, and if no signs suggestive of any other cause of visual loss were present, the cause of blindness was considered to be cataract. If index myopia was present due to cataract, and even if the vision improved with refraction, the cause of blindness was considered cataract and not refractive error because the former was the underlying cause. If the two eyes of a subject were blind from two different causes, both were given 50% weight, rather than arbitrarily choosing one or the other as the cause for that participant.

Cataract and refractive error were considered easily treatable causes of blindness because their treatment is relatively simple in most cases. The majority of blindness due to corneal disease encountered in this study, primary angle-closure glaucoma, complications of cataract surgery, and refractive error–related amblyopia, and half of that due to primary open-angle glaucoma, were considered preventable with the currently available knowledge. It was then assumed that with effective provision of eye care services, 95% of the cataract-related and refractive error–related blindness, 90% of the corneal blindness, and 90% of the preventable glaucoma blindness, might be prevented.

To calculate the number of blind-person-years[20] from treatable and preventable causes of blindness, the age of onset of blindness from the different causes was estimated from the history obtained from each participant. Because past examination data were not available for most participants, the estimation of the age of onset of blindness had to be based on the best interpretation of the history of poor vision. Based on this, the average number of years lived with blindness over a lifetime from the different causes, after accounting for the reduced life expectancy due to blindness,[21] were estimated as follows: 5 for cataract, primary glaucoma, aphakia, and complications of cataract surgery; 32 for myopia; 40 for hyperopia and amblyopia; 43 for childhood corneal opacity,[21] and 10 for other corneal disease.

Data Management

Data were initially documented on the APEDS data collection forms by the clinical examiners and the field investigators.[8] This data collection was monitored by the principal investigator and coinvestigator of the study and discussed with the clinical and field teams at regular intervals. The data were entered in a FoxPro database at the study headquarters in Hyderabad, and consistency checks were performed for these data.[8]

Statistical Analysis

The age- and sex-specific rates of blindness in the ≤15, 16 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69, and ≥70 years age groups in each of the four study areas were used to standardize the estimates of blindness to the estimated age and sex distribution of the population of India in mid-2000.[10] To obtain the composite estimate of blindness in Andhra Pradesh, the age- and sex-adjusted rates from the four study areas were combined by giving 0.284 weight to the urban rates and 0.239 weight to each of the three rural rates, because 28.4% of the population in India was estimated to be urban in 2000.[22]

The variations of blindness rates among the different clusters were used to calculate the design effect of the cluster sampling strategy with the method described by Bennett et al.[23] A multiplication factor equal to the square root of the design effect was used to calculate the 95% confidence intervals (CIs) for the estimates of blindness to avoid erroneously narrow CIs.[23] Poisson distribution[24] was assumed for prevalence < 1%, and normal approximation of binomial distribution for prevalence ≥1%. The association of blindness with age, sex, socioeconomic status, and urban–rural residence was evaluated with univariate and multivariate analyses.[24] The software SPSS for Windows (SPSS Inc., Chicago, IL) was used for statistical analysis.

Results

Of the 11,786 eligible persons, 10,293 (87.3%) participated in the study. The participation rates were 85.4% in Hyderabad, 84.6% in West Godavari, 91.7% in Adilabad, and 87.7% in Mahabubnagar. Of the 10,293 participants examined, 122 (1.2%) were examined at home. Results with blindness definition one (presenting distance visual acuity < 6/60 or central visual field < 20° in the better eye) are presented in detail because the equivalent of this has been used before in India,[4,9] followed by a summary of results with blindness definition two (presenting distance visual acuity < 3/60 or central visual field < 10° in the better eye).

A total of 275 participants were blind by definition one. After adjustment for the age, sex, and urban–rural distribution of the population in 2000, the prevalence of blindness was 1.84% (95% CI, 1.49%–2.19% [design effect 1.84]). Table 1 shows the prevalence of blindness for the four study areas and the causes of blindness. Of this blindness, 9.8% was due to visual field constriction, the causes of which included retinitis pigmentosa, glaucoma, and optic atrophy. The prevalence of blindness in the three rural areas combined was 2.03% (95% CI, 1.64%–2.42% [design effect 1.58]).

With multivariate analysis, the odds of having blindness increased with increasing age and decreasing socioeconomic status, and were higher for female subjects (Table 2). Similar multivariate analysis for blindness due to the easily treatable causes (cataract and refractive error) revealed an even higher

TABLE 1. Prevalence and Causes of Blindness with Definition 1

Cause of Blindness*	Hyderabad: Urban†	West Godavari: Well-off Rural†	Adilabad: Poor Rural†	Mahabubnagar: Poor Rural†	Urban–Rural Combined‡	% of Total Blindness
Cataract	0.45	1.30	1.10	0.46	0.81 (0.60–1.06, 1.61)	44.0
Age-related	0.45	1.26	1.10	0.46	0.80	
Other	0	0.04	0	0	0.01	
Refractive error	0.15	0.47	0.26	0.33	0.30 (0.19–0.43, 1.13)	16.3
Myopia	0.13	0.32	0.15	0.24	0.21	
Aphakia	0.02	0.07	0.04	0.09	0.06	
Hyperopia	0	0.08	0.07	0	0.03	
Retinal disease	0.22	0.26	0.12	0.20	0.20 (0.12–0.31, 1.04)	10.9
Retinitis pigmentosa	0.12	0.06	0.03	0.13	0.09	
Myopic degeneration	0.01	0.05	0.05	0.02	0.03	
Age-related maculopathy§	0.03	0.10	0	0.01	0.03	
Chorioretinitis scar	0.05	0.03	0	0	0.02	
Retinal detachment	0.01	0	0.01	0.02	0.01	
Other	0	0.02	0.03	0.02	0.02	
Glaucoma	0.16	0.06	0.25	0.11	0.15 (0.08–0.24, 1.00)	8.2
Primary open-angle	0.09	0.05	0.17	0.05	0.09	
Primary angle-closure	0.07	0.01	0.06	0.04	0.05	
Secondary	0	0	0.02	0.02	0.01	
Corneal disease	0.19	0.03	0.20	0.12	0.13 (0.06–0.24, 1.40)	7.1
Opacity after childhood fever	0.10	0.03	0.09	0.08	0.07	
Keratitis scar	0	0	0.06	0.02	0.02	
Harmful traditional eye medicine	0.03	0	0	0.02	0.01	
Other	0.06	0	0.05	0	0.03	
Optic atrophy	0.16	0.11	0.05	0.09	0.11 (0.05–0.20, 1.10)	6.0
Cataract surgery-related	0.05	0.07	0.02	0.02	0.04	
Other	0.11	0.04	0.03	0.07	0.07	
Amblyopia	0	0.13	0.07	0.12	0.08 (0.02–0.17, 1.54)	4.3
Refractive error-related	0	0.06	0.07	0.12	0.06	
Other	0	0.07	0	0	0.02	
Congenital eye anomaly	0	0	0.04	0.05	0.02 (0–0.07, 1.00)	1.1
Microphthalmos	0	0	0.04	0.05	0.02	
Other	0.03	0.04	0.04	0.07	0.04 (0.01–0.10, 1.00)	2.2
Total	1.36	2.40	2.13	1.55	1.84 (1.49–2.19, 1.84)	100

Values are expressed as percentage prevalence. The subtotals may not add up exactly to the total due to rounding.

* Presenting distance visual acuity < 6/60 or central visual field < 20° in the better eye.

† Prevalence adjusted for the age and sex distribution of the population of India in 2000.[10]

‡ Prevalence adjusted for the 0.284:0.716 urban–rural distribution of the population of India in 2000.[22] Values in parentheses are 95% CI and design effect.

§ Includes atrophic macula thought to be related to aging.

odds ratio of 1.76 (95% CI, 1.28–2.42) for female subjects, and for cataract blindness alone this odds ratio for female subjects was 1.96 (95% CI, 1.36–2.83). This analysis also revealed that the rural population had higher odds of blindness due to cataract or refractive error (odds ratio, 1.82; 95% CI, 1.17–2.84), and for blindness due to cataract alone (odds ratio, 1.72; 95% CI, 1.04–2.84).

Table 3 shows the total potential cataract blindness after taking into account the blindness prevented due to prior cataract surgery and the blindness due to cataract surgery-related causes. The total potential cataract blindness was more than twice as much in West Godavari as in Mahabubnagar, and was higher for female subjects in rural areas compared with male subjects. Table 3 also shows the total potential refractive error blindness after taking into account the blindness prevented because of prior refractive correction and the blindness due to refractive error-related amblyopia. The majority of the refractive error blindness in rural areas was untreated, especially in female subjects.

Table 4 shows the estimated number of persons blind in Andhra Pradesh due to the easily treatable and possibly preventable causes, and the blind-person-years totaled over their lifetimes if these persons continue to be blind. Effective treatment of 95% of the blindness due to the easily treatable causes

Table 2. Effect of Age, Sex, Socioeconomic Status, and Urban–Rural Residence on the Prevalence of Blindness

	Total in Group	No. of Blind*	Odds Ratio for Blindness with Multiple Logistic Regression†
Age (years)‡			
≤15	2859	5 (0.17)	1.00
16–29	1847	6 (0.32)	1.93 (0.59–6.32)
30–39	1862	18 (0.97)	5.80 (2.16–15.6)
40–49	1425	21 (1.47)	9.58 (3.62–25.4)
50–59	1047	53 (5.06)	32.5 (13.0–81.5)
60–69	900	100 (11.11)	73.9 (30.1–182)
≥70	353	72 (20.40)	176 (70.3–439)
Sex§			
Male	4855	117 (2.41)	1.00
Female	5438	158 (2.91)	1.37 (1.05–1.77)
Socioeconomic status‡‖			
Upper	362	2 (0.55)	1.00
Middle	3172	59 (1.86)	2.85 (0.68–11.9)
Lower	5212	149 (2.86)	5.07 (1.22–21.0)
Extreme lower	1354	61 (4.51)	9.72 (2.30–41.0)
Residence¶			
Urban	2522	49 (1.94)	1.00
Rural	7771	226 (2.91)	1.27 (0.91–1.77)

* Blindness definition 1: presenting distance visual acuity < 6/60 or central visual field < 20° in the better eye. Values in parentheses are percentages.

† Values in parentheses are 95% CIs.

‡ $P < 0.0001$ with univariate χ^2 test for trend.

§ $P = 0.12$ with univariate χ^2 test.

‖ Upper socioeconomic status defined as monthly per capita income > 2000 Indian Rupees (US$ 45.5 at the exchange rate in early 2000); middle, 501–2000 Indian Rupees; lower, 201–500 Indian Rupees; and extreme lower, ≤200 Indian Rupees. Socioeconomic status information not available for 4 blind subjects and 169 subjects without blindness.

¶ $P = 0.009$ with univariate χ^2 test.

cataract and refractive error would have resulted in prevention of 3.40 and 7.45 million blind-person-years, respectively. Effective prevention of 90% of the preventable corneal and glaucoma blindness would have resulted in prevention of 2.74 million blind-person-years.

Blindness with definition two was present in 194 of the 10,293 participants, an adjusted prevalence of 1.34% (95% CI, 1.07%–1.61% [design effect 1.49]), the causes of which are shown in Table 5. Of this blindness, 7.8% was due to visual field constriction.

Discussion

To achieve the goal of VISION 2020, the global initiative to eliminate avoidable blindness,[1–3] it is necessary for countries around the world to develop suitable strategies, which should ideally be based on current data on blindness. We assessed the current prevalence and causes of blindness in the Indian state of Andhra Pradesh, which has a population of 76 million, to determine whether blindness had decreased from the prevalence of 1.5% in the late 1980s. In the background of the target of the National Program for Control of Blindness to reduce the prevalence of blindness to 0.3% by 2000, we found that the prevalence of blindness in Andhra Pradesh has increased to 1.84% instead. This implies that the number of blind persons in Andhra Pradesh has increased by 40% from 1 to 1.4 million over the past decade. The possible reasons for this, and the issues that need to be addressed to reverse this trend, are raised in this discussion.

Cataract-related Blindness

The survey of 1986–1989 reported that 80% of the 1.5% prevalence of blindness in Andhra Pradesh was due to cataract.[4] This proportion of blindness attributed to cataract was an overestimate because detailed dilated eye examination was not done in that survey which would have misclassified blindness due to glaucoma, optic atrophy, and retinal causes as cataract blindness.[9] We estimated that the real proportion of blindness due to cataract would have been <55%.[9] This and the 4.7% aphakic blindness reported in the previous survey[4] would suggest that a decade ago approximately 60% of the 1.5% blindness in Andhra Pradesh was cataract related, which amounts to a 0.9% prevalence or 585,000 persons among the 65 million population then. The data reported in this article suggest that currently the prevalence of cataract-related blindness in Andhra Pradesh is 0.94% or 714,400 persons. During the past decade, the population of Andhra Pradesh has increased by 11 million, and the life expectancy by 4 years, which would result in a larger number of persons developing cataract. However, the lack of reduction in cataract-related blindness is disturbing given the background of the stated emphasis of the National Program for Control of Blindness to reduce cataract blindness.[5,6] The World Bank sanctioned a loan for a US$ 135 million project to reduce cataract blindness in seven states of India, including Andhra Pradesh, from 1994 to 2001.[5] The annual number of cataract surgeries in India has increased rapidly over this period, with about half still without intraocular lens implantation.[25] Even with this increase there is no evidence of reduction in cataract-related blindness, which may be due to a combination of poor outcome of cataract surgery and a low number of surgeries on blind persons. The poor outcome of cataract surgery is evident from our finding that for every six persons blind from cataract there is one person blind from cataract surgery complications or aphakia. As part of APEDS, we found that among the eyes operated for cataract in the population of Hyderabad, 21.4% were blind after surgery, the majority due to surgery complications or aphakia.[26] In the populations of West Godavari, Adilabad, and Mahabubnagar, blindness after cataract surgery was present in 36.4%, 34%, and 43% of the eyes, respectively. Such poor results of cataract surgery in the community at large are likely discouraging many from seeking treatment. Poor quality cataract surgery seems to be a widespread phenomenon in the developing world because poor outcomes have also been reported recently from other parts of India[27–29] as well as other countries.[30–32] Better outcome of cataract surgery in India has to be achieved by improving the quality of surgical training and improving the eye care infrastructure to provide reasonable follow-up care. Some new models of providing good quality and sustainable eye care in rural India are showing reasonable results.[33] Similar experiments are needed on a larger scale. Another reason for the continuing high rate of cataract blindness may be that the increase in the number of cataract surgeries includes a large number of surgeries on persons who are not blind in both eyes.

An interesting finding was that the total potential cataract blindness in the well-off rural West Godavari was more than twice that in the poor rural Mahabubnagar. The reasons for this are not clear yet, but may include a possibly higher life expectancy in West Godavari or other demographic, environmental, or biological variables, which need to be explored further. However, this finding suggests that the risk of developing cataract blindness can vary considerably between different areas of the same state. Another finding that needs to be

Table 3. Total Potential Cataract Blindness and Refractive Error Blindness

	Blindness Prevented because of Cataract Surgery*	Cataract Blindness	Cataract Surgery–related Blindness†	Total Potential Cataract Blindness	Refractive Error Blindness Prevented‡	Refractive Error Blindness§	Amblyopia Blindness‖	Total Potential Refractive Error Blindness
In males¶								
Hyderabad	1.57	0.60	0.11	2.28	0.35	0.13	0	0.48
West Godavari	1.14	0.83	0.19	2.16	0.27	0.46	0.10	0.83
Adilabad	0.24	0.77	0.09	1.10	0.08	0.21	0.13	0.42
Mahabubnagar	0.67	0.35	0.12	1.14	0.14	0.13	0.07	0.34
All combined#	0.93	0.64	0.13	1.70	0.21	0.23	0.08	0.52
In females¶								
Hyderabad	1.14	0.32	0.07	1.53	0.79	0.14	0	0.93
West Godavari	1.39	1.72	0.13	3.24	0.03	0.35	0.02	0.40
Adilabad	0.67	1.40	0.09	2.16	0	0.23	0	0.23
Mahabubnagar	0.77	0.55	0.17	1.49	0	0.33	0.17	0.50
All combined#	1.00	0.97	0.12	2.09	0.23	0.26	0.05	0.54
In total population**								
Hyderabad	1.34	0.45	0.09	1.88 (1.01–2.75, 2.68)	0.58	0.13	0	0.71 (0.42–1.13, 1.00)
West Godavari	1.27	1.30	0.16	2.73 (1.76–3.70, 2.32)	0.14	0.40	0.06	0.60 (0.35–0.97, 1.00)
Adilabad	0.46	1.10	0.09	1.65 (1.02–2.28, 1.70)	0.04	0.22	0.06	0.32 (0.13–0.64, 1.01)
Mahabubnagar	0.72	0.46	0.15	1.33 (0.74–1.92, 1.79)	0.06	0.24	0.12	0.42 (0.19–0.80, 1.25)
All combined#	0.97	0.81	0.12	1.90 (1.49–2.31, 2.47)	0.22	0.24	0.06	0.52 (0.38–0.70, 1.16)

* If a person had had cataract surgery in one eye, that eye not blind after surgery, and the other eye blind; if a person had had cataract surgery in both eyes, at least one eye not blind after surgery.
† Includes cataract surgery complications and aphakia.
‡ If a person with myopia or hyperopia of 5 diopters or higher in both eyes was using refractive correction and was not blind.
§ Due to myopia or hyperopia.
‖ Due to refractive error–related amblyopia.
¶ Values are % prevalence, adjusted for the age distribution of the population of India in 2000.[10]
# Adjusted for the 0.284:0.716 urban–rural distribution of the population of India in 2000.[22]
** Values are % prevalence, adjusted for the age and sex distribution of the population of India in 2000.[10] Values in parentheses are 95% CI and design effect.

Table 4. Number of Blind Persons and Blind-Person-Years Due to Easily Treatable and Possibly Preventable Causes in Andhra Pradesh

Cause of Blindness	Prevalence of Blindness (%)	No. of Persons*	Years with Blindness†	Blind-Person-Years (in millions)
Cataract-related	0.94	714400		3.58
Cataract	0.81	615600	5	3.08
Cataract surgery complications‡	0.07	53200	5	0.27
Aphakia	0.06	45600	5	0.23
Refractive error–related	0.30	228000		7.84
Myopia	0.21	159600	32	5.11
Hyperopia	0.03	22800	40	0.91
Amblyopia	0.06	45600	40	1.82
Corneal disease	0.12	91200		2.67
Opacity after childhood fever	0.07	53200	43	2.29
Other§	0.05	38000	10	0.38
Glaucoma	0.10	76000		0.38
Primary angle-closure	0.05	38000	5	0.19
Primary open-angle‖	0.05	38000	5	0.19

* Calculated for the 76 million population of Andhra Pradesh in 2000.[7]

† Average number of years with blindness for each person from a particular cause over his/her lifetime if he/she continues to be blind; estimated from our data.

‡ Includes the following prevalences: iatrogenic optic atrophy 0.04%, aphakic corneal edema 0.01%, endophthalmitis 0.004%, aphakic retinal detachment 0.004%, inflammatory membrane 0.004%, chronic cystoid macular edema 0.003%, and posterior capsule opacity 0.002%.

§ Excluding the 0.01% prevalence of aphakic corneal edema, which is included in cataract surgery complications.

‖ Half of the actual prevalence shown here because only half of this blindness considered preventable.

understood further is that the total potential cataract blindness in rural female subjects was more than in the male subjects, which may be related to the higher life expectancy of women,[10] or to other biological or nutritional variables.

Refractive Error-related Blindness

Refractive error–related blindness in Andhra Pradesh accounts for more than twice the number of blind-person-years compared with cataract over the lifetime of those currently blind because blindness due to refractive error manifests at a young age. Of this burden 65.2% was due to high myopia and 11.6% due to high hyperopia, which are easily correctable. The remaining 23.2% of this burden due to amblyopia caused by uncorrected high refractive error during childhood is preventable if adequate refractive services are available. Only 17.9% of the total potential refractive error blindness had been prevented in rural areas, compared with 81.7% in urban Hyderabad. This prevented blindness was particularly low for rural women at 2.7%. Because of the large burden on society due to the easily treatable refractive error blindness, it is necessary to develop simple and effective community screening programs in India. Knowledge about the distribution of refractive errors in the population[34] and the pattern of utilization of eye care services[35] would assist in developing these programs. Screening of school children has been suggested for detecting refractive error.[36] This has the advantage of having a concentrated target population, but misses out a large proportion of the children in rural India who do not attend school. In addition to detection of refractive error blindness, two other major issues have to be addressed to reduce this burden in India. One is the need to have many more ophthalmic technicians in underserved areas who are trained adequately to do a reasonable refraction. The other is the need to develop systems through which the poor can obtain spectacles at an affordable price. Some success is reported with a program which addresses these various issues,[33] but this is an isolated example that needs to be developed further and applied widely.

Corneal Blindness

Corneal blindness also causes a large number of blind-person-years in Andhra Pradesh as a large proportion is due to corneal opacity after childhood fever, which could possibly be vitamin A deficiency precipitated by measles or debilitation, and is preventable. Control of vitamin A deficiency is covered under the Reproductive and Child Health Program in India. The coverage of prophylactic vitamin A administration along with immunization in India has been reported to be poor.[37] This has to be improved through better primary health care, along with efforts to improve awareness about and intake of vitamin A rich foods. The other major causes of corneal blindness in our study, keratitis scar and use of harmful traditional eye medicine, can be prevented with behavioral change brought about with better awareness. It is interesting that the prevalence of corneal blindness was high in urban Hyderabad, the reason for which was that many of these persons had migrated previously from rural areas to beg in Hyderabad because corneal opacity is clearly visible to others and makes it easier to arouse sympathy in others. Both, improvements in primary health care and behavioral change, which could lead to prevention of the majority of the corneal blindness, are slow processes and can be brought about only with sustained strategies.

Glaucoma Blindness

Blindness due to primary angle-closure glaucoma is potentially avoidable if this condition is detected early and peripheral iridotomy or iridectomy is done. This requires detection of occludable angles, which lead to primary angle-closure glaucoma, using slitlamp examination and gonioscopy. Blindness due to primary open-angle glaucoma is more difficult to prevent,[38] and therefore, we made a conservative assumption that 50% of this may be preventable if this condition is detected early with good optic disc examination and applanation tonometry. Because the examination techniques required to detect glaucoma early are not practiced commonly in India, better training of eye care providers in India has to be initiated if blindness due to glaucoma has to be prevented.[38,39]

TABLE 5. Prevalence and Causes of Blindness with Definition 2

Cause of Blindness	% Prevalence*	Percent of Total Blindness
Cataract	0.61 (0.45–0.79, 1.34)	45.5
Age-related	0.60	
Other	0.01	
Refractive error	0.15 (0.08–0.24, 1.00)	11.2
Myopia	0.10	
Aphakia	0.04	
Hyperopia	0.01	
Retinal disease	0.17 (0.10–0.28, 1.04)	12.7
Retinitis pigmentosa	0.08	
Myopic degeneration	0.02	
Age-related maculopathy†	0.02	
Chorioretinitis scar	0.02	
Retinal detachment	0.01	
Other	0.02	
Glaucoma	0.12 (0.07–0.21, 1.00)	9.0
Primary open-angle	0.07	
Primary angle-closure	0.04	
Secondary	0.01	
Corneal disease	0.12 (0.06–0.22, 1.29)	9.0
Opacity after childhood fever	0.07	
Keratitis scar	0.02	
Harmful traditional eye medicine	0.01	
Other	0.02	
Optic atrophy	0.06 (0.02–0.13, 1.20)	4.5
Cataract surgery-related	0.03	
Other	0.03	
Amblyopia	0.06 (0.01–0.14, 1.51)	4.5
Refractive error-related	0.05	
Other	0.01	
Congenital eye anomaly	0.02 (0–0.7, 1.00)	1.5
Microphthalmos	0.02	
Other	0.03 (0.01–0.08, 1.00)	2.2
Total	1.34 (1.07–1.61, 1.49)	100

The subtotals may not add up exactly to the total due to rounding. Definition 2: presenting distance visual acuity $< 3/60$ or central visual field $< 10°$ in the better eye.

* Adjusted for the age, sex, and urban–rural distribution of the population of India in 2000.[10,22] Values in parentheses are 95% CI and design effect.

† Includes atrophic macula thought to be related to aging.

Because the strategies required to reduce the preventable blindness due to corneal disease and glaucoma are likely to become effective only over a long time, it would seem prudent to initiate these now so that their benefits start manifesting in a decade or so.

CONCLUSION

We found blindness in the Indian state of Andhra Pradesh to be quite high currently with a prevalence of 1.84% in the population, 80% of which is treatable or preventable. This imposes substantial social and economic burden on society. We found women and those belonging to the lower socioeconomic strata, particularly in the rural areas, to be at a higher risk of having blindness. The major disease-related issues that need to be addressed in the eye care policy of India, if the goal of VISION 2020 to eliminate avoidable blindness is to be achieved, are (i) improvement in the quality of cataract surgery and increase in the number of surgeries on persons blind in both eyes, (ii) effective screening to detect refractive error blindness and provision of spectacles, and (iii) initiation of long-term strategies to prevent corneal and glaucoma blindness. These issues are more likely to be successfully addressed if emphasis is placed on training professionals to provide quality comprehensive eye care instead of a piecemeal approach addressing the different blinding conditions separately. One such approach is showing some success.[33] Similar approaches would have to be experimented with on a much larger scale for avoidable blindness to be eliminated in India. These approaches would have to take into account recent data on blindness and barriers to eye care to plan the appropriate infrastructure and human resources needed to reduce blindness in India.[40]

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