

Estimating Incidence of Vision-Reducing Cataract in Africa

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NICE TITLE

A New Model With Implications for Program Targets

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Clearly stated question or objective?

Objective: To estimate the incidence of vision-reducing cataract in sub-Saharan Africa and use these data to calculate cataract surgical rates (CSR) needed to eliminate blindness and visual impairment due to cataract.

Methods: Using data from recent population-based, standardized, rapid-assessment surveys, we calculated the age-specific prevalence of cataract (including operated and unoperated eyes) from surveys in 7 “districts” across Africa. This was done at 3 levels of visual acuity. Then we used the age-specific prevalence data to develop a model to estimate age-specific incidence at different visual acuities, taking into account differences in mortality rates between those with cataract compared with those without. The model included development of opacity in the first eye and second eye of people older than 50 years. The incidence data were used to calculate target cataract surgical rates.

Results: Incidence and CSR needs varied significantly in different sites and were lower in some than expected. Cataract surgical rates may depend on genetic, environmental, or cultural variations and will vary with population structure, which is not uniform across Africa.

Conclusion: Africa should not be viewed as homogeneous in terms of cataract incidence or CSR needed. These CSR calculations should be useful for more appropriate planning of human resources and service delivery on the continent. The methodology can be applied to other population-based data as they become available to determine appropriate CSR targets.

Short and to the point conclusion.

Arch Ophthalmol. 2010;128(12):1584-1589

Introduction and Background

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This problem is important

FOR MANY YEARS, THE MAGNITUDE of vision loss and blindness in Africa has been estimated using a limited number of population-based surveys. It is usually assumed that about 1% of the population is blind, with half of this due to cataract,¹ although some recent data indicate that the prevalence of blindness may not be this high²⁻⁴ — good references

Cataract remains the leading cause of blindness in Africa; therefore, planning for its treatment is a priority of the VISION 2020 initiative to eliminate avoidable blindness by the year 2020. The VISION 2020 strategy includes planning by administrative districts of around 1 million people. Planning requires realistic target setting—how many cataract operations need to be done to eliminate blindness or visual impairment? The cataract surgical rate (CSR), the number of operations done per million persons, is a convenient indicator for planning and monitoring.⁵ However, esti-

imating what the CSR needs to be requires one to take into account a number of factors and to make assumptions. Key factors that determine what the CSR to eliminate visual disability from cataract needs to be for any population of 1 million people include (1) the age structure or proportion of the population that is old enough to be at significant risk of cataract-related vision loss (for convenience, this is often assumed to be those aged 50 years and older); (2) the visual acuity threshold at which cataract is operated on, ie, how blindness or visual disability is defined (this factor might be determined by policy [rationing or case selection] or by the demands of the population); and (3) biologic or environmental factors that determine incidence of cataract in a population. For example, cataract occurs at a younger age and has a higher incidence among Indians than among Europeans.⁶

The Rapid Assessment of Avoidable Blindness (RAAB) survey uses a population-

Table 1. Prevalence of Vision Loss Due to Cataract in Persons Aged 50 Years or Older at Different Visual Acuity Levels

Study Site	Prevalence (95% Confidence Interval) per 100 Persons								
	<3/60			<6/60			<6/18		
	Unilateral	Bilateral	Overall	Unilateral	Bilateral	Overall	Unilateral	Bilateral	Overall
Nakuru, Kenya	4.1 (3.5-4.8)	3.1 (2.6-3.7)	10.4 (9.4-11.4)	4.5 (3.8-5.2)	3.5 (3-4.2)	11.5 (10.5-12.6)	5.2 (4.5-6)	5.0 (4.3-5.8)	15.2 (14.1-16.4)
Kilimanjaro, Tanzania	4.8 (4.1-5.5)	3.1 (2.6-3.8)	11.1 (10.1-12.2)	5.4 (4.7-6.3)	3.5 (3-4.2)	12.5 (11.4-13.6)	6.8 (6-7.6)	6.3 (5.6-7.2)	19.4 (18.2-20.8)
Western Province, Rwanda	3.2 (2.6-4)	1.5 (1.1-2.2)	6.3 (5.4-7.4)	3.3 (2.6-4.1)	2.0 (1.5-2.7)	7.3 (6.3-8.5)	4.3 (3.5-5.2)	4.6 (3.8-5.6)	13.6 (12.2-15.0)
Kericho, Kenya	6.4 (5.5-7.5)	3.9 (3.2-4.7)	14.2 (12.9-15.6)	7.0 (6.0-8.0)	4.5 (3.8-5.4)	16.0 (14.6-17.5)	7.5 (6.5-8.6)	6.6 (5.7-7.7)	20.8 (19.2-22.4)
Koulikor, Mali	9.5 (8.4-10.7)	9.1 (8.0-10.3)	27.7 (26.0-29.5)	10.1 (9.0-11.4)	11.1 (9.9-12.4)	32.3 (30.5-34.2)	10.9 (9.7-12.2)	18.5 (17.0-20.0)	47.8 (45.8-49.8)
The Gambia	5.0 (3.6-6.9)	5.7 (4.2-7.8)	16.4 (13.8-19.5)	5.7 (4.2-7.8)	7.1 (5.4-9.3)	19.9 (17.1-23.1)	6.3 (4.7-8.4)	12.6 (10.3-15.4)	31.6 (28.2-35.2)
Eritrea	11.2 (10.2-12.4)	9.4 (8.4-10.4)	30.0 (28.4-31.6)	11.9 (10.8-13.1)	8.7 (7.8-9.7)	29.3 (27.7-30.9)	12.0 (10.9-13.2)	16.3 (15.0-17.6)	44.5 (42.8-46.3)

be calculated from death probabilities), and λ_2 and λ_4 , which are unknown first- and second-eye cataract incidence rates.

$$A = e^{-(\lambda_1 + \lambda_2)}$$

$$B = \frac{\lambda_2}{\lambda_1 + \lambda_2 - \lambda_3 - \lambda_4} (-e^{-(\lambda_1 + \lambda_2)} + e^{-(\lambda_3 + \lambda_4)})$$

$$C = e^{-(\lambda_3 + \lambda_4)}$$

$$D = \frac{\lambda_2 \lambda_4}{\lambda_3 + \lambda_4 - \lambda_5} \left(\frac{e^{-(\lambda_1 + \lambda_2)} - e^{-(\lambda_3 + \lambda_4)}}{\lambda_1 + \lambda_2 - \lambda_3 - \lambda_4} - \frac{e^{-(\lambda_1 + \lambda_2)} - e^{-\lambda_5}}{\lambda_1 + \lambda_2 - \lambda_5} \right)$$

$$E = \frac{\lambda_4}{\lambda_3 + \lambda_4 - \lambda_5} (-e^{-(\lambda_3 + \lambda_4)} + e^{-\lambda_5})$$

$$F = e^{-\lambda_5}$$

The age-specific probability of death during the interval for each country was taken from life tables published by the World Health Organization.⁸ We used the average of these for the African countries from which we had data. The 5-year death rate, λ_1 , for people who are cataract free was calculated from the 5-year probability of death, nq_x , as follows: $\lambda_1 = -\ln(1 - nq_x)$. We assumed that the death rate for people with cataract in 1 or both eyes would be 1.5 times that of those without cataract. That is, we let $\lambda_3 = \lambda_5 = 1.5\lambda_1$.

Manipulating the 3 equations above, we can eliminate the total number of people at each time to yield 2 equations:

$$\frac{(1 - P_0^U - P_0^B)}{(1 - P_1^U - P_1^B)} P_1^U A = (1 - P_0^U - P_0^B) B + P_0^U C$$

$$\frac{(1 - P_0^U - P_0^B)}{(1 - P_1^U - P_1^B)} P_1^B A = (1 - P_0^U - P_0^B) D + P_0^U E + P_0^B F$$

Substituting the values for A through F gives us:

$$\frac{(1 - P_0^U - P_0^B)}{(1 - P_1^U - P_1^B)} P_1^U e^{-(\lambda_1 + \lambda_2)} = (1 - P_0^U - P_0^B) \frac{\lambda_2}{\lambda_1 + \lambda_2 - \lambda_3 - \lambda_4}$$

$$\frac{(1 - P_0^U - P_0^B)}{(1 - P_1^U - P_1^B)} P_1^B e^{-(\lambda_1 + \lambda_2)} = \frac{(-e^{-(\lambda_1 + \lambda_2)} + e^{-(\lambda_3 + \lambda_4)}) + P_0^U e^{-(\lambda_3 + \lambda_4)}}{\lambda_3 + \lambda_4 - \lambda_5} \left(\frac{e^{-(\lambda_1 + \lambda_2)} - e^{-(\lambda_3 + \lambda_4)}}{\lambda_1 + \lambda_2 - \lambda_3 - \lambda_4} - \frac{e^{-(\lambda_1 + \lambda_2)} - e^{-\lambda_5}}{\lambda_1 + \lambda_2 - \lambda_5} \right) + \frac{P_0^U \lambda_4}{\lambda_3 + \lambda_4 - \lambda_5} (-e^{-(\lambda_3 + \lambda_4)} + e^{-\lambda_5}) + P_0^B e^{-\lambda_5}$$

With 2 equations and 2 unknowns, we can solve for λ_2 and λ_4 using prevalence data from each site.

The λ_2 value we find in this way can be interpreted directly as 5-year, first-eye cataract incidence. To find the 5-year, second-eye incidence from λ_4 (incidence of second eye cataract among those who already have cataract in 1 eye), we multiply by the prevalence of unilateral cataract averaged over the initial and final age periods. To calculate the overall incidence in the survey population (aged ≥ 50 years), we multiplied the age-specific incidence by the proportion of population in each age group. We divided the incidence rate per 5 years by 5 to arrive at an annual incidence for both first eye cataract and second eye cataract.

To calculate target CSRs, we assumed, as have previous models, that operating on the incident cataracts each year would gradually result in a steady-state situation in which visual loss from cataract would be eliminated in 5 to 10 years. Target CSRs to operate on first or second eye incident cataracts were calculated for a hypothetical population of 1 million, of which 10% of the population was older than 50 years. A final adjustment was needed to take into account the proportion of the population older than 50 years, if it is not 10%. The CSR with X% aged 50 years or older is a simple proportion: $CSR_{10\%}/10 = CSR_X/X$.

RESULTS

Raw data from 5 published RAAB surveys in sub-Saharan Africa (Kilimanjaro, Tanzania; Kericho, Kenya; Nakuru, Kenya; Western Region, Rwanda; and The Gambia)^{2,4,9,10} and 2 unpublished surveys (Koulikor, Mali, and Eritrea) were obtained. Teams carrying out these RAABs were all trained by persons who attended a standardization workshop.

The prevalence and incidence of cataract causing vision loss in each site at different levels are shown in **Table 1** and **Table 2**, respectively. **Table 3** shows the CSR required to operate on first and second eyes at each visual acuity level, calculated for districts where 10% of the population is older than 50 years. **Table 4** shows how CSR varies as the proportion of the population older than 50 years changes, using incidence rates from Kilimanjaro, Tanzania as an example.

Prevalence and incidence at each visual acuity level increased with age according to the model as shown in

The full general model is presented.

Some basic calculations are shown.

Includes info about parameters or #'s calculated

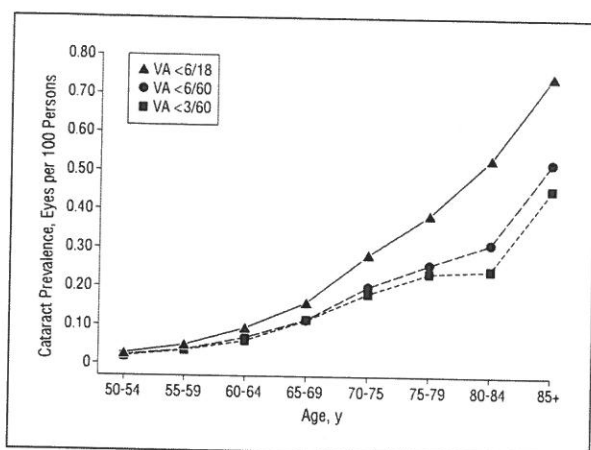


Figure 2. Prevalence of cataract by age for 4 eastern Africa sites. VA indicates visual acuity.

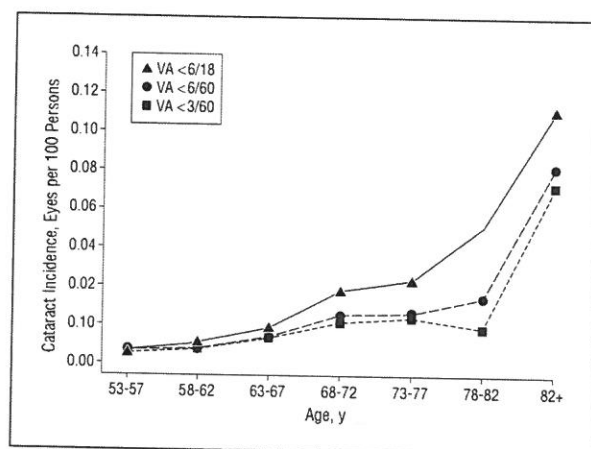


Figure 3. Incidence of cataract by age for 4 eastern Africa sites, calculated for the midpoint between prevalence data points. VA indicates visual acuity.

eliminate visual impairment from cataract at different visual acuity levels.

There are a number of limitations to the model, starting with the RAAB examination of the lens, which is based only on the red reflex and does not use any of the accepted cataract grading schemes. We only included eyes with cataract if the main cause of visual loss was considered to be lens opacity, similar to the criteria used to determine whether an eye is suitable for cataract surgery in these settings. Therefore, eyes with cataract and obvious vision-reducing posterior pole pathology would not be included as cataracts. This will result in underestimation of the true magnitude of cataract, but we wanted to use the data to estimate the number of surgical procedures that needed to be done. If the examination teams at some sites were more careful than others to exclude posterior pole disease (by dilating all pupils, for example) the systematic error introduced would affect relative prevalence among the sites. This would be especially problematic if there were more posterior pole disease in one site compared with another. Therefore, caution must be taken in making comparisons between sites.

The need to make assumptions about the visual acuity of eyes preoperatively is also a limitation. The esti-

mates at visual acuity of less than 6/18 are likely to be most accurate because a negligible number of cataracts in Africa are operated on at a visual acuity better than this. Estimates of incidence (and hence CSRs) for less than 6/60 and less than 3/60 visual acuity are too high because an unknown proportion of cases that received surgery would have had visual acuity better than this at the time of operation.

We assumed a mortality rate of 1.5 times in those with cataract compared with those without. This is a question that has received considerable study; although many studies include important methodological flaws, most evidence suggests that there is increased mortality among those who develop cataract (whether operated on or not) compared with those who do not.¹¹ Minassian et al¹² assumed a difference of 1.25 times in their model, while others have suggested larger differences.¹¹ Had we assumed mortality to be 1.75 times higher, rather than 1.5 times, it would increase the incidence by around 12%; assuming 1.25 times higher results in a decreased incidence of roughly 12% compared with our calculation.

Despite the limitations, there is new and valuable information derived from this analysis. A strength of the study is the fact that the RAAB surveys were all conducted according to a standard methodology, justifying some comparisons among them. We found in all sites that the incidence of cataract at visual acuity less than 6/18 was just less than twice the incidence at 6/60, which is consistent with other modeling of cataract.¹³

Our findings are also consistent with those from a small incidence study in Uganda¹⁴ that reported an estimated 24 872 new cases of people older than 55 years with visual acuity less than 6/18 each year, of which 41% (10 197) would be due to cataract. Assuming that 6% (1 476 000) of the population of 24.6 million at that time would have been older than 55 years, the incidence of bilateral cataract causing visual acuity of less than 6/18 in those older than 55 years would be $10\,197/1\,476\,000 = 0.007$. In comparison, our model predicted the incidence of bilateral cataract at visual acuity of less than 6/18 in the population older than 50 years to be 0.006, 0.007, and 0.008 in sites in neighboring Rwanda, Tanzania, and Kenya, respectively.

For planning purposes, 2 extreme CSR rates can be considered. These are the number of surgical procedures needed to operate on 1 eye of each person with bilateral cataract at visual acuity of 3/60 (corresponding to the number of surgical procedures that would be necessary to eliminate cataract blindness in people) and the number of surgical procedures needed to operate on all eyes with cataract at visual acuity of less than 6/18. These 2 rates define a range within which the CSR would need to fall, depending on demands of the population and on surgical practices. In reality, programs in Africa rarely, if ever, restrict surgery to 1 eye per patient, and targets will probably be set to reach all or most eyes at a particular level of visual acuity, depending on the surgeons' practices. If the quality of surgery is good, we should expect that the case mix will change over time, tending toward demand for more surgery at better preoperative visual acuities. This is already happening in urban settings in Africa.

The age structure of various districts in Africa will make a large difference in the CSR needed. Although census

Discussion of assumption

compare to other models