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THE COST-EFFECTIVENESS OF BLINDNESS PREVENTION BY THE ONCHOCERCIASIS CONTROL PROGRAM IN UPPER VOLTA

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ABSTRACT

This paper presents a cost-effectiveness analysis of blindness prevention by the Onchocerciasis Control Program in Upper Volta, utilizing recent epidemiological data on changes in the incidence of blindness. The effectiveness measure aggregates the prevention of permanent disability and premature death in four different ways: years of healthy life added and years of productive healthy life added, both undiscounted and discounted. An illustrative comparison with the cost-effectiveness of measles vaccination in Ivory Coast and Zambia suggests that onchocerciasis control may be an efficient health intervention if weights are introduced for productive age and time preference.

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INTRODUCTION

The analysis proposed in this paper differs from previous economic analyses of onchocerciasis control (reviewed in 7,8) in three important respects. First, for the first time it uses empirical data as the basis of an estimate of the epidemiological effectiveness of the intervention. Second, it focuses on the prevention of permanent disability and premature death due to onchocercal blindness as the major health improvement attributable to onchocerciasis control. Third, it emphasizes cost-effectiveness rather than cost-benefit analysis. This limitation is imposed by the practical difficulty of undertaking a comprehensive and empirically defensible assessment of all the benefits of onchocerciasis control. In particular, the extent to which control of partial visual impairment and infection with : ocular involvement would increase the effective supply of labor, and also the extent to which control would increase the effective supply of land by inducing new settlement in the river valleys, have not been clearly established. The cost-effectiveness approach is limited because it foregoes the opportunity provided by cost-benefit analysis to compare the relative desirability of investing in onchocerciasis control with alternative investments in other sectors. However, it does permit useful judgements to be made about the relative efficiency of allocating scarce resources to onchocerciasis control compared to other possible investments within the health sector. For this purpose, an illustrative comparison is made with estimates of the cost-effectiveness of measles immunization.

BACKGROUND INFORMATION

A map of the distribution and prevalence of blindness in Upper Volta during the period 1970-1975 was recently drawn up using information collected by the fiscal authorities (9). The average prevalence of blindness in the whole country was estimated at 7 to 9 per thousand population. However, in many districts, blindness accounts for 30 to 50 per 1,000 population, and in selected villages blindness rates as high as 100 to 130 per 1,000 population can be observed. Districts where blindness rates exceed 10 per 1,000 are all located in hyperendemic areas for onchocerciasis. The 1975 census estimated the population of these counties at 800,000 people. In addition, foci of onchocerciasis also exist outside these administrative units, but their limited size does not influence the average blindness rate in the unit. Therefore, the population living in areas where the risk of blindness is significantly higher than the average rate in the country is estimated at approximately 1 million people. This increased risk of blindness is a result of the intensity of infection with onchocerciasis. For the purpose of the present study, we assume that among the 1 million people at risk, 500,000 live in hyperendemic areas for onchocerciasis, and another 500,000 in mesoendemic areas. This assumption is rather conservative.

In hyperendemic areas of Upper Volta, incidence of blindness varies from 3 cases per 1,000 population per year to 11 per 1,000 (12) with an average rate of 5 per 1,000 (10). Incidence ranges from 1.7 to 2 per 1,000 in mesoendemic areas, with an average of 1.8, and decreases to 0.5

per 1,000 in areas where onchocerciasis is no longer the leading cause of blindness (10). For the purpose of this study, we will retain the conservative assumption that the annual incidence of blindness due to causes other than onchocerciasis is about 1 per 1,000. This figure is consistent with observations by Rolland /a that prevalence of blindness due to causes other than onchocerciasis is about 9 per 1,000 population in endemic zones, indicating an annual incidence of 1 per 1,000 if the average lifespan in the blind is 9 years. It is also consistent with indications from OCP surveys that onchocerciasis is the cause of no more than 80% of blindness cases in hyperendemic areas.

The average age at onset of blindness is 39 years in hyperendemic areas. It is delayed to the age of 49-51 in areas of very low prevalence of onchocerciasis, with an intermediate figure of age 45 in mesoendemic areas (10). The same study indicated that the mean duration of life in the blind ranges from 7 in mesoendemic areas to 9 in hyperendemic areas, 13 to 14 years shorter than the life expectancy of the non-blind (Table 1). This observation is consistent with the results of a follow-up of blind and non-blind people in Upper Volta (11) which indicated that blindness reduces life expectancy by 13 years at least at age 30. It should be understood that the association of onchocercal blindness with excess mortality is only indirectly causal, reflecting social rather than pathological consequences of blindness.

Table 1 summarizes this information, based on a retrospective study of a 50,000 population sample during the 20 year period 1960-1980.

/a Rolland, A., Les cécités onchocerquiennes dans les zones couvertes par le projet régional de lutte contre l'onchocercose en Afrique de l'ouest. Unpublished document, IOTA, Bamako (1972)

Table 1. **Summary of Recent Data on Blindness in the Bougouriba River Valley, 1960 - 1980** /a

Endemicity	Average Incidence of Blindness per Year	Mean Age at Onset	Mean Duration of Life	Normal Life Expectancy at Age of Onset /b
Hyperendemic	5 per 1,000	39	9	23
Mesoendemic	1.8 per 1,000	45	7	20

(Sample: 50,000 people)

/a According to Prost et Paris (10)
/b Life expectancy data from (11)

MEASUREMENT OF COSTS

The measurement of costs is complicated by the problem of allocating joint costs between Upper Volta and the other six countries included in the Onchocerciasis Control Program area. The control of onchocerciasis in the Volta River basin began in 1975 with larviciding operations carried out in the western part of Upper Volta. Control was progressively extended to other river basins to cover the entire program area in seven west African countries by the end of 1977. At this stage, the total annual expenditure was US$ 10.5 million (Table 2).

Table 2. **Expenditure on the Onchocerciasis Control Program, 1975-1981**

Year	US$	Year	US$
1975	6,033,089	1979	13,984,364
1976	10,006,205	1980	16,506,724
1977	10,415,711	1981	16,646,363
1978	10,449,875		

We will use this figure because the subsequent increase in the budget in later years is due to an extension of the program area in Ivory Coast, to the use of alternative and more expensive insecticides in southern regions, or to other factors which are not relevant to Upper Volta. At that time, the area covered by the Program in Upper Volta represented 32% of the total area; out of the 510,000 kilometers of rivers treated in 1977, an estimated 27% were in Upper Volta; and 25% of operational staff was assigned to control in that country. Therefore, we can estimate that the cost of onchocerciasis control in Upper Volta represents about 25% of the total program expenditure, i.e., US$ 2.6 million per year. At present, expenditures in Upper Volta are significantly lower, as a result of temporary or permanent interruption of larviciding spraying, of the reduction of the surveillance network, and of redeployment of staff. However, these achievements are made possible by successful control in the central zone of the program and by ongoing operations in surrounding areas. Upper Volta is actually protected by treatments carried out in neighboring countries. Present expenditures in Upper Volta do not represent the cost of maintaining control of onchocerciasis in the country alone.

MEASUREMENT OF EFFECTIVENESS

Since 1977, OCP has achieved complete interruption of the tramsmission of onchocerciasis in Upper Volta (5). The decrease in the prevalence of the disease is gradual because people infected before the beginning of vector control still carry living parasites. However, ophthalmological follow-up indicates that the incidence of onchocercal blindness in hyperendemic areas of Upper Volta decreased to about 2.5 per 1,000 per year during the period 1975-78 (14), and that the overall incidence of blindness decreased to 3.2 per 1,000 per year during the period 1975-1980 (4). Since 1980, only sporadic new cases of blindness have been recorded, resulting from the deterioration of old and irreversible eye lesions.

A comparison of these data with the pre-control data presented above enables us to estimate changes in the annual incidence of blindness (Table 3). Pre-control figures are the average rates resulting from the study of the Bougouriba focus (10). Incidence due to onchocerciasis is considered to be negligible since 1981, although an incidence of 1 per 1,000 is conservatively attributed to other causes. Both series are based on the average figures of 3.2 (all causes) and 2.5 (onchocerciasis alone) recorded by ophthalmological follow-up during the period 1975-1980.

Table 3. **Estimated Incidence of Blindness in Upper Volta, 1975-1982**
(Per thousand population)

	All Causes		Due to Onchocerciasis	
	Hyper	Meso	Hyper	Meso
Pre-control	5.0	1.8	4.0	0.8
1975	5.0	1.8	4.0	0.8
1976	4.2	1.7	3.2	0.7
1977	3.5	1.5	2.5	0.5
1978	2.8	1.3	1.8	0.3
1979	2.0	1.1	1.0	0.1
1980	1.3	1.0	0.3	0.0
1981	1.0	1.0	0.0	0.0
1982	1.0	1.0	0.0	0.0

The difference between the pre-control and post-control incidence of onchocercal blindness can be attributed to the intervention of the Onchocerciasis Control Program. These data can be transformed into different measures of effectiveness as follows.

Cases of blindness prevented: The simplest effectiveness measure is the number of cases of blindness prevented by onchocerciasis control. This can be estimated from the blindness rates with and without intervention shown in Table 3 above and projections of the at-risk population, assuming an annual growth rate of the population of 1.7%. Resulting estimates of the numbers of cases of blindness prevented in each year during 1975 - 1982 are presented in Table 4.

Table 4. **New Cases of Onchocercal Blindness in Upper Volta, 1975-1982**

	Without OCP	With OCP	Prevented by OCP
1975	2,400	2,400	0
1976	2,441	1,983	458
1977	2,483	1,552	931
1978	2,524	1,105	1,420
1979	2,568	589	1,979
1980	2,611	163	2,448
1981	2,656	0	2,656
1982	2,700	0	2,700

Although it is simple to estimate, the number of cases of blindness prevented is of very limited value as a measure of effectiveness for use in cost-effectiveness analysis. It only permits comparisons with other health interventions which prevent blindness. It does not readily enable comparisons to be made with other health interventions which result in different types of morbidity and mortality reduction. For policy purposes, it would be more revealing to use a composite health status index which aggregates morbidity and mortality reductions into a single measure which can be used to make such comparisons.

Years of healthy life added: A measure of this type has been applied for the first time in any developing country by the Ghana Health Assessment Project Team to measure the combined effects of morbidity and mortality due to different diseases in Ghana (2). This measure represents a special case of the general class of health status index models originally devised for health planning purposes in developed countries (15).

Years of healthy life added by preventing onchocercal blindness are estimated by aggregating the effects of preventing disability before death and the number of years of premature death. The number of years of premature death are estimated to be the difference between life expectancy at the age of onset of blindness minus the average age of death among the onchocercal blind. The relevant data were given previously in Table 1. These indicate that in hyperendemic areas blind people expect an average of 9 years of disability and a subsequent 14 years of premature death. The corrresponding figures for mesoendemic areas are 7 and 13 years. Assuming that blindness results in complete disability, and that one year of complete disability is equivalent to one year of death, as was assumed by the Ghana Health Assessment Project Team (2), each case of blindness prevented is estimated to add 23 years of healthy life in hyperendemic areas and 20 years in mesoendemic areas. The resulting transformation of cases of blindness prevented into healthy years of life added is shown in Table 5. Our estimate of this measure of effectiveness excludes the additional health benefits of averting the periods of infection without ocular involvement and subsequently partial visual impairment because the lack of adequate data precludes a realistic assessment of these effects.

Table 5. **Undiscounted Years of Healthy Life Added 1975-1982**

	Disability	Death	Total
1975	0	0	0
1976	4,020	6,361	10,381
1977	8,069	12,879	20,948
1978	12,254	19,617	31,871
1979	17,063	27,332	44,395
1980	21,162	33,837	54,999
1981	23,018	36,741	59,759
1982	23,400	37,350	60,750

It is important to note that the number of years of healthy life added which are attributed to each year in Table 5 do not actually occur in that year. Rather, the measure represents an estimate of the future number of years of healthy life which are added by preventing the onset of blindness in each year. It will be assumed in this paper that the prevention of a new case of blindness in hyperendemic areas in any year t will lead to the addition of one year of prevented disability in each of the subsequent years (t+1)....(t+9), followed by the addition of one year of prevented premature death in each of the years (t+10)....(t+23). Similarly, prevention of the onset of blindness in mesoendemic areas in year t will be assumed to add one year of prevented disability in each of the years (t+1)....(t+7), and one year of prevented premature death in each of the years (t+9)....(t+20). For example, the health benefit produced by preventing one new case of blindness in hyperendemic areas in 1976, the first year in which intervention is assumed to have reduced the incidence rate, would begin to accrue one year later in 1977 and terminate 23 years later in 1999.

The problem of weighting: It was indicated previously that the design of an effectiveness measure for use in cost-effectiveness analysis must reflect the purpose of that analysis. The purpose of cost-effectiveness analysis is to make comparisons between the costs and effectiveness of allocating scarce resources to alternative health interventions. Since different interventions generally have different effects on morbidity and mortality it follows that a useful effectiveness measure must combine both types of outcome in a single measure. Hence, the number of years of healthy life added is proposed as an appropriate measure of effectiveness. However, it is obvious that the aggregation of morbidity and mortality reductions into a single measure necessarily involves making value judgements about the relative weight which should be assigned to these reductions. This intrusion of value judgements into cost-effectiveness analysis is an inescapable consequence of transforming it into an informative analytical tool. For our purposes here, we question three types of value judgement that are implicit in the formulation given in the previous section of the measure of years of healthy life added.

Weighting disability versus death: The measure assumes that one year of complete disability is equivalent to one year of premature death. The argument is that complete disability is equivalent to economic death, in the sense that the completely disabled person is totally non-productive, and therefore may be regarded the same as premature death, which has the same result. However, some would argue that complete disability is worse than premature death and should therefore be given a higher weight. The principal reason is that, in addition to foregoing the output that would have been produced by a blind worker if he was not disabled, the other members of society are imposed with the burden of sharing the remaining total output with the disabled worker in order to meet his consumption requirements. Although total consumption is equal under the two alternatives, consumption per capita is lower if the worker is completely disabled than if he were dead. The extent to which this consideration should influence the relative weights given to disability and death is difficult to resolve and will not be attempted here. Instead, we retain the assumption of equal weights and simply note the view that a higher relative weight for disability may be more apropriate.

Weighting for age preference: The measure assumes that additional years of life are equally valuable regardless of the age at which they accrue. Thus, prevention of child mortality appears to be much more valuable than preventing adult mortality, simply because life expectancy at the average age of child death is much greater than it is at the average age of adult death. This approach is consistent with the popular interest in primary health care and its emphasis on reducing infant and child mortality. However, it conflicts with the common notion that adult mortality is more serious than child mortality. For example, suppose that there is a choice between saving the life of a mother or her baby during delivery. There is no doubt that the physician's preference would always be to save the mother. An extreme method of taking into account this view would be to assign zero weight to years of healthy life added in the non-productive age group and a weight of one to those added in the productive age group. For this purpose, it is convenient to utilize the conventional definition of the working age group as years 15 to 60. We adopt this approach in a subsequent comparison of onchocerciasis control with measles immunization.

Weighting for time preference: The measure assumes that a year of healthy life added is equally valuable regardless of when it accrues. Thus, for example, saving 100 lives 10 years in the future would be considered just as valuable as saving 100 lives this year. This is not consistent with an established convention in the economic analysis of projects that future benefits (and costs) should be assigned progressively lower weight the later they occur in the life of the project. An important justification for this convention is simply that there exists a clear social preference for receiving benefits sooner rather than later. The implication is that society would, in fact, prefer to save 100 lives this year rather than 10 years later, instead of being indifferent between the two alternatives.

The relative value of benefits occurring in different time periods is expressed by a social discount rate. A fairly typical value is 10% and will be used for illustrative purposes here. This implies that 100 years of healthy life added in one year is worth the same as 110 years of healthy life added in the following year. Conversely, it implies that 100 years of healthy life added next year is worth the same as 91 years added this year. More generally, the discount factor applied to the quantity of benefits in each year t is:

$$\left(\frac{1}{1 + r}\right)^t$$

where r is the discount rate. Weighting the benefit accruing in any year t by the appropriate discount factor yields the present discounted value of those benefits in the pre-project year, $t=0$. Detailed tables of discount factors for different discount rates and time periods are compiled in (~~2~~3). For an example of the application of discounting to the health benefits of tuberculosis control, see (1).

The estimation of discounted years of healthy life added can be explained as follows. Prevention of the onset of blindness in any year t results in the addition of one year of healthy life added in each of the subsequent years (t+1)....(t+n) where n equals 23 in hyperendemic and 20 in mesoendemic areas. The discounted value of this increment represents the sum of the benefit of one year accruing in each of these years, weighted by their appropriate discount factors. This sum equals 8.88 discounted years of healthy life added in hyperendemic areas, compared to 23 undiscounted years. Similarly, prevention of a case of blindness in mesoendemic areas yields 8.51 discounted years of healthy life added, compared to 20 undiscounted years.

Clearly the discounted value of healthy years of life added by preventing blindness decreases the further into the future that blindness is prevented. Thus, prevention of a blindness case in a hyperendemic area in year 10 would yield only 3.43 discounted years of healthy life added, and prevention of a case in a mesoendemic area would add 3.28 discounted years. Estimates of the number of discounted years of healthy life added each year in the first 8 years of the OCP are given in Table 6.

Table 6. **Discounted Years of Healthy Life Added 1975-1982**

Year	Disability	Death	Total
1975	0	0	0
1976	2,158	1,199	3,357
1977	3,953	2,239	6,192
1978	5,464	3,115	8,579
1979	6,918	3,949	10,867
1980	7,794	4,431	12,225
1981	7,700	4,361	12,061
1982	7,117	4,031	11,148

A comparison of Table 6 with the estimates of undiscounted years added in Table 5 clearly demonstrates the effect of discounting. While undiscounted years added continue to increase in each year of the project, their discounted value starts to decline after 1980. By 1982, the discounted value amounts to less than one-fifth of the undiscounted value generated by a reduction in the incidence of blindness in that year.

COST-EFFECTIVENESS ANALYSIS

This section brings together the cost and effectiveness estimates developed for onchocerciasis control in Upper Volta and presents an illustrative comparison with similar cost-effectiveness estimates for measles immunization in Ivory Coast and Zambia. Four different effectiveness measures are used in the comparison: years of healthy life added, productive years of healthy life added, discounted years of healthy life added, and discounted productive years of healthy life added.

Onchocerciasis Control: The essence of the procedure for estimating the cost-effectiveness of onchocerciasis control is to discount the costs and effectiveness over the life of the control project, assumed here to run for 20 years from 1975 to 1994. In order to highlight the effect of introducing a discount rate, the effectiveness measures are presented both in undiscounted and discounted form. Costs are discounted in all cases.

It was estimated previously that the cost of the OCP which should be attributed to onchocerciasis control in Upper Volta is US$ 2.6 million per year in 1977 prices. Assuming a 10% discount rate, the sum of the discounted value of these costs over 20 years is US$ 22.1 million.

Our estimates of the effectiveness of the OCP are based on a projection to 1994 of the series of cases of blindness prevented given in Table 4. Cases prevented are transformed into years of healthy life added using the same assumptions underlying Table 5. Thus, the total number of years of healthy life added by preventing blindness over the 20 year life of the project is 1,098,935. Since all of these additional years fall within the productive age group of 15-59 years, the total number of productive years of healthy life added is also 1,098,935. Total discounted years of healthy life added are estimated by discounting future years of healthy life added to their present value in the pre-project year 1974. The relevant formulae are as follows:

Hyperendemic areas: $$\sum_{t=1}^{20}\left[\left(\frac{1}{1+r}\right)^t\right]\left[Q_t \sum_{n=t+1}^{t+23}\left(\frac{1}{1+r}\right)^n\left(1\right)\right]$$

Mesoendemic areas: $$\sum_{t=1}^{20}\left[\left(\frac{1}{1+r}\right)^t\right]\left[Q_t \sum_{n=t+1}^{t+20}\left(\frac{1}{1+r}\right)^n\left(1\right)\right]$$

where r denotes the discount rate, Q_t the number of new cases of blindness prevented in year t and n the number of future years of healthy life added per case of blindness prevented. In each formula the second term in square brackets represents the number of years of healthy added life added by preventing blindness in year t and discounted to year t. The first term in square brackets discounts this number back to its present value in the pre-project year. Assuming a discount rate of 10%, the total discounted number of both years of healthy life and productive years of healthy life added is 148,294.

These results yield the following cost-effectiveness estimates for blindness prevention under onchocerciasis control: US$20 per year of healthy life and per productive year of healthy life added, and US$149 per discounted year of healthy life and per discounted productive year of healthy life added.

Measles immunization: Shepard (13) and Pönnighaus (6) have prepared cost-effectiveness estimates for mortality reduction through measles immunization in Ivory Coast and Zambia respectively. Shepard estimates the cost per measles death averted at US$479 at 1977 prices. Asssuming that the average age of death from measles is 1 year, and that the expectation of life at age 1 is 46 years, this implies a cost per healthy year of life added of US$10. However, the initial 14 years of this gain in life expectancy, between ages 1 and 15, are non-productive years. This leaves a gain in productive life expectancy of 33 years, implying a cost per productive year of healthy life added of US$15. At a discount rate of 10%, the discounted years of healthy life added per death averted are 9.88 years. The discounted productive years of healthy life added are only 2.52 years since the gain in productive years does not begin to accrue until 14 years later at age 15. Thus, the cost per discounted year of healthy life added is US$49, and the cost per discounted productive year of healthy life added is US$190.

Pönnighaus's estimate of the cost per measles death averted is slightly higher, equivalent to approximately US$557 in 1977 prices for a program offering 100% coverage to a rural population. Utilizing the same assumptions about average age of death and life expectancy at that age yields the following cost-effectiveness estimates: US$12 per year of healthy life added, US$17 per productive year of healthy life added, US$56 per discounted year of healthy life added, and US$221 per discounted productive year of healthy life added.

Cost-effectiveness comparisons: The different cost-effectiveness estimates for onchocerciasis control and measles immunization are brought together in Table 7 below:

Table 7. **Estimated Cost-Effectiveness of Onchocerciasis Control and Measles Immunization**

Cost in US$:	Onchocerciasis Control	Measles Immunization Ivory Coast	Measles Immunization Zambia
Per year of healthy life added:	20	10	12
Per productive year of healthy life added:	20	15	17
Per discounted year of healthy life added:	149	49	56
Per discounted productive year of healthy life added:	149	190	221

These comparisons are subject to conventional but unavoidable reservations about cross-country comparisons based on international exchange rates. They indicate that the relative cost-effectiveness of onchocerciasis control is very sensitive to the choice of effectiveness measure. Without differential weights for productive years and social time preference, onchocerciasis control appears to be a less efficient use of resources than measles immunization. The separate introduction of these weights in the measures of productive years and discounted years of healthy life added does not alter this policy inference. However, the combination of these weights in the measure of discounted productive years of healthy life added switches the cost-effectiveness ranking in favor of onchocerciasis control. The reason is, of course, that blindness prevention results in an immediate gain of productive years whereas the gain of productive years generated by measles immunization is deferred for 14 years, and is therefore heavily discounted. We argue that the introduction of weighting for age preference and of discounting for time preference are both consistent with conventional social values. Thus we conclude that onchocerciasis control may be compared favorably with a popular primary health care intervention.

This conclusion is reinforced by the fact that our analysis focuses on blindness only and thus excludes additional health and economic benefits of onchocerciasis control which may be significant. Our measure of health benefits does not include the benefit of averting the periods of infection without ocular involvement and subsequently partial visual impairment which usually precede the onset of blindness. Similarly, our emphasis on cost-effectiveness analysis sets aside the potential benefit of increased output resulting from increases in the effective supply of labor and land that might be attributable to onchocerciasis control.

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