IS POLIO ERADICATION IN THE AMERICAS ECONOMICALLY JUSTIFIED?[1]

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INTRODUCTION

Since the eradication of smallpox in the 1970s, no other disease has been eliminated from the world by vaccination. Advances in mass immunization campaigns using oral vaccine have successfully interrupted the transmission of wild poliomyelitis virus in many countries, however, and have sharply reduced its incidence in many others *(1, 2)*. The benefits of polio immunization appear from some studies to outweigh its costs *(3)*, and the cost-effectiveness of mass campaigns relative to other means of reaching the susceptible population has been established, at least in some circumstances *(4)*. It therefore seems possible, by a suitable intensification of such efforts, to eradicate polio—if not all over the world, then at least in the Western Hemisphere—within the next few years.

In view of the success of the PAHO/WHO Expanded Program on Immunization (EPI) in the Americas since its inception in 1977, in April 1985 *(5)* PAHO recommended that its Member Governments support a five-year, US $46 million campaign to eliminate polio entirely from the Americas, after which it would be relatively easy to deal with whatever cases might be imported. The Member Governments ratified this proposal in September 1985 *(6)*; and since then PAHO has been developing the campaign's detailed strategy and obtaining financial commitments from private, bilateral, and multilateral donor agencies.

To satisfy some of these agencies' requirements, a cost-benefit analysis was prepared. This article describes the assumptions and findings of that analysis, which indicate that the eradication of polio is economically justified, and discusses some of their implications. Its concluding section considers the terms according to which the eradication of polio can be deemed an alternative to curative care.

ASSUMPTIONS

The analysis that follows attempts to answer one specific question: Is the cost of eradicating polio, through the program adopted by PAHO, justified through the medical costs saved by not having to treat or rehabilitate polio victims? This estimate of the benefits from polio eradication takes no account of the

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gains from reduced pain and suffering, from the greater economic productivity of individuals who would otherwise be paralyzed and rendered unproductive, or from the reduction in other vaccine-preventable diseases that can be expected to result from a successful campaign against polio. If eradication is economically justified by reduced medical costs alone, then there is no doubt that it is still more justified when account is taken of other benefits.

The logic of the argument is as follows: For each of the five years of the eradication campaign, and then for each of 10 years thereafter, estimates are made of the following: the number of cases of paralytic polio that would be prevented; the cost of treating and rehabilitating that number of polio victims; the cost of the eradication effort; and the net benefit (in terms of reduced medical expenses minus the cost of eradication). These net benefits are then discounted at 12% per year, meaning that $1.00 saved next year is worth only $0.88 saved today, etc.[3] (This is the discount rate used by the Inter-American Development Bank for project evaluation, and is chosen because the Bank is helping to finance the eradication campaign).

[3] If benefits in year t are designated B_t, while costs incurred in that year are C_t, $B_t - C_t$ is the net benefit. The corresponding discounted net benefit is $(B_t - C_t)/(1 + i)^t$, where i is the interest or discount rate used. The present value of this stream of net benefits (positive or negative) is the sum of these terms over all the years of a project, or in the present case through the first 15 years, after which net benefits are positive but, because of discounting, are quite small.

Because the campaign is superimposed upon continuing national efforts to control polio through the EPI, two cost-benefit calculations are made. One compares the total cost—US $74 million in national effort and $46 million from international donor agencies over the first five years, plus $10 million per year in national resources thereafter—with the total cases and costs that could be expected to occur in the absence of *any* substantial effort to control polio. The other calculation finds costs derived from the current estimated incidence of polio and compares these to the cost of the resources being sought from donors in order to ensure polio eradication by eliminating the relatively small numbers of cases that still persist after nearly a decade of the EPI. The first calculation compares total costs to total benefits (in terms of reduced medical expense), while the second compares marginal or incremental costs to the marginal benefits of going from the present case incidence to eradication. In both cases it is assumed that every polio victim would receive treatment, so that the comparison is really between the cost of preventing polio and the cost of treating all those who would otherwise get the disease. This assumption that all victims receive treatment is relaxed later, so that no benefit is attributed to cases not actually treated.

A number of additional assumptions underlying the calculations deserve further explanation. These assumptions are as follows:

1) The background or "natural" level of polio incidence is derived from the situation existing before the EPI began, when about 3,000 cases of paralysis and 350 deaths were reported annually in the Americas. It is recognized that before the EPI started, polio was greatly underreported *(5)*, perhaps by a factor of

five.[4] If this estimate is accurate, then the true pre-EPI incidence would have been about 15,000 cases per year. This should probably be regarded as an upper bound.

2) The EPI helped to reduce the hemispheric total of reported polio cases to about 500 a year in 1984 and 1985. Assuming no change in the degree of underreporting, this means the actual incidence would have been about 2,500 cases annually. Of course, the improved surveillance that accompanied the EPI might also have reduced the underreporting significantly, so that the true incidence might have been lower, say on the order of 1,500 cases per year. It is also possible that expecting the level to remain at 2,500 cases per year for the near future without eradication is being overoptimistic. In the absence of an eradication campaign, national efforts might not be able to keep the incidence that low. For one thing, polio fluctuates cyclically, and the 1984–1985 level of cases appears to represent a cyclical trough from which a slight rebound could be expected. For another, vaccination coverage could actually decline because of financial difficulties and a false sense of confidence about the extent of control in the absence of a reliable surveillance system.

The example of Jamaica illustrates this latter risk. After over five years of reporting zero cases, levels of coverage declined; an outbreak then occurred in 1982 that produced over 50 cases. The cost of controlling the epidemic and treating the victims has been estimated at more than ten times the cost needed over the preceding five years to prevent the outbreak *(7)*.

There were substantial polio increases in Brazil and Colombia from 1985 to 1986 *(8)*, although these were partly offset by declines in Mexico, Haiti, and Peru. The buildup of a pool of susceptibles and any decline in vaccination coverage would have the same results in other countries. For this reason it is assumed that 3,000 cases a year remain to be eliminated, rather than the 2,500 figure that would result from 500 observed cases with 80% underreporting. This 3,000 figure should also probably be regarded as an upper bound, the lower bound being about half as high.

The external funds to be utilized in the eradication project will go to ensure that a surveillance system is built up and that supervisory systems are in place—so as to guarantee continued high levels of coverage and eventual eradication of the wild poliovirus. Without these additional resources, it may be very difficult for the countries involved to organize the needed surveillance systems, and it is to be feared that prevailing levels of coverage will decline for lack of supervisory systems.

3) The cost of treating a polio victim has been estimated from a 1982 study conducted in Brazil *(9)*. The expenses included were those of treatment during the acute phase of the disease (US $880 on the average, within a range of US $350 to US $2,800 in different hospitals), together with those of surgery, rehabilitation, and subsequent therapy.

Rehabilitation sometimes extends over several years, so rehabilitation costs must be discounted. In the Brazil-

[1] It is not easy to estimate polio underreporting, although surveys of residual lameness provide a basis (see *1*, Session III, Section A). The assumption that before the EPI only about 20% of the polio cases were reported in Latin America and the Caribbean has been suggested by Ciro de Quadros and Marjorie Pollock as a reasonable estimate.

ian study, discounting was done at 6% per year and was applied over 10 years; for purposes of the present calculations, the results reported have been adjusted to reflect the discount rate of 12% used here. With that adjustment, the average cost of the surgery, rehabilitation, and therapy phase is estimated at $4,949. Hence, the total estimated cost of treating a polio case is $5,829.

The combination of such a high individual treatment cost and a large number of unreported cases means, of course, that the estimated total cost of treating all polio victims would be quite high. In that sense, cost and case estimates could bias the results in favor of the eradication campaign. However, any such bias is offset by excluding from consideration all of the other costs associated with paralytic polio. Furthermore, the calculations based on these high estimates are modified later in the analysis in order to determine whether eradication would still be justified with fewer cases or lower treatment costs.

4) The five-year eradication campaign could not expect to bring the incidence of polio down to zero in the first year. Instead, as surveillance and coverage expand, the campaign is expected to achieve zero cases by the fifth year. It is assumed for purposes of simplicity that the decline in cases is linear over the five years of the campaign. This means that net benefits increase from the first to the fifth year, increase sharply in the sixth year (when spending drops back to the maintenance level of US $10 million per year), and thereafter remain constant, apart from discounting. At the end of the campaign, some 15,000 cases per year are being prevented. If there are currently about 3,000 cases annually, the difference of 12,000 cases that do not occur can be attributed to the current level of control exerted through the EPI. The eradication campaign is assumed to prevent another 1,000 cases in the first year (for a total of 13,000) and an additional 500 cases in each succeeding year.

5) Benefits and costs are calculated for 10 years beyond the end of the eradication campaign, which carries the calculation to the end of the century. Net benefits continue to accrue beyond that point if eradication is maintained, but discounting makes their present value quite small ($1.00 is worth only $0.18 fifteen years from now).

COSTS AND BENEFITS WHEN ALL POLIO VICTIMS ARE TREATED

The foregoing assumptions lead to the costs and benefits shown in Table 1. When total costs (including national efforts as well as donor contributions to eradication) are compared to total savings (assuming all cases are treated), there is a net present benefit, after discounting, of US $217.2 million in the first five years, and the eradication campaign is economically justified in each of the first five years, well before full eradication is achieved. This simply reflects the fact that the current level of EPI coverage is economically justified by the potential savings in treatment costs on the basis of the assumptions made here.

During the 10 years following eradication, these calculations indicate a further discounted net saving of US $264.2 million. Because of discounting, this is much less than the estimated sum of undiscounted savings over 10

TABLE 1. Costs and benefits associated with polio eradication during a successful five-year campaign and an ensuing ten-year maintenance period, assuming all polio victims are treated.

	Years of eradication campaign					Campaign years, total	Years 6–15, per annum	Years 6–15, total	All 15 years, total
	1	2	3	4	5				
Discount factor[a]	0.945	0.844	0.753	0.673	0.601	—	—[b]	—	—
Total costs versus total benefits (in millions of US$):									
Number of cases prevented (thousands)	13.0	13.5	14.0	14.5	15.0	70.0	15.0	150.0	220.0
Savings in treatment expenses (millions of US$)	75.8	78.7	81.6	84.5	87.4	408.0	87.4	874.4	1,282.4
Cost of eradication or maintenance	24.0	24.0	24.0	24.0	24.0	120.0	10.0	100.0	220.0
Net saving (net benefit)	51.8	54.7	57.6	60.5	63.4	288.0	77.4	774.4	1,062.4
Net present value of discounted savings	48.9	46.1	43.4	40.7	38.1	217.2	—[c]	264.2	481.4
Donor costs versus marginal benefits (in millions of US$):									
Number of cases prevented (thousands)	1.0	1.5	2.0	2.5	3.0	10.0	3.0	30.0	40.0
Savings in treatment expenses (millions of US$)	5.8	8.7	11.7	14.6	17.5	58.3	17.5	174.9	233.2
Cost of eradication or maintenance	9.2	9.2	9.2	9.2	9.2	46.0	0	0	46.0
Net saving (net benefit)	−3.4	−0.5	2.5	5.4	8.3	12.3	17.5	174.9	187.2
Net present value of discounted savings	−3.2	−0.4	1.9	3.6	5.0	6.9	—[c]	55.2	62.1

[a] Discount factors are calculated at mid-year; thus the factor for year one corresponds to discounting at 12% annually for six months.
[b] This discount factor varies from 0.536 in year six to 0.194 in year 15.
[c] Because of variations in the discount factor from year to year, only the ten-year totals are shown.

years, which is US $774.4 million. (Savings in each year of the decade would be US $77.4 million, but discounting would reduce their present value to only US $41.5 million in the first year and even smaller values in each subsequent year.) Discounting would also reduce the present value of anticipated savings during the five-year eradication effort from US $288.0 million to US $217.2 million.

During the whole fifteen year interval, the present value of net savings is estimated at US $481.4 million. Whether the prevention of 220,000 cases of paralytic polio would be worth this much (or more, or less) to the potential victims and their families is not considered.

This estimate is so high because it is very expensive to treat even one polio victim. However, the conclusion that eradication is justified does not depend on this cost being as high as US $5,829. In fact, if the treatment cost were only US $1,728 the net total discounted savings over the five-year eradication campaign would be zero, and the effort would still pay for itself over the next 10 years. (Net savings in each year would be US $15.9 million, for a ten-year discounted total benefit of US $54.3 million.) If the campaign had the entire 15 years to pay for itself, the cost of treatment could be as low as US $1,207.

Alternatively, the incidence of polio could be much lower than is assumed in Table 1. That is, assuming treatment costs of US $5,829 per patient, the number of cases could be reduced to about 3,100 and eradication could still be justified.

Given that the current level of polio control by vaccination is much cheaper than treatment of all the cases that would otherwise occur, it may still be asked whether the donor contribution of US $46 million for the eradication campaign would pay for itself in terms of reduced incidence and associated lower treatment costs. The amount requested from donor agencies is 38% of the total cost of eradication, but it would be used to eliminate only 20% of the pre-EPI level of incidence (3,000 cases per year out of 15,000), the other 80% being controlled by national efforts costing US $74 million during the five years of the campaign.

Consequently, as the second part of Table 1 shows, the donor contribution exceeds the anticipated saving (again assuming treatment of all polio victims) during each of the campaign's first two years. This is followed by positive net benefits as eradication is achieved, for a total net benefit of US $6.9 million during the five years of the campaign. There would also be a positive net benefit of US $17.5 million in each subsequent year, while eradication would presumably be maintained by national efforts without further donor financial assistance. Even with discounting, over the next decade this latter benefit would amount to a further US $55.2 million. The result is an estimated net discounted positive benefit of US $62.1 million over the entire fifteen-year period.

This calculation naturally depends more for its positive value upon the assumed high cost of curative treatment. For the campaign to break even in five years (showing zero net discounted savings from the donors' contributions), treatment could not cost less than US $4,874. That would result in total discounted savings of US $46.1 million over the ensuing decade. These savings (over all 15 years) would still be positive at any treatment cost higher than US $2,106. Therefore, roughly speaking,

the eradication of polio appears justified if treatment costs at least US $2,000, purely on the grounds of reducing the total discounted costs of treatment plus prevention over a fifteen-year period.

In other words, while the donor contribution directed at eradication pays off more slowly than the level of polio control already achieved, it is still an economically justified investment compared to the cost of treating everyone who would otherwise get polio. This remains true despite the higher marginal cost associated with expanded coverage, and despite the need to devote resources to activities other than immunization (surveillance and laboratory work) that are necessary in order to ensure that eradication is achieved and maintained. Moreover, as in the previous calculation, no account is taken of other benefits anticipated from this investment—such as an increased capacity to control other diseases and consequent further medical savings.

In sum, there is no reason to suppose that the current level of polio control has already absorbed all the potential benefit, leaving nothing more to be gained from complete eradication of the disease. Rather, making an additional effort to eliminate polio entirely appears justified. This conclusion seems invalid only if the cost of treating a polio victim is much less than that assumed here, or if the number of victims treated is far smaller. The next section considers the second of these possibilities.

COSTS AND BENEFITS WHEN TREATMENT IS INCOMPLETE

The apparent economic justification for eradicating polio contradicts the findings of a cost-benefit analysis of polio vaccination in Brazil covering the mass immunization campaigns begun in 1980 *(10)*. On the assumption that such campaigns would end in 1983, and that thereafter the normal, precampaign rate of vaccination would be enough to keep polio from reappearing before 1990, it was concluded that the mass campaigns did not justify their costs (US $30 million), and that no more than US $3.4 million per year should be spent to maintain the pre-1980 level of vaccination coverage.

This study made several assumptions that differ from those reflected in Table 1. For one thing, the discount rate was taken to be 18% rather than 12%, which made future benefits less valuable. For another, the fixed costs of treating children in the acute stage of the disease were assumed to be zero, because of supposed excess facility and staff resources at pediatric hospitals. This amounts to supposing that any such resources would not be used for other medical care and would not be released—in other words, that ministries of health would maintain superfluous staff and facilities. (The costs of the subsequent rehabilitation and surgery, which were acknowledged to require specialized personnel and facilities, were not regarded as zero.) The most important difference, however, is that savings were calculated only for the estimated number of actual curative treatments, rather than for the number of victims who could benefit from such care but did not always receive it. Primarily for this reason, the mass vaccination campaign appeared to

be justified in Northeast Brazil, where the incidence of polio was relatively high, but not in the rest of the country.

Relating the costs of immunization to actual rather than potential costs of treatment in this way raises two important issues. The first concerns the appropriate way to deal with those victims who get polio but receive no medical care. These people are entirely ignored if only actual spending is considered, but of course they account for much of the potential benefit of immunization if any kind of price is put on pain and suffering *(10)*. The second issue concerns marginal costs and benefits. Once polio has been brought partly under control by immunization, the remaining gain from greater coverage may be small. However, the cost of obtaining greater coverage is likely to be high, since the current level has to be maintained while immunization is extended to the rest of the population. This makes polio very different from smallpox, which could be combated by concentrating only on those areas still reporting the disease (only surveillance activities, not vaccination, were needed in areas where smallpox had already been eradicated).

As a result of this problem of increasing marginal cost and decreasing marginal gain in the case of polio, it may never seem justified to *finish* the job. The calculations in Table 1 indicate, however, that complete eradication is justified for polio if the extra expense of donors' contributions is compared to the extra gain made possible thereby. Among the benefits from complete rather than almost-complete eradication are the prevention of later outbreaks like the previously mentioned one in Jamaica. These can be expensive to control, but because of their uncertain magnitude and frequency no attempt has been made to estimate the present discounted value of the costs they represent. It should also be noted that because of uncertainty in the estimates of costs and incidences it is impossible to determine either the marginal point where preventive efforts cease to be justified or the maximum vaccination coverage that pays for itself.

Both calculations in Table 1 assume that treatment would be provided to everyone who actually contracted the disease. Most of the estimated benefits, however, are only potential savings that greatly exceed realizable savings attainable through actual reduction in treatment expenditures. Therefore, the next task is to see whether those realizable savings, by themselves, are enough to pay for the cost of eradication, without attributing any benefit to cases where people are affected by polio but receive no medical care.

This requires estimating the number of cases that are or would be treated. Before introduction of the EPI, the number of cases treated was roughly equal to the number reported, in part because some countries reported only those cases actually treated. (This accounts in large part for the very high level of underreporting.) In the absence of control measures, the number of cases treated would be at least as large as it was a decade ago. Allowing for some improvement in coverage or expansion of treatment, and recognizing that in many pre-EPI years there were more than 4,000 reported cases of polio, it seems reasonable to take 4,000 cases per year as the background or "normal" level of treatment that would occur in the absence of immunization. As in the calculations reported above, it cannot be supposed that the eradication campaign would imme-

diately eliminate the need to treat those cases. Instead, it is supposed that in the first year of the campaign there would be savings from 2,000 fewer treatments, and that this number would rise to 4,000 cases over the five-year period. This estimate, which appears in the first line of Table 2, shows that over the entire fifteen-year period some 55,000 fewer treatments would be required.

Following this assumption, net savings are of course much smaller than they would be if all polio victims were treated. Savings remain negative throughout the five years of the campaign and turn positive thereafter. The result is a total net discounted benefit of −US $27.3 million during the eradication campaign, followed by a positive net benefit, after discounting, of US $45.4 million during the next decade. Total net benefits during the entire fifteen-year period are estimated at US $18.1 million.

This means that eradication of polio would pay for itself by reducing the medical costs of treating those victims who actually are or probably would be treated. Hence, in order to justify an eradication campaign, it is not necessary to attribute any benefits to people who probably would not receive treatment. The magnitude of the net discounted benefit is drastically reduced (from US $481.4 to US $18.1 million), but it continues to be positive. However, because the number of treatments is much reduced, the cost per treatment could not fall appreciably without turning savings negative; specifically the minimum cost would be US $5,097.

Assuming that some polio victims are not treated has exactly the same effect on estimated savings as assuming that fewer people get polio in the first place. Ethically, of course, the two situations are very different; and the total benefits are also different once pain and suffering are taken into account. Nevertheless, for the purpose of this analysis the two are identical. Thus, the calculations in Table 2 can be interpreted as meaning that polio eradication would be justified if there were only 4,000 cases annually in the absence of vaccination with all cases being treated—in which case only about 1,000 cases would remain to be prevented by the eradication campaign. This implies that the results do not depend critically on the assumed high incidence of unreported polio; and so, as noted earlier, the level could be as low as 3,100 cases per year.

The profile derived in Table 2 of immunization expenditures and savings ascribed to reduced treatment costs is displayed graphically in Figure 1. The upper panel of that figure shows the undiscounted profile while the lower one includes the effect of discounting. As a result of discounting, the area of net gain is shrunken compared to the area of net loss.

Table 2 also compares marginal (donor) costs and marginal benefits in the manner of Table 1, assuming only a small number of cases treated. Here it is supposed that the reduction in treatments never exceeds 1,000 cases per year, starting from an approximate reduction of 600 cases the first year. This calculation shows a total discounted net benefit of only US $0.6 million over the entire 15-year period. Based on reduced medical costs alone, the donors' contribution almost exactly pays for itself, assuming treatment costs of US $5,829 per case.

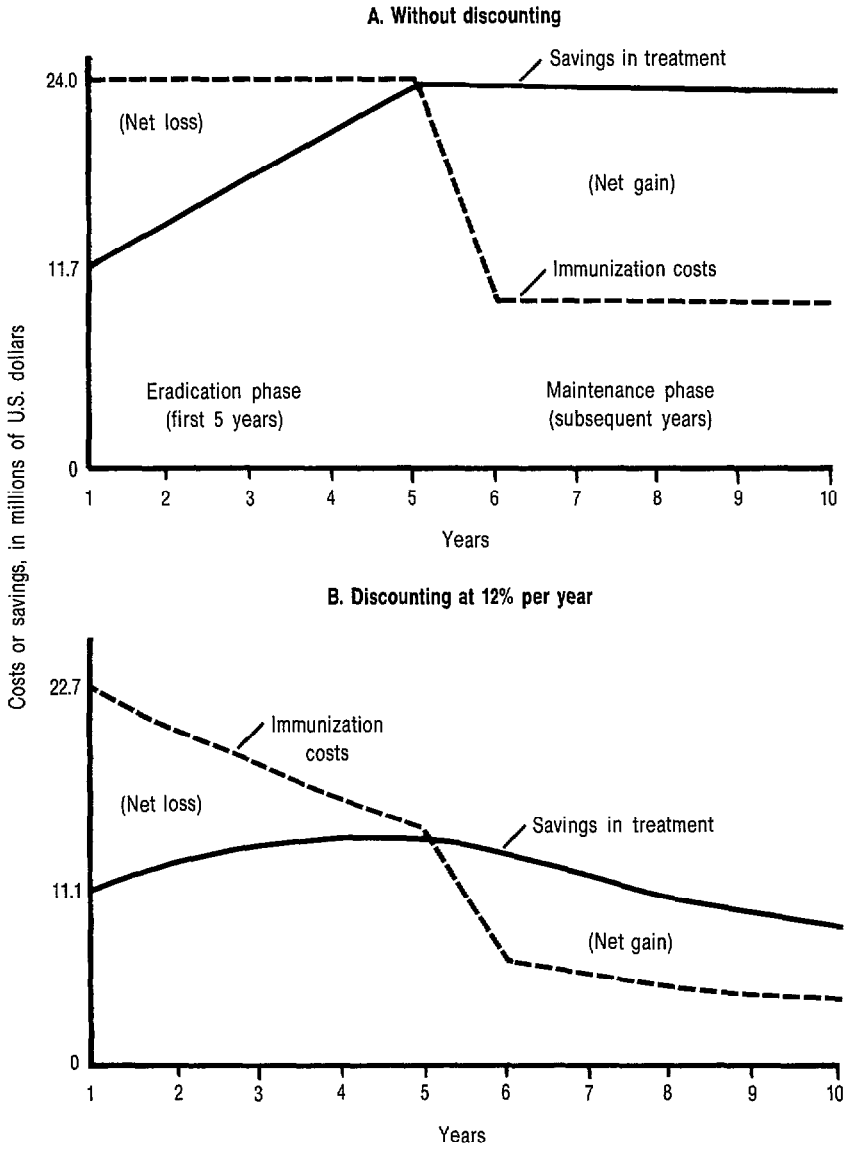
In summary, these estimates indicate that the eradication of poliomyelitis is a justifiable investment, even without making any allowance for bene-

TABLE 2. Costs and benefits associated with polio eradication during a successful five-year campaign and ten-year maintenance period, assuming only a fraction of all polio victims are treated. The discount factor is the same as that shown in Table 1.

	Years of eradication campaign					Campaign years, total	Years 6–15, per annum	Years 6–15, total	All 15 years, total
	1	2	3	4	5				
Total costs versus total benefits (in millions of US$):									
Number of treatments prevented (thousands)	2.0	2.5	3.0	3.5	4.0	15.0	4.0	40.0	55.0
Savings in treatment expenses (millions of US$)	11.7	14.6	17.5	20.4	23.3	87.5	23.3	233.2	320.7
Cost of eradication or maintenance	24.0	24.0	24.0	24.0	24.0	120.0	10.0	100.0	220.0
Net saving (net benefit)	−12.3	−9.4	−6.5	−3.6	−0.7	−32.5	13.3	133.2	100.7
Net present value of discounted savings	−11.6	−7.9	−4.9	−2.5	−0.4	−27.3	—[a]	45.4	18.1
Donor costs versus marginal benefits (in millions of US$):									
Number of treatments prevented (thousands)	0.6	0.7	0.8	0.9	1.0	4.0	1.0	10.0	14.0
Savings in treatment expenses (millions of US$)	3.5	4.1	4.7	5.2	5.8	23.3	5.8	58.3	81.6
Cost of eradication or maintenance	9.2	9.2	9.2	9.2	9.2	46.0	0	0	46.0
Net saving (net benefit)	−5.7	−5.1	4.5	4.0	3.4	−22.7	5.8	58.3	35.6
Net present value of discounted savings	−5.4	−4.3	−3.4	−2.6	−2.0	−17.8	—[a]	18.3	0.6

[a] Because of variations in the discount factor from year to year, only the ten-year totals are shown.

FIGURE 1. Costs and benefits of polio eradication, assuming treatment of only some victims or reduced numbers of cases (from data in Table 2).



fits other than those due to realizable reductions in expenditures to treat victims of the disease. Indeed, the cost of treating even a small fraction of those who need treatment is large enough to pay for the total prevention of polio. In other words, the eradication of polio would actually put money in the coffers of the Ministry of Health, or whoever now pays to treat polio victims.

It is important, however, to sound a note of caution. This projected result depends on there being enough

current expenditure on treatment. It would no longer hold, for example, if the level of treatment were only one-fourth lower than that assumed in Table 2. This process of justifying an eradication campaign by its effect in reducing public expenditure depends on there being sufficiently high public expenditure to start with; and so the process can lead to effects that are clearly perverse. In our case, literally applied, and giving no allowance for nonmonetary benefits in terms of reduced pain and suffering, it implies that the eradication of polio would be justified *after* spending millions of dollars over many years to treat polio victims, but would not be justified as an *alternative* to such a treatment expenditure. That is, eradication would be more justified the later it came, after increasingly large sums of money were spent for treatment.

IMMEDIATE VERSUS DELAYED ERADICATION

To see how such justification of immunization, in terms of reduced costs alone, could lead to a delay in vaccination efforts, consider two hypothetical regions (A and B) with 15,000 cases of paralytic polio per year (the estimated pre-EPI level in Latin America and the Caribbean). Suppose that immunization has not begun in either region, and suppose further that in neither case are victims of the disease initially being treated. The costs of treating a case (US $5,829), conducting a five-year eradication campaign (US $120 million), and maintaining eradication thereafter (US $10 million per year) are assumed to be the same as in the previous analysis.

In Region A, efforts are made to start treating victims for purely ethical reasons, treatment being extended to 1,000 patients the first year and 1,000 additional patients per year thereafter. At the end of five years, someone performs a cost-benefit estimate of the sort presented above and discovers that it would be cheaper to immunize people. Over the next five years, immunization is gradually extended to enough of the population to interrupt the transmission of wild poliovirus, and eradication is achieved. Thereafter, immunization of infants is maintained, and while treatment continues for the victims accumulated during the whole ten-year period (five without immunization and five after immunization began), no new patients are admitted for treatment in the eleventh and subsequent years. Assuming linear treatment and immunization trends, as shown in Table 3, 112,500 people get polio during the decade, of whom 41,500 are treated and 71,000 receive no treatment.

In Region B, nobody worries about cost-benefit analysis of this sort. Immunization is begun immediately, rather than waiting for five years. Treatment of victims begins at the same time and is extended at the same rate as in Region A, except that because of immunization, treatment never rises beyond 4,000 cases per year and falls to zero in the sixth year. Over the ten-year period only 37,500 people get polio, of whom 11,500 receive treatment and 26,000 do not. This latter figure is only 37% of the number of untreated victims accumulated in Region A. From year 11 onward both regions are identical, in that they have no new polio cases and spend US $10 million each per year to maintain eradication. Any comparison of the two regions need therefore consider only the first 10 years.

TABLE 3. A comparison of ten-year costs and results of two hypothetical polio eradication campaigns, one immediate and one delayed, discounted at 12% per year as in Tables 1 and 2.

	Years										Ten-year total
	1	2	3	4	5	6	7	8	9	10	
Region A (delayed campaign):											
Number of polio cases (thousands)	15.0	15.0	15.0	15.0	15.0	13.5	10.5	7.5	4.5	1.5	112.5
Number of cases treated (thousands)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	4.5	1.5	41.5
Untreated victims (thousands)	14.0	13.0	12.0	11.0	10.0	7.5	3.5	0	0	0	71.0
Cost of treatment (million US$)	5.8	11.7	17.5	23.3	29.1	35.0	40.9	43.7	26.2	8.7	241.9
Cost of immunization (million US$)	0	0	0	0	0	24.0	24.0	24.0	24.0	24.0	120.0
Total cost	5.8	11.7	17.5	23.3	29.1	59.0	64.8	67.7	50.2	32.7	361.9
Discounted total	5.5	9.9	13.2	15.7	17.5	31.6	31.0	28.9	19.2	11.1	183.6
Region B (immediate campaign):											
Number of polio cases (thousands)	13.5	10.5	7.5	4.5	1.5	0	0	0	0	0	37.5
Number of cases treated (thousands)	1.0	2.0	3.0	4.0	1.5	0	0	0	0	0	11.5
Untreated victims (thousands)	12.5	8.5	4.5	0.5	0	0	0	0	0	0	26.0
Cost of treatment (million US$)	5.8	11.7	17.5	23.3	8.7	0	0	0	0	0	67.0
Cost of immunization (million US$)	24.0	24.0	24.0	24.0	24.0	10.0	10.0	10.0	10.0	10.0	170.0
Total cost	29.8	35.7	41.5	47.3	32.7	10.0	10.0	10.0	10.0	10.0	237.0
Discounted total	28.2	30.1	31.3	31.8	19.7	5.4	4.8	4.3	3.8	3.4	162.7

What do costs look like in the two cases? Region A spends a total of US $241.9 million on treatment and US $120.0 million on immunization over the decade, for an undiscounted total cost of US $361.9 million. Region B spends only $67.0 million on treatment (just 28% of what Region A spends), but—since five years of maintenance are included after the five years of eradication—it spends US $170.0 million on immunization, US $50.0 million more than Region A. Region B's undiscounted total expenditure is therefore US $237.0 million, or 66% as much as Region A's.

Discounting expenditures at 12% per year has more effect on the costs in Region A, because spending there reaches its peak later, in year eight. This is due to initial postponement of the eradication campaign and also to the relatively slow expansion of treatment that is assumed; costs would be shifted toward the early years if treatment were extended more rapidly. In Region B, total expenditure reaches its peak in year four, being higher than in Region A during each of the first five years. As a consequence, the discounted total costs are US $183.6 million in Region A and US $162.7 million in Region B, so that the Region B costs are 89% as high as those in Region A.

At the end of 10 years, neither region has any new polio cases. However, Region B is clearly better off. It has spent US $20.9 million less after discounting (US $124.9 million less without discounting); it has 30,000 fewer *treated* polio victims (who suffer some damage from the disease despite treatment); and it has 45,000 fewer untreated, paralyzed victims. Thus, making an immediate effort to eradicate the disease pays off both in reduced health damage and in lower total treatment and prevention costs. If either the cost of treating a polio victim or the number of victims were lower, the monetary saving in Region B compared to Region A would of course be smaller, but it would always be positive. If one assumed that eradication could only be justified by saving actual (not potential) expenditure on treatment, however, Region A pursued the right course by not starting immunization until the costs of treatment had become relatively high.

Concluding remarks

What accounts for this perverse result? Part of it is due to discounting future costs and benefits. When the assumed number of treatments is reduced from 15,000 per year (Table 1) to 4,000 per year (Table 2), the undiscounted net savings fall from US $1,062.4 million to US $100.7 million. (This is much more than the approximately 15:4 reduction in treatment savings, because the costs of immunization are independent of treatment levels.) Discounting means that net savings are reduced much more than ten-fold, because savings increase through time; thus, net savings of US $481.4 million become only US $18.1 million, a 24-fold reduction. What this means is that the higher the discount rate, the higher the number of current treatments necessary to justify the cost of eradication. If, as in Region A, immunization is delayed while treatment costs increase, the effect of discounting is to delay eradication still more.

It might seem that the answer to this problem is not to discount the future, but instead to base decisions on undiscounted costs and benefits. The logic of discounting, after all, supposes that a given individual, who is the same person today and tomorrow, values tomorrow less than today *(11)*. But the children who will suffer paralytic polio in the future, if the disease is not eradicated, have for the most part not been born yet. Discounting their future therefore means valuing them less than those who are already here, which is very different from making intertemporal choices for a given person.

However, to abandon discounting means being willing to wait forever, provided that eventually benefits outweigh costs. The resources required to eradicate polio could be applied to other uses, including medical uses, which might pay off more quickly. So even though discounting the future raises an awkward ethical question, there is no escaping the need to give priority to the present, at least so long as the benefits considered in the two periods can be compared.

The whole question of whether eradicating polio is worth the cost would not even arise if the private market for immunization worked properly. No parent wants to see his child paralyzed, and the cost of immunization is less than the expected cost of treatment per unimmunized child. Therefore,

every parent should be more than willing to pay to have his child protected.[5] If this does not happen, the fault lies with some combination of poverty and ignorance. It is true that public expenditure to eradicate the disease takes resources away from competing private uses. But requiring that such expenditure "pay its way" amounts to supposing that the alternative private expenditures would be equally justified—which seems questionable in a world where private demand has not yet caused all susceptible children to be immunized. And if the rationality of private spending is to be doubted, then it is not clear why public spending must produce positive discounted net benefits.

But the most important reason why the eradication of polio may not appear to be economically justified (as in Region A) does not arise from distinctions between the present and the future or between public and private expenditure. It arises from the different way that curative treatment and preventive activities are judged. The "justification" for immunization is that it costs less than treating polio victims. If the aim is to minimize the expenditure required to avoid paralysis or death from polio, then eradicating the disease is clearly preferable to continued curative treatment. But if the aim is to reduce public expenditure on health, then immunization appears to be justified only if curative spending is high enough.

In general, the foregoing account assumes that some level of treatment will be provided, with or without economic justification, and then applies an economic test to see whether prevention should replace treatment as the way to deal with polio. Why should this be considered the right test of an eradication campaign's merit? After all, treating polio victims does not save money for the government; and if the aim were simply to reduce expenditure, then curative care could not be justified either. But if "it is unacceptable, given the technology presently available, that any child in this hemisphere should suffer paralytic poliomyelitis" (*5*, p. ii), then the eradication of polio is not only ethically justified but also economically sound.

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[5] Once coverage by vaccination is almost complete a parent might consider that his unvaccinated child was adequately protected by the screen of vaccinated children, so that there would be no further gain from the child's immunization. This argument would apply, if ever, only when coverage was complete enough so that the risk of infection was essentially zero; it would not hold at the typically quite incomplete levels of coverage found in Latin America. Even at higher levels of coverage, this argument would make sense only if the cost of having the child vaccinated were high compared to the benefit, or the risk of paralysis from the vaccine itself were substantial.

SUMMARY

For several years PAHO has been seeking financial contributions from various donor agencies to support the hemispheric polio eradication campaign. To satisfy some of these agencies' requirements, a cost-benefit analysis of polio eradication was prepared. This article describes the assumptions and findings of that analysis.

Starting from the beginning, the analysis estimated the numbers of polio cases occurring before widespread immunization began under the PAHO/WHO Expanded Program on Immunization (EPI) in 1977, together with the costs of treating cases and achieving eradication. It then sought to estimate the case incidence prevailing at the start of the eradication campaign, after considerable progress had been made through the EPI, together with the lesser case-treatment and immunization costs involved. In both instances, it was found that polio eradication appeared economically justified solely in terms of reduced treatment costs, irrespective of reduced pain, suffering, and incapacitation. Moreover, the analysis found that eradication would still be economically justified if treatment costs were considerably lower, if substantially fewer cases occurred, or if somewhat fewer victims were treated.

One problem with all this is that the economic desirability of eradication comes to be viewed through the lens of reduced treatment costs; and so, if relatively few victims are being treated, the need for eradication appears less urgent. Obviously, this involves considerable distortion (among other things, if the aim were simply to reduce expenditures, then curative care would not be justified either). It is only after other important factors are given their due that this distortion is corrected and polio eradication appears justified in ethical as well as economic terms.

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