Articles

Cost-effectiveness of HIV/AIDS interventions in Africa: a systematic review of the evidence

Andrew Creese, Katherine Floyd, Anita Alban, Lorna Guinness

Summary

Background Evidence for cost-effectiveness of interventions for HIV/AIDS in Africa is fragmentary. Cost-effectiveness is, however, highly relevant. African governments face difficult choices in striking the right balance between prevention, treatment, and care, all of which are necessary to deal comprehensively with the epidemic. Reductions in drug prices have raised the priority of treatment, though treatment access is restricted. We assessed the existing cost-effectiveness data and its implications for value-for-money strategies to combat HIV/AIDS in Africa.

Methods We undertook a systematic review using databases and consultations with experts. We identified over 60 reports that measured both the cost and effectiveness of HIV/AIDS interventions in Africa. 24 studies met our inclusion criteria and were used to calculate standardised estimates of the cost (US$ for year 2000) per HIV infection prevented and per disability-adjusted life-year (DALY) gained for 31 interventions.

Findings Cost-effectiveness varied greatly between interventions. A case of HIV/AIDS can be prevented for $11, and a DALY gained for $1, by selective blood safety measures, and by targeted condom distribution with treatment of sexually transmitted diseases. Single-dose nevirapine and short-course zidovudine for prevention of mother-to-child transmission, voluntary counselling and testing, and tuberculosis treatment, cost under $75 per DALY gained. Other interventions, such as formula feeding for infants, home care programmes, and antiretroviral therapy for adults, cost several thousand dollars per infection prevented, or several hundreds of dollars per DALY gained.

Interpretation A strong economic case exists for prioritisation of preventive interventions and tuberculosis treatment. Where potentially exclusive alternatives exist, cost-effectiveness analysis points to an intervention that offers the best value for money. Cost-effectiveness analysis is an essential component of informed debate about priority setting for HIV/AIDS.

Lancet 2002; **359:** 1635–42

Essential Drugs and Medicines Policy Department (A Creese BPhil), **and Stop Tuberculosis Department** (K Floyd PhD), **WHO, Geneva, Switzerland; University of Copenhagen, Denmark** (A Alban MSc); **and London School of Hygiene and Tropical Medicine, UK** (L Guinness MSc)

Correspondence to: Mr Andrew Creese (e-mail: creesea@who.ch)

Introduction

HIV/AIDS accounts for about 20% of all deaths and disability-adjusted life-years (DALYs) lost in Africa, which makes it the biggest single component of the continent's disease burden.[1] The epidemic has reduced life expectancy in the worst affected countries by more than 10 years, and its social and economic consequences have been devastating.[2]

Substantial new resources are becoming available for prevention, care, and support. The European Commission is committed to a major increase in spending on the diseases of poverty, including HIV/AIDS.[3] A global fund to fight AIDS, tuberculosis, and malaria became operational in January, 2002; so far pledges are in the region of US$2 billion (www.globalfundatm.org).

To ensure that any new resources have the maximum possible effect on the epidemic, cost-effectiveness should be considered in the design of strategies for prevention, care, and support. As Kahn and Marseille have pointed out,[4] the scale of the HIV/AIDS epidemic combined with scarcity of resources makes cost-effectiveness especially important in developing countries. Up to now, however, cost-effectiveness has been well documented only for industrialised countries.[5,6] For low-income and middle-income countries, we could identify only one detailed review, which addressed interventions to reduce mother-to-child transmission.[7] For Africa, investigators focused on individual HIV/AIDS-related interventions. We could not identify any published report that brought together the evidence base in a standardised way that allowed comparison among interventions.

We report a critical assessment of studies of the cost-effectiveness of HIV/AIDS interventions in Africa, and present their results in a standard form.

Methods

Review of published work

We searched Medline, Popline, and EconLit databases for 1984–2000 using the key words HIV, AIDS, and HIV/AIDS in combination with each of the terms: costs; cost-effectiveness; cost-benefit analysis; economics; and Africa. Citations and reference lists were then reviewed to identify any additional relevant studies. Abstracts from international conferences were searched but were not included because they provided insufficient detail. Unpublished data were obtained through contact with experts in HIV/AIDS. A total of 57 studies and nine reviews were identified, including several unpublished reports and presentations.

Criteria for inclusion and exclusion of identified studies

We assessed each study using a standard checklist (panel 1). We then decided in three stages about inclusion in our review. First, we included any study that met all these five criteria: (i) the report contained data for Africa; (ii) it measured both cost and effectiveness; (iii) it seemed

Panel 1: **Checklist for summary and assessment of each study**

Definition of intervention(s)
Countries of intervention
Questions addressed
Year of evaluation
Year of prices
Discount rate
What costs are included?
(total/average/marginal/incremental, capital/recurrent)
Are all important costs included or does the study focus on only one or two cost items, such as drugs?
Do standard costing methods (ingredients or step-down method) seem to have been used?
What outcome measures are used?
Are assumptions transparent?
List main assumptions
Target group, risk group or general population?
Type of study
Sensitivity analysis done?
Which assumptions are tested?
Main results

to use standard methods for estimating costs and outcomes,[8,9] (iv) it seemed to include all major cost items, and (v) it allowed a generic measure of outcome (either HIV infections prevented or DALYs gained) to be calculated. We focused on studies in which investigators had analysed costs and effects together, rather than reviewing evidence on costs and effects separately, because the two items are not independent of each other.

Second, studies that met these inclusion criteria were excluded if (a) they were about regimens that are now out of date, such as long-course zidovudine for prevention of mother-to-child transmission; (b) they had estimated the effectiveness of an intervention before clinical trial results were available, and subsequent cost-effectiveness studies had used clinical trial results in their effectiveness estimates; or (c) drug prices had altered substantially since publication. We therefore excluded three studies of interventions to reduce mother-to-child transmission (table 1).[10-12]

Third, we identified interventions not covered by studies meeting the five initial inclusion criteria, but for which some cost and effectiveness data existed. We identified two such interventions—highly active antiretroviral treatment (HAART) for HIV-positive

	Place and year of publication	Reason for exclusion	Cost per HIV infection prevented	Cost per DALY gained
Intervention				
MTCT by short course ZDV	Sub-Saharan Africa, 1996[10]	Outcomes modelled, clinical trial data subsequently became available. Drug costs subsequently fell	4527	155
MTCT by short course ZDV+ 3TC	Sub-Saharan Africa, 1998[11]	Outcomes modelled, drug costs subsequently fell	1280–5822	44–199
MTCT by ZDV and ZDV +3TC	South Africa, 1997[12]	Outcomes modelled, drug costs subsequently fell	2739–6381	94–218*

3TC=lamivudine. MTCT=mother-to-child transmission. ZDV=zidovudine. *In US$ for year 2000, the cost per DALY figure falls to $30–54 if present day prices (which are 10% of those in 1997) are considered.

Table 1: **Standardised cost-effectiveness results for studies that met initial inclusion criteria but were subsequently excluded**

	Standardised value	Method/assumptions used for standardisation	Reference
Year of prices	US$ for year 2000	All costs converted to 2000 prices with standard correction factors	34
Costing perspective	Provider costs*	Any patient costs excluded from calculations	n/a
Cost savings associated with averted treatment costs	All cost savings excluded	Value of cost savings identified from study, or directly from authors, and excluded from calculations	n/a
Cost savings associated with averted productivity losses	Productivity losses excluded	As above for cost savings associated with treatment	n/a
Discount rate for present value of future health gains	3%	Recalculation of figures wherever 3% discount rate was not used	35
Life expectancy at birth	50 years	Effects recalculated. 50 was the average life expectancy in Africa in 1998	36
Average age at HIV infection	25 years	Effects recalculated	n/a†
Average life expectancy at age 25	66 years	Effects recalculated	37
Tuberculosis mortality rate in absence of treatment for HIV-negative patients	64%	Effects calculated/recalculated with value of variable in combination with other TB-related variables and methods used in earlier study	31
HIV-1 mortality rate in absence of treatment	1	As above	38
Years of life gained per cured HIV-positive patient with tuberculosis	3	As above	39–41
Years of life gained per cured HIV-negative patient with tuberculosis	24	As above	31
Deaths averted in treated patients as a percentage of all deaths averted by treatment of a tuberculosis patient‡	18%	As above	24,31
Cure rate in tuberculosis patients who default or transfer from their district of registration during treatment	65%	As above	24,31
HIV prevalence among tuberculosis patients	30–75%	As above—values chosen to accord with range in Africa	39–41, et al
Disability weighting for AIDS	0·505	Effectiveness of 1 year of home-based care assumed to be 0·495	42
Frequency of home-based care visits, where not cited in original study	1 per month	Cost per year of care calculated as 12× cost per visit	Author assumption
Cost of antiretroviral drugs for 1 year	$350	Replaces pre-2000 prices	14

n/a=not applicable. TB=tuberculosis. *We recognise that it can be important to consider patient and household costs in a cost-effectiveness analysis. However, these were only documented in a few of the studies reviewed, so we were unable to include such costs. †Walker N, personal communication. ‡Including secondary deaths averted by prevented transmission.

Table 2: **Variables that were standardised, methods and assumptions used, and sources of evidence**

adults, and promotion of female condoms. In view of the current importance of antiretroviral treatment, we decided to include a study that used only drug costs,[13] even though drug prices have fallen since its publication, and we could only calculate a cost per life-year gained rather than a cost per DALY gained from the data presented. To provide a more recent estimate of cost-effectiveness, we used laboratory test costs for antiretroviral therapy in adults enrolled in the HIV drugs access initiatives in Uganda and Côte d'Ivoire, and the cost of drugs cited by Médecins Sans Frontières in 2001.[14] An unpublished study of promotion of female condoms was included only after written communication with its authors.

Standardisation of studies meeting inclusion criteria

Thus, we included 24 of the initial 66 studies identified (Homan RK, Visness C, Welsh M, Schwingl P, personal communication; Kumaranayake L, Mangtani P, Boupda-Kuate A, et al, personal communication; Watts C, Goodman H, Kumaranayake L, personal communication; Guinness L, personal communication).[13,15,33] Data from these studies spanned 13 years (1988–2000), and differed widely in their methods and assumptions. A few studies had primary data for both costs and outcomes, but most used epidemiological models to estimate effectiveness. In the modelling, some studies included analysis of the secondary infections prevented by an intervention, whereas others did not; and different values were used for some variables (eg, the efficiency of HIV transmission) that determine effectiveness. Several studies included an analysis of treatment-cost savings but most did not; others also included savings from averting loss of productivity in their calculations. In most studies, investigators focused on costs from a provider perspective only, but a few also looked at costs incurred by patients. Different prices were used, particularly for antiretroviral drugs, whose prices and regimens have changed substantially in the past 5 years. Discount rates, effectiveness measures, the reporting of costs and effects, assumed life expectancy at birth, and the year in which costs were assessed also varied.

To ensure the widest possible comparability among interventions, we standardised both cost and effectiveness data; therefore, the figures we report differ from the results shown in the original publications. Standardisation of cost data included the year of prices, the price of 1 year of triple combination therapy, how costs were assessed, and savings related to averted treatment costs and productivity losses. For effectiveness, we undertook no new modelling. However, we standardised the discount rate used to estimate the present value of future health gains; life expectancy at birth; average age at HIV infection; assumptions for tuberculosis treatment, including years of life gained through cure and death rates in the absence of treatment; the disability weighting associated with years of life lived with AIDS; and the frequency of home-based care visits (table 2).[14,24,31,34-42]

For all studies we calculated unit costs and effectiveness. Once both had been standardised, we calculated two measures of cost-effectiveness: (1) cost per HIV infection averted (for the preventive interventions) and (2) cost per DALY gained (for all interventions). Sensitivity analyses were excluded if they were based on variable measurements (eg, life expectancy at birth, discount rate) for which we had already standardised results, or if there was too little detail to allow recalculation of figures. Panel 2 shows a worked example of how the data in tables 3, 4, and 5 were calculated from the results of one study.

Panel 2: **Cost-effectiveness of universal nevirapine administration in sub-Saharan Africa. Standardisation of data presented by Stringer et al[32]**

The authors present data per 10 000 women (in US$ for year 1999) as $4·64 per maternal dose, $0·18 per infant dose, $0·42 cost of counselling for mass therapy, 0·69 rate of adherence, 0·058 rate of delivering outside hospital, and 0·2 probability of repeat (maternal) dose due to prodromal labour. Effectiveness was given as 160 HIV infections averted. The financial correction factor to correct 1999 US$ to 2000 US$ is 1·032.

Counselling costs in US$ for year 2000 are:
10 000×$0·42×1·032=$4334·4

Treatment costs are:
([6900×($4·64+0·18)×(1–0·058)]+[(6900×0·2×4·64)×[1–0·058)])×1·032=$38 556·4

Total cost is: $42 890·80 (table 3, column 4)
160 HIV infections averted=4672 DALYS (table 3, column 7 based on our standard 29·2 disability-adjusted life years gained, discount rate of 3% per infant case prevented). This gives cost per HIV infection prevented in US$ for year 2000 of $42 891/160=$268 and cost per DALY gained of $42 891/4672=9·20, rounded to $9 (table 5).

Results

For information about the costs included in each study and the principal assumptions used in measuring effectiveness see webtable 1 (http://image.thelancet.com/extras/01art9117webtable1.pdf) and webtable 2 (http://image.thelancet.com/extras/01art9117webtable2.pdf). Tables 3 and 4 show the HIV prevalence rates that applied to the study populations, and unit costs and unit effectiveness for prevention (table 3) and treatment and care (table 4).

Cost per HIV infection prevented

There was a wide range in the cost per HIV infection prevented (table 5). Costs for condom distribution ranged from as little as $11 to over $2000. Measures to improve blood safety cost between just under $20 and about $1000 to prevent one case of HIV. There was especially large variation in the different strategies to reduce mother-to-child transmission. Breastfeeding and formula-feeding interventions cost from around $4000 to over $20 000 per infection prevented, whereas single-dose nevirapine cost much less—about $20–341. Diagnosis and treatment of sexually transmitted infections cost just over $270 per infection prevented, and the figure for voluntary counselling and testing (VCT) was higher, at around $400–500.

Cost per DALY gained

The cost per DALY gained by interventions ranged from around $1 for a combined treatment of sexually-transmitted disease (STD) and condom promotion programme and for blood screening, to well over $1000 for HAART in adults. Blood safety measures, and single-dose nevirapine for prevention of mother-to-child transmission, cost as little as $10 per DALY gained. Tuberculosis treatment could also be less than $10 per DALY gained, but as high as $68 when inpatient care was involved. VCT and co-trimoxazole prophylaxis for HIV-positive patients with tuberculosis cost around or below $20. Home-based care varied from around $100 to $1000, with community based care programmes having a lower cost per DALY than programmes organised from health facilities.

	Place and year of publication	HIV prevalence	Unit cost, year 2000 prices (US$)	Unit	Effectiveness, HIV infections averted per unit	Effectiveness, DALYs gained per unit*
1. Condom distribution						
Condom distribution plus STD treatment for prostitutes	Sub-Saharan Africa, 1991[22]	Prostitutes: 80% Clients: 90%	217·76 0·18	Per prostitute reached Per contact	12·8–19·25	283·5–425·2
Female condoms targeted to:						
prostitutes	Kenya, 1999†	F: 55% M: 14%	237·38		0·86	19·10
high-risk women	Kenya, 1999†	F: 28% M: 14%	5·33	Per woman	0·005	0·11
medium-risk women	Kenya, 1999†	F: 15% M: 14%	5·47		0·002	0·06
2. Blood safety						
Strengthening blood transfusion services through:						
Rapid test	Zimbabwe, 1995[21]	19%	11·5	Unit of blood transfused	0·187	4·14
Test and defer high-risk donors	Zimbabwe, 1995[21]		9·1–14·3		0·189–0·193	4·13–4·27
Defer high-risk donors	Zimbabwe, 1995[21]		0·42–8·6		0·023–0·081	0·52–1·78
Hospital-based screening	Zambia, 1995[18]	16%	15·0	Usable unit of blood	0·140	3·1
Hospital-based screening	Tanzania, 1999[43]	12%	1·3	Usable unit of blood	0·071	1·6
Improved blood collection and transfusion safety, excluding screening	Tanzania, 1999[43]	12%	14·7	Usable unit of blood	0·015	0·3
Improved transfusion safety with outreach	Zimbabwe, 2000‡	Donors: 7% Recipients: Adults: 25–50% Children: 5–9%	33·31	Usable unit of blood	0·13–0·16	2·9–3·5
3. Peer education for prostitutes	Cameroon, 1998§	21%	60·84	Per prostitute covered per year	0·38–0·77	8·32–17·01
4. Prevention of mother-to-child transmission						
Single-dose nevirapine (universal coverage)	Uganda, 1999[20]	5–30%	85 999	Per 20 000 women treated	603	17 607
Single-dose nevirapine (targeted coverage)			146 463		476	13 899
Single-dose nevirapine (universal coverage)	Sub-Saharan Africa, 2000[32]	5–30%	42 891	Per 10 000 pregnant women	160	4672
Single-dose nevirapine (targeted coverage)			1750–48 455		89–142	467–4146
Zidovudine/CDC Thai regimen	South Africa, 2000[27]	6–27%	187–330	Per HIV–positive pregnant woman treated	0·15–0·20	4·4–5·8
Zidovudine/CDC Thai regimen	South Africa, 1999[25]		377 095		160	4672
Petra regimen	South Africa, 1999[25]		33 279	Per 20 000 women	124	3621
Formula recommendation	South Africa, 1999[25]		99 684		26	759
Formula provision	South Africa, 1999[25]	0·1–40%	125 138		25	730
Breast feeding 3 months	South Africa, 1999[25]		106 777		5	146
Breast feeding 6 months	South Africa, 1999[25]		235 130		37	1080
5. Diagnosis and treatment of STDs	Tanzania, 1997[19]	4%	12·66	Per client	0·047	1·03
6. Voluntary counselling and testing¶	Kenya, 2000[26]	20%	28·76	Per client per year	0·073	1·6
	Tanzania, 2000[26]	20%	30·89	Per client per year	0·068	1·5

F=female. M=male. STD=sexually transmitted disease. *Rounding errors mean that DALYs gained per infection averted (column 7 divided by column 6) do not always appear consistent; †Homan RK, Visness C, Welsh M, Schwingl P, personal communication; ‡Watts C, Goodman H, Kumaranayake L, personal communication; §Kumaranayake L, Mangtani P, Boupda-Kuate A, et al, personal communication; ¶voluntary counselling and testing is considered in the literature as an intervention related to both prevention and care. However we have classified it as a prevention activity in accordance with the study.

Table 3: **Unit costs and estimated effects for intervention groups (numbered) and individual interventions aimed at prevention**

Discussion

Our results show that there are few studies of the cost-effectiveness of HIV/AIDS prevention, treatment, and care interventions in Africa, and there is considerable variability in the cost-effectiveness of such interventions. The most cost-effective interventions are for prevention of HIV/AIDS and treatment of tuberculosis, whereas HAART for adults, and home based care organised from health facilities, are the least cost effective. For some interventions, such as prevention of mother-to-child transmission, tuberculosis treatment, and home based care, there are particular strategies that provide the best value for money (best buy).

This review has several limitations. For five interventions, only one study was identified, and the maximum number of studies—for mother-to-child transmission—was four. In no one country were all interventions assessed, which made unbiased comparison of interventions difficult. Cost data were not always comprehensive, and were sometimes too few for standardised sensitivity analysis. The cost of HAART was underestimated, because data for only a very restricted subset of costs were considered. There were no data for the costs of use and strengthening of general health services necessary for provision of HAART. The effect of some interventions on HIV prevention might have been underestimated because some potential effects that are difficult to measure—such as reduced stigma arising from increased knowledge of status—were not accounted for. None of the studies on interventions to reduce vertical transmission looked at the effect of VCT on horizontal transmission. The effectiveness of HAART might have been underestimated because we had insufficient data to measure its effect on transmission through lowering viral loads. It could also have been overestimated. First, its use might increase transmission since risky behaviour by HIV-positive people with improved life expectancy could be encouraged. Second, side-effects mean that the value of 1 year of life is likely to be less than the 1 DALY assumed here. Some studies are based on project implementation at only a few sites (for example the study of VCT), or on theoretical analyses of interventions (eg, some studies of

	Place and year of publication (reference)	HIV prevalence (%)	Unit cost, 2000 prices (US$)	Unit	Effectiveness, DALYs gained per unit
1. Short-course treatment for new sputum-smear positive tuberculosis patients					
Ambulatory care	Malawi, Mozambique, Tanzania, 1991[24,31]	HIV prevalence among tuberculosis patients not quoted in original studies. Assumed to vary from 30–75% in standardised analysis	101–129	Per patient treated (applies to all studies)	37–61
	Uganda, 1995[29]		113		32–47
	South Africa, 1997[17]		485		31–60
IUATLD model (involves 2 months' stay at hospital at treatment outset followed by monthly visits to a health clinic to collect drugs during the remainder of treatment)	Malawi, Mozambique, Tanzania, 1991[24,31]		226–306		37–61
	Uganda, 1995[29]		134		32–47
	South Africa, 1997[17]		2078		31–60
Community-based directly observed treatment	South Africa, 1997[17]		760		36–55
2. Co-trimoxazole prophylaxis for HIV-positive tuberculosis patients	Hypothetical low income country*	Not relevant to analysis	14·76	Person year of treatment	2·5
3. Home-based care for people with AIDS					
Community-based programme	Zambia, 1994[16]	Not relevant to analyses	49	Person year of care	0·495
	Tanzania, 2000[23]		38		
Health-facility-based programme	Zambia, 1994[16]		337		
	Tanzania, 2000[23]		389		
	Zimbabwe, 1998[30]		232 (urban) 609 (rural)		
4. Preventive therapy for tuberculosis					
Isoniazid, 6 months	Uganda, 1999[15]	Not stated	25	Person treated	0·15
Isoniazid plus rifampicin, 3 months	Uganda, 1999[15]		40		0·14
Rifampicin plus pyrazinamide, 2 months	Uganda, 1999[15]		48		0·17
5. Antiretroviral therapy for adults	Senegal and Côte d'Ivoire, 2000	11% Cote d'Ivoire	1100	Person year of treatment	1
	South Africa, 2000[13]	12–16% South Africa	350	Person year of treatment, 25% of HIV-positive adults	5–7 life years gained

IUATLD=International Union Against Tuberculosis and Lung Disease. *Guinness L, personal communication.

Table 4: **Unit costs and estimated effects for intervention groups (numbered) and individual interventions, aimed at treatment and care**

mother-to-child transmission). Thus, costs and effects in practice and on a large scale might be different from those shown. Finally, some interventions may complement each other in ways that are missed in analyses of individual interventions.

These limitations mean that both generalisability and interpretation should be viewed with caution. Ideally, we would have data for every intervention from several studies in similar settings—both income levels and prevalence rates can distort comparisons within and between countries. Salaries are linked to average national income and can thus affect costs. HIV prevalence does not affect the cost-effectiveness of every intervention but, where costs are incurred in diagnosis of a case of HIV (such as with VCT), the lower the prevalence, the higher the cost per HIV-positive case detected. For example, all studies of prevention of mother-to-child transmission show a relation between prevalence rates and cost-effectiveness.

Our review includes data from low-income countries in each intervention group, typically with high HIV prevalence. For mother-to-child transmission and tuberculosis treatment, we included data from both low-income and middle-income countries with a wide range in HIV prevalence, and the rankings of the types of intervention were consistent. For some other interventions, such as tuberculosis prevention, costs are likely to be higher in wealthier countries with lower rates of HIV infection. Two possible exceptions are blood safety and VCT. For blood safety, the major costs are probably supplies and equipment, which are likely to be similar across countries. For VCT, the estimated cost was similar to other estimates that have been made for Africa.[43] A drawback to the VCT data is that the study used an index for HIV transmission efficiency that was ten times that typically used by the UN programme on HIV/AIDS. Together with very high rates of reported behaviour change, we might have overstated the effectiveness of this intervention elsewhere.

The evidence base could be improved by more cost-effectiveness studies that included all economic costs and used standard methods. Guidelines for cost-effectiveness analysis, including those for HIV/AIDS prevention, should be more widely and rigorously used. Ideally, analyses for several interventions in a single setting should be undertaken. In view of the powerful advocacy for access to antiretroviral therapy for HIV-infected adults, and the poor evidence currently available, work on the cost and effectiveness of such treatment in African settings is a priority. But in five other intervention areas—peer education for prostitutes, diagnosis and treatment of STDs, VCT, prevention therapy for tuberculosis, and co-trimoxazole prophylaxis for HIV-positive patients with tuberculosis—we depend on the results of only one study. Moreover, apart from tuberculosis, there are no data for treatment of opportunistic infections. New analysis could initially focus on interventions for which we have effectiveness data, but for which costs are not documented, and vice versa.

How can the existing data be used to inform policy? Cost-effectiveness rankings do not, on their own, indicate which health interventions are priorities for public funding. A recent framework based on seven questions[1,44] has proposed that an intervention should be publicly funded if it is cost effective and it is (1) a public good; or (2) associated with important externalities and demand is inadequate; or (3) represents a catastrophic cost and insurance is not available; or (4) beneficiaries are poor.

Intervention groups (numbered) and individual interventions	Place and year of publication	Cost per HIV infection prevented	Cost per DALY gained§§§
Prevention			
1. Condom distribution			
Condom distribution plus STD treatment for prostitutes*	Sub-Saharan Africa, 1991[22]	11–17	1
Female condoms targeted to:			
Prostitutes	Kenya, 1999||||	275	12
High-risk women	Kenya, 1999||||	1066	48
Medium-risk women	Kenya, 1999||||	2188	99
2. Blood safety			
Hospital based screening	Tanzania, 1999[29]	18	1
	Zambia, 1995[18]	107	5
Strengthening blood transfusion services through:			
Defer high risk donors	Zimbabwe, 1995[21]	18–107	1–5
Test and defer high risk donors†	Zimbabwe, 1995[21]	48–74	2–3
Rapid test	Zimbabwe, 1995[21]	62	3
Improved transfusion safety with outreach‡	Zimbabwe, 2000***	208–256	10–12
Improved blood collection and transfusion	Tanzania, 1999[33]	950	43
3. Peer education for prostitutes§	Cameroon, 1998†††	79–160	4–7
4. Prevention of mother-to-child transmission			
Single dose nevirapine-targeted	Sub-Saharan Africa, 2000[32]	20–341	1–12
	Uganda, 1999[20]	308	10
Single-dose nevirapine-universal¶	Uganda, 1999[20]	143	5
	Sub-Saharan Africa[32]	268	9
Petra regimen||	South Africa, 1999[25]	268	9
ZDV CDC Thai regimen**	South Africa, 2000[27]	949–2198	33–75
	South Africa, 1999[25]	2356	81
Formula recommendation||	South Africa, 1999[25]	3834	131
Breastfeeding 3 months||	South Africa, 1999[25]	5006	171
Formula provision||	South Africa, 1999[25]	6355	218
Breasfeeding 6 months||	South Africa, 1999[25]	21 355	731
5. Diagnosis and treatment of STIs||	Tanzania, 1997[19]	271	12
6. Voluntary counselling and testing††	Kenya and Tanzania, 2000[26]	393–482	18–22
Treatment and care			
7. Short-course tuberculosis treatment for new sputum-smear positive pulmonary patients‡‡			
Ambulatory care	Malawi, Mozambique, Tanzania, 1991[24,31]	n/a	2–3
	Uganda, 1995[29]	n/a	2–4
	South Africa, 1997[17]	n/a	8–16
IUATLD model (involves 2 months hospitalisation	Uganda, 1995[29]	n/a	3–4
at treatment outset followed by monthly visits	Malawi, Mozambique, Tanzania, 1991[24,31]	n/a	4–8
to a health clinic to collect drugs)	South Africa, 1997[17]	n/a	34–68
Community-based DOT	South Africa, 1997[17]	n/a	14–21
8. Co-trimoxazole prophylaxis for HIV+ tuberculosis patients§§	Hypothetical low income country, sub-Saharan Africa‡‡‡	n/a	6
9. Home-based care			
Community-based programme	Tanzania, 2000[23]	n/a	77
	Zambia, 1994[16]	n/a	99
Health facility based programme¶¶	Zambia, 1994[16]	n/a	681
	Tanzania, 2000[23]	n/a	786
	Zimbabwe, 1998[30]	n/a	469–1230
10. Preventive therapy for tuberculosis||			
Isoniazid for 6 months	Uganda, 1999[15]	n/a	169
Rifampicin plus pyrazinamide, 2 months	Uganda, 1999[15]	n/a	282
Isoniazid plus rifampicin, 3 months	Uganda, 1999[15]	n/a	288
11. Antiretroviral therapy for adults	Senegal and Côte D'Ivoire, 2000	n/a	1100
	South Africa, 2000[13]	n/a	1800¶¶¶

DALY=disability-adjusted life year. DOT=directly observed treatment. n/a=not applicable. IUATLD=International Union Against Tuberculosis and Lung Disease. STD-sexually-transmitted disease. ZDV=zidovudine. Ranges reflect: *Sensitivity analysis for variation in condom use, HIV transmission and efficacy; †Sensitivity analysis undertaken within the study to explore implications of the changes in HIV prevalence, STD incidence, and prevalence of STD history; ‡Sensitivity analysis done to explore the effect of adding outreach services to identify donors and varying HIV prevalence in the donor and recipient populations; §Sensitivity analysis undertaken within the study to explore the effect of changes in coverage, HIV prevalence, condom use, and transmission probabilities; ¶Ranges show results of analysis undertaken to explore all plausible scenarios of costs and effects including targeted versus universal coverage; ||Sensitivity analyses were carried out for Uganda,[15] South Africa, 1999,[25] and Tanzania, 1997.[19] However, in the first two studies, it was not possible to recalculate the cost-effectiveness ratios with the information provided; in the third, the variables tested were those used in our recalculation of the cost-effectiveness ratios, eg, discount rate and life expectancies. For these reasons, ranges are not presented. **Analysis was undertaken for each province and cost-effectiveness varied among provinces, principally due to variation in HIV prevalence (which affects the costs per pregnant women identified to be eligible for the intervention). The differences in the cost-effectiveness ratios for universal and targeted coverage were also explored; ††Study undertaken in two countries; ‡‡Range in possible HIV prevalence among tuberculosis patients (table 2), range in plausible cure rates, and that some studies were done in more than one setting; §§Plausible variation in mortality, morbidity, drug resistance, wastage, and cost; ¶¶Variation in cost-effectiveness between rural and urban areas; ||||Homan RK, Visness C, Welsh M, Schwingl P, personal communication; ***Watts C, Goodman H, Kumaranayake L, personal communication; †††Kumaranayake L, Mangtani P, Boupda-Kuate A, et al, personal communication; ‡‡‡Guinness L, personal communication; §§§Rounding errors mean that cost-effectiveness ratios may differ slightly from unit cost divided by unit effectiveness; ¶¶¶Cost per life year gained, not DALY, used. Reported value of $15 000 (based on annual drugs cost of $2900) recalculated using drugs costs in reference 14.

Table 5: **HIV/AIDS intervention groups, individual interventions, and standardised cost-effectiveness results, US$ for year 2000**

	Public good?	Important externalities	Adequate demand?	Catastrophic cost?	Voluntary insurance available for catastrophic cost?	Benefit group poor?	Costeffective? (US$ cost per DALY)
Condom distribution	No	Yes	No	No	N/a	Yes	1–99
Blood safety	No	Yes	Yes	No	N/a	Yes	1–43
Peer education for prostitutes	No	Yes	No	No	N/a	Yes	4–7
MTCT	No	No	?	No	N/a	Yes	1–731
STDs	No	Yes	No	No	N/a	Yes	12
VCT	No	Yes?	No	No	N/a	Yes	18–22
TB short course	No	Yes	Yes	Yes	N/a	Yes	2–68
Co-trimoxazole prophylaxis	No	No	?	No	N/a	Yes	6
Home care	No	No	?	Yes	No	Yes	77–1230
TB preventive therapy	No	Yes	No	?	No	Yes	169–288
ARV therapy	No	?	Yes	Yes	No	Yes	1100–1800

Reading from left to right, answers to the seven questions included in the framework[14,15] are suggested, in the order in which they should be asked. ARV=antiretroviral therapy. MTCT=mother-to-child transmission. TB=tuberculosis. VCT=voluntary counselling and testing. N/a=not applicable.

Table 6: **Economic factors affecting priority of health interventions for public funding**

Table 6 shows how this economic framework supplements the cost-effectiveness data we have collated. The use of a more comprehensive framework makes little difference. No intervention is ruled out with the first six questions, and the determining factor for public finance is cost-effectiveness.

Despite the limitations of our review and difficulties with generalisation, cost-effectiveness can be used for some broad prioritisation among interventions. The World Development Report of 1993[15] suggested that any intervention achieving a DALY gain for $50 or less ($62 in year 2000 prices) was highly cost effective in the context of the poorest countries. The general inference was that these interventions should be made available to all those in need before less cost-effective options are provided to a few. On this basis, several preventive interventions (targeted condom distribution, blood screening, nevirapine for the prevention of mother-to-child transmission and STD treatment), and two treatment interventions (co-trimoxazole prophylaxis for patients with HIV and tuberculosis) and tuberculosis treatment should have first call on new funds for HIV/AIDS in Africa. Within intervention categories first priority should be given to the intervention that is a clear best buy—for example, short-course nevirapine treatment for mothers and babies, and targeted condom distribution.

In practice, cost-effectiveness will need to be balanced with several other considerations. Affordability is one important issue; in the context of health budgets, a cost-effective intervention is not necessarily affordable when it is relevant to many people, and public funding will result in high demand. In Africa, this concern is most likely to apply to interventions to prevent mother-to-child transmission. Even with only restricted provision of antiretroviral treatment to HIV-positive adults, it could also become relevant for VCT services. Antiretroviral treatment for HIV-positive adults may not be as cost-effective as some other interventions, but the overwhelming pressure being placed on governments to provide such care is impossible to ignore. Recent estimates are that 20%, 40%, and 50% of health resources are already being consumed by HIV infected persons in Malawi, Zambia, and Zimbabwe, respectively.[16,18]

In addition, HIV-infected people and the non-governmental organisations assisting them represent an increasingly important political force. Therefore, provision of care and support is more politically attractive, at least in the short term. Furthermore, care and support are essential parts of an enabling environment (in which people are empowered to address their difficulties) that is required to reduce discrimination and stigmatisation. By contrast, people at risk of becoming infected, the young in particular, are a more disparate and less easily organised group, with no clear cut or well articulated interests, and weak advocates. Prioritisation of care can be reinforced by difficulties in implementing or expanding the more cost-effective preventive interventions. Effective prevention strategies for the most vulnerable populations are still not scaled up to levels that could have a major impact on the HIV epidemic, even where funds are available.

The kind of cost-effectiveness evidence presented here can, however, help to inform policy decisions on resource allocation between prevention and care. For example, the results and estimates of the reachable population (ie, the population size that is feasible to cover with each intervention) have been used to explore the consequences of alternative ways to use an additional $400 million per year. At a WHO workshop (HSI/WHO/HQ, WHO/ AFRO, UNAIDS. Costing and prioritisation of WHO's contribution to the International Partnership Against AIDS in Africa. Geneva, Sept 4–5, 2000), participants estimated that with this increase in funding, about 750 000 more people with HIV/AIDS in Africa could be treated every year, and almost one million infections prevented (17·9 million DALYs gained). A 10% spending reallocation from treatment towards more prevention (defined as management of STDs, blood safety, VCT, prevention of mother-to-child transmission, and preventive programmes among prostitutes) would increase the total DALYs gained by over 15%.

Allocation of new funds for HIV/AIDS requires more than rankings of cost-effectiveness. Nevertheless, value for money is important, especially in African countries, where resources are particularly scarce and needs are so great. Existing cost-effectiveness data are few, and much more high quality research is needed for detailed planning and programming. Yet even the available data make it clear that a spending programme for HIV/AIDS relief in Africa that neglects to bring cost-effectiveness evidence into the consultation process risks unnecessary sacrifice of hundreds of thousands of prevention opportunities, treatment opportunities, and lives.

Contributors
The four authors contributed jointly to the conception, analysis, and writing of the study, and to data collection. No specific funding was sought or provided for this work, which was done as part of the professional responsibilities of the four authors.

Conflict of interest statement
None declared.

Acknowledgments
Richard Laing (Boston University), David Evans, Hans Hogerzeil, Jonathan Quick, and staff in the HIV/AIDS department (WHO), and Olusoji Adeyi, and Robert Hecht (UNAIDS) all made helpful comments

and suggestions on drafts of this paper, as did Jeffrey Stringer and two anonymous reviewers. They are not responsible for any errors of fact or judgment. The views expressed in this paper are those of the authors and not necessarily those of the institutions with which they are affiliated.

References

1 WHO. World Health Report 2000: Health systems: Improving performance. Geneva: WHO, 2000.

2 Guinness L, Alban A. The Economic Impact of AIDS in Africa: a review of the literature. UNAIDS background paper for ADF 2000. AIDS: the greatest leadership challenge, Addis Ababa, December, 2000. www.unaids.org.

3 UNAIDS. European Commission, World Health Organization and Joint United Nations Programme on HIV/AIDS take a united stand against killer diseases. www.unaids.org/whatsnew/press/eng/pressarc00/geneva280900.html (accessed Feb 12, 2002).

4 Kahn JG, Marseille E. Fighting global AIDS: the value of cost-effectiveness analysis. *AIDS* 2000; **14:** 2609–10.

5 Schrappe M, Lauterbach K. Systematic review on the cost-effectiveness of public health interventions for HIV prevention in industrialised countries. *AIDS* 1998; **12:** S231–38.

6 Pinkerton SD, Johnson-Masotti AP, Holtgrave DR, Farnham PG. Using cost-effectiveness league tables to compare interventions to prevent sexual transmission of HIV. *AIDS* 2001; **15:** 917–28.

7 Newell M-L, Dabis F, Tolley K, Whynes D. Cost-effectiveness and cost-benefit in the prevention of mother-to-child transmission of HIV in developing countries. *AIDS* 1998; **12:** 1571–80.

8 Drummond MF, O'Brien B, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes, 2nd edn. New York: Oxford University Press, 1997.

9 Gold MR, Siegel JE, Russell LB, Weinstein MC, eds. Cost-effectiveness in health and medicine. New York: Oxford University Press, 1996.

10 Mansergh G, Haddix A, Steketee RW, et al. Cost-effectiveness of short course zidovudine to prevent perinatal HIV type 1 infection in a sub-Saharan African developing country setting. *JAMA* 1996; **276:** 139–45.

11 Marseille E, Kahn JG, Saba J. Cost-effectiveness of antiviral drug therapy to reduce mother-to-child HIV transmission in sub-Saharan Africa. *AIDS* 1998; **12:** 939–48.

12 Wilkinson D, Floyd K, Gilks C. Antiretroviral drugs as a public health intervention for pregnant HIV-infected women in rural South Africa: an issue of cost-effectiveness and capacity. *AIDS* 1998; **12:** 1675–82.

13 Wood E, Braitstein P, Montaner JSG, et al. Extent to which low-level use of antiretroviral treatment could curb the AIDS epidemic in sub-Saharan Africa. *Lancet* 2000; **355:** 2095–100.

14 Médecins Sans Frontières. AIDS triple therapy for less than $1 per day. www.msf.org/content/page.cfm?articleid=994F25C0-B3F7-415D-943186A5D0F6E1BA (accessed Feb 12, 2002)

15 Bell JC, Rose DN, Sacks HS. Cost effectiveness of tuberculosis preventive therapy for HIV-infected people in sub-Saharan Africa. *AIDS* 1999; **13:** 1549–56.

16 Chela CM, Msiska R, Sichone M, Mwinga B. Cost and impact of home-based care for people living with HIV/AIDS in Zambia. 1994. Global Programme on AIDS/WHO. Geneva: WHO, 1994.

17 Floyd K, Wilkinson D, Gilks CF. Costs and cost-effectiveness of community-based DOTS *vs* conventional treatment in Africa. *BMJ* 1997; **315:** 1407–11.

18 Foster S, Buve A. Benefits of HIV screening of blood transfusions in Zambia. *Lancet* 1995; **346:** 225–27.

19 Gilson L, Mkanje R, Grosskurth H, et al. Cost-effectiveness of improved treatment services for sexually transmitted diseases in preventing HIV-1 infection in Mwanza Region, Tanzania. *Lancet* 1997; **350:** 1805–09.

20 Marseille E, Kahn JG, Mmiro F, et al. Cost effectiveness of single dose nevirapine regimen for mothers and babies to decrease vertical transmission in sub-Saharan Africa. *Lancet* 1999; **354:** 803–09.

21 McFarland W, Kahn JG, Katzenstein DA, Mvere D, Shamu R. Deferral of blood donors with risk factors for HIV infection saves lives and money in Zimbabwe. *J Acquir Immune Defic Syndr Hum Retrovirol* 1995; **9:** 183–92.

22 Moses S, Plummer FA, Ngugi EN, Nagelkerke NJD, Anzala AO, Ndinya-Achola JO. Controlling HIV in Africa: effectiveness and cost of an intervention in a high-frequency STD transmitter core group. *AIDS* 1991; **5:** 407–11.

23 Msobi N, Msumi Z. HIV/AIDS and other chronic conditions: home based care cost study, Bagamoyo District - Tanzania. www.iaen.org/conferences/durbansym/papers/42Msobi.pdf (accessed Feb 12, 2002).

24 Murray C, DeJonghe E, Chum HJ, Nyangulu DS, Salomao A, Styblo K. Cost effectiveness of chemotherapy for pulmonary tuberculosis in three sub-Saharan African countries. *Lancet* 1991; **338:** 1305–08.

25 Soderlund N, Zwi A, Kinghorn A, Gray G. Prevention of vertical transmission of HIV: analysis of cost effectiveness of options available in South Africa. *BMJ* 1999; **318:** 1650–56.

26 Sweat M, Gregorich S, Sangiwa G, et al. Cost-effectiveness of voluntary HIV-1 counselling and testing in reducing sexual transmission of HIV-1 in Kenya and Tanzania. *Lancet* 2000; **356:** 113–21.

27 Wilkinson D, Floyd K, Gilks CF. National and provincial estimated costs and cost-effectiveness of a programme to reduce mother-to-child transmission in South Africa. *S Afr Med J* 2000; **90:** 794–98.

28 Winsbury R. Safe blood in developing countries. Brussels: European Commission, 1995.

29 Saunderson P. An economic evaluation of alternative programme designs for tuberculosis control in rural Uganda. *Soc Sci Med* 1995; **40:** 1203–12.

30 Hanson K, Woelk G, Jackson H, et al. The cost of home-based care for HIV/AIDS patients in Zimbabwe. *AIDS Care* 1998; **10:** 751–59.

31 De Jonghe E, Murray CJL, Chum HJ, Nyangulu DS, Salomao A, Styblo K. Cost-effectiveness of chemotherapy for sputum smear-positive pulmonary tuberculosis in Malawi, Mozambique and Tanzania. *Int J Health Plann Manage* 1994; **9:** 151–81.

32 Stringer JSA, Rouse D, Vermund SH, Goldenberg RL, Sinkala S, Stinnett A. Cost-effective use of nevirapine to prevent vertical HIV transmission in Sub-Saharan Africa. *J Acquir Immune Defic Syndr* 2000; **24:** 369–77.

33 Jacobs B, Mercer A. Feasibility of hospital-based blood banking: a Tanzanian case study. *Health Policy Plan* 1999; **14:** 354–62.

34 Kumaranayake L. The real and the nominal? Making inflationary adjustments to cost and other economic data. *Health Policy Plan* 2000; **15:** 230–34.

35 Russell LB, Gold MR, Siegel JE, Daniels N, Weinstein MC. The role of cost-effectiveness analysis in health and medicine. *JAMA* 1996; **276:** 1172–79.

36 WHO. World health report 1999: Making a difference. Geneva: WHO, 1999.

37 The AIDS Epidemic and its Demographic Consequences. Proceedings of the United Nations/World Health Organization Workshop on Modelling the Demographic Impact of the AIDS Epidemic in Pattern II Countries: Progress to Date and Policies for the Future. New York: United Nations Population Division, 1989.

38 Dye C, Garnett GP, Sleeman K, Williams BG. Prospects for worldwide tuberculosis control under the WHO DOTS strategy. *Lancet* 1998; **352:** 1886–91.

39 Glynn J, Warndorff DK, Fine PEM. Measurement and determinants of tuberculosis outcome in Karonga District, Malawi. *Bull World Health Organ* 1998; **76:** 295–305.

40 Elliot AM, Halwindi B, Hayes RJ et al. The impact of human immunodeficiency virus on mortality of patients treated for tuberculosis in a cohort study in Zambia. *Trans R Soc Trop Med Hyg* 1995; **89:** 78–82.

41 Harries AD, Nyangulu DS, Kang'ombe C et al. Treatment outcome of an unselected cohort of tuberculosis patients in relation to human immunodeficiency virus serostatus in Zomba hospital, Malawi. *Trans R Soc Trop Med Hyg* 1998; **92:** 343–47.

42 Murray CJL, Lopez A, eds. The global burden of disease: a comprehensive assessment of mortality and morbidity from diseases, injuries and risk factors in 1990 and projected to 2020. Harvard School of Public Health, on behalf of WHO and the World Bank, Boston: Harvard University Press, 1996.

43 Kumaranayake L, Watts C. Economic costs of HIV/AIDS prevention activities in sub-Saharan Africa. AIDS 2000; **14** (suppl)**:** S239–52.

44 Musgrove P. Public spending on health care: how are different criteria related? *Health Policy* 1999; **47:** 207–23.

45 World Bank. World Development Report 1993: Investing in Health. New York: Oxford University Press, 1993.

46 World Bank. Malawi AIDS assessment study. Washington DC: World Bank, 1998.

47 Bail R, Mwikisa C, Kaambwa B, Masiye M. Costing the Zambia national HIV/AIDS strategic framework. Lusaka, Zambia: 2000.

48 HIV/AIDS in Zimbabwe: background, projections, impact, interventions. National AIDS co-ordination programme. Harare: Ministry of Health and Child Welfare, 1988.