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Cost-Effectiveness of a Community-Level HIV Risk Reduction Intervention

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ABSTRACT

Objectives. The authors evaluated the cost-effectiveness of a community-level HIV prevention intervention that used peer leaders to endorse risk reduction among gay men.

Methods. A mathematical model of HIV transmission was used to translate reported changes in sexual behavior into an estimate of the number of HIV infections averted.

Results. The intervention cost $17 150, or about $65 000 per infection averted, and was therefore cost-saving, even under very conservative modeling assumptions.

Conclusions. For this intervention, the cost of HIV prevention was more than offset by savings in averted future medical care costs. Community-level interventions to prevent HIV transmission that use existing social networks can be highly cost-effective. (*Am J Public Health.* 1998;88:1239–1242)

Introduction

Carefully conducted experimental and quasi-experimental studies have established the effectiveness of small-group and individual-level interventions that combine HIV-relevant risk reduction education with cognitive–behavioral skill-building activities to help individuals decrease their sexual risk behaviors and foster positive attitudes toward safer sex.[1–9] Unfortunately, the scale and scope of such interventions are limited. Much larger, community-level interventions are needed to prevent the further spread of HIV among at-risk populations.[10] To date, however, comparatively few community-level HIV prevention interventions have been rigorously evaluated.[11–16]

Community-level interventions attempt to alter social norms toward risk behaviors (as well as altering the behaviors themselves) and thereby effect widespread and durable changes throughout the target population. One especially promising community-level HIV prevention model is based on diffusion of innovation principles.[17] This model hypothesizes that social norms propagate through a population starting with influential trend setters who convince others, through word and action, to adopt the target attitudes and behaviors. In this manner, an intervention of limited scale can have far-reaching, communitywide effects. As a result, community-level interventions have the potential to be highly cost-effective relative to smaller, possibly more intensive behavioral interventions.

Although recent studies have established the cost-effectiveness of several small-group HIV behavioral risk reduction interventions,[18–21] the economic efficiency of community-level HIV prevention interventions has not been rigorously evaluated.[22] As a first step toward filling this knowledge gap, we assessed the cost-effectiveness of an experimental community-level HIV risk reduction intervention conducted at gay bars in a small southern city.[14]

Description of the Intervention

The intervention, which consisted of 3 main phases, was conducted at 2 gay bars in Biloxi, Miss, in 1989.[14,23] In the first phase, bartenders were trained to observe social interactions among bar patrons and thereby identify "popular opinion leaders" within social networks in the gay bar community. Twenty-two of these men were recruited into the next phase of the intervention, which consisted of 4 weekly 90- to 120-minute instructional sessions. The purpose of these sessions was to teach the popular opinion leaders effective communication techniques for endorsing HIV risk reduction and safer sex in conversations with their peers.[14,23] In the final phase of the

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TABLE 1—Associations Between Symptoms and Bacterial Sexually Transmitted Diseases (STDs), with Positive Predictive Values: Prenatal Clinic Patients (n = 271) in Rural South Africa, 1996

	Neisseria gonorrhoea		*Chlamydia trachomatis*		*Trichomonas vaginalis*		Any STD	
Symptom	OR (95% CI)	PPV, %	OR (95% CI)	PPV, %	OR (95% CI)	PPV, %	OR (95% CI)	PPV, %
Lower abdominal pain	1.0 (0.3, 3.0)	6	0.9 (0.4, 1.9)	13	0.8 (0.5, 1.3)	37	0.8 (0.5, 1.4)	46
Abnormal vaginal discharge	1.3 (0.4, 4.1)	7	1.3 (0.6, 2.7)	15	1.6 (0.9, 2.7)	46	1.5 (0.9, 2.6)	54
Dysuria	1.3 (0.4, 4.0)	7	1.2 (0.6, 2.6)	15	1.3 (0.8, 2.2)	43	1.2 (0.7, 2.0)	50
Genital itch	0.3 (0.1, 1.4)	2	1.6 (0.8, 3.6)	18	1.5 (0.8, 2.6)	15	1.3 (0.7, 2.3)	52
Dyspareunia	2.2 (0.7, 6.9)	10	0.8 (0.3, 2.0)	12	1.3 (0.7, 2.4)	44	1.3 (0.7, 2.3)	52
No symptoms	0.3 (0.01, 2.1)	2	0.5 (0.1, 1.6)	8	0.7 (0.3, 1.4)	33	0.5 (0.3, 1.0)	38

Note. OR = odds ratio; CI = confidence interval; PPV = positive predictive value of infection. "Any STD" refers to *N gonorrhoea* or *C trachomatis* or *T vaginalis* infection.

previously treated STD within the last year, and many women (153, 47%) described their partner as being a migrant (defined as spending most nights away from home).

Prevalence was 7.8% for gonorrhea, 8.4% for active syphilis, 12.9% for chlamydia, 15.6% for HIV infection, and 41.4% for trichomoniasis. In all, 271 women (83%) had microbiological results available for all 4 bacterial STDs: missing results were due to occasional samples' not being taken or to technical errors. Of these 271 women, 141 (52%) had at least 1 STD, 46 (17%) had 2 concurrent infections, and 3 (1%) had 3 infections, but no women had all 4.

No women volunteered abnormal urogenital symptoms during their routine consultation, but on direct questioning at least 1 urogenital symptom was elicited from 225 women (83%), and 180 (80%) of these had more than 1 symptom. Lower abdominal pain was most frequent (119; 53%), followed by abnormal vaginal discharge (99; 44%), dysuria (99; 44%), genital itch (72; 32%), and dyspareunia (54; 24%). No social or demographic variables were associated with these symptoms. Associations between *T vaginalis, N gonorrhoea,* and *C trachomatis* and elicited symptoms were studied in the 269 women with complete clinical and microbiological data available. Associations were weak and not statistically significant, and the positive predictive value of symptoms for infection ranged from 2% to 54% (Table 1).

We observed a strong association between current STD and HIV infection (Table 2). A strong positive association was also observed between 2 individual STDs and HIV infection: gonorrhea (OR = 3.0; 95% CI = 0.8, 10.2; $P = .06$) and current chlamydial infection (OR = 2.2; 95% CI = 0.8, 5.3; $P = .06$). The association with HIV was weaker for both trichomoniasis (OR = 1.7; 95% CI = 0.8, 3.5; $P = .7$) and active syphilis (OR = 1.4; 95% CI = 0.4, 4.6; $P = .4$).

HIV-infected and uninfected women were similar in age (26.1 vs 24.7 years; $P = .12$) and gravidity (3.0 vs 2.8; $P = .16$).

TABLE 2—Univariate Analysis of Selected Potential Risk Factors for Prevalent Sexually Transmitted Diseases (STDs) and HIV Infection: Prenatal Clinic Patients (n = 271) in Rural South Africa, 1996

	HIV Infection	Prevalent STD
Risk Factor	OR (95% CI)	OR (95% CI)
Marital status (married vs not)	0.9 (0.4, 2.2)	0.6 (0.3, 1.0)
Partner's residence status (migrant vs resident)	1.3 (0.6, 2.8)	1.2 (0.7, 2.0)
STD in last year	2.6 (1.2, 5.6)	1.0 (0.6, 1.9)
Number of partners in last year (1 vs >1)	0.5 (0.1, 2.1)	0.7 (0.2, 2.1)
Current STD	2.6 (1.9, 6.1)	. . .

Note. OR = odds ratio; CI = confidence interval.

Women with an STD and those without were similar in age (23.9 vs 26.0 years) and gravidity (2.5 vs 3.2) as well. Of other possible risk factors studied (see Table 2), only a history of an STD in the last year was significantly associated with HIV infection.

Discussion

The estimated prevalence of undetected STDs among pregnant women in this rural district is very high. More than half the women studied had at least 1 infection, and under service conditions most remain undetected, as only syphilis screening is offered; there are no facilities for microbiological diagnosis in settings such as this. Although abnormal urogenital symptoms were frequently elicited on direct questioning, no women volunteered that they had abnormal symptoms. This suggests that the women either did not recognize the symptoms as being important or did not feel the setting was appropriate for reporting them—further research is clearly warranted. Elicited symptoms were weakly associated with laboratory-confirmed infection and their positive predictive value was poor. Most STDs in pregnant women, and in their partners, will remain undetected and untreated in these settings unless novel approaches to diagnosis and treatment are developed.

There are several important implications of a high prevalence of untreated STDs among pregnant women. Optimal pregnancy outcome is less likely[7]; the woman and her partner both risk serious long-term sequelae, including death[1]; transmission of STDs within the broader community will continue unchecked, and an important opportunity for controlling HIV infection is lost.[2] Opportunities for disease control may exist in this context.

A large proportion of pregnant women present for prenatal care in resource-poor settings. The logistical difficulties of identifying and reaching groups to be screened for apparently asymptomatic infections are thereby overcome by targeting this population. Most pregnant women are highly motivated to achieve a positive pregnancy outcome, making them likely to be compliant with treatment. Pregnant women may also find it easier than nonpregnant women to inform their partners of the need to be treated,[8] and strong partner treatment strategies are critical to support any intervention directed at the pregnant woman. The large number of pregnant women with an STD provides an important opportunity to reduce the reservoir of infection in the broader community.

How can this reservoir be reduced? Syndromic management is not effective when screening pregnant women. Urogenital symptoms commonly associated with symptomatic STDs are also common symptoms of pregnancy, and the association between symptoms and infection is therefore weak.[9,10] Accurate laboratory diagnosis of most STDs is not possible in resource-poor settings. The cost-

TABLE 2—Base-Case Analysis

	Discount Rate, %		
	0	Base Case (3)	5
Intervention cost, $	17 150	17 150	17 150
QALYs lost per infection	21.21	11.26	7.62
Lifetime medical care costs,[a] $	118 892	87 045	71 143
HIV infections averted by intervention	0.262	0.262	0.262
QALYs saved by intervention	5.56	2.95	2.00
Medical care costs saved by intervention, $	31 150	22 806	18 639
Cost-effectiveness ratio, $	65 458	65 458	65 458
Cost-utility ratio	<0[b]	<0[b]	<0[b]

Note. QALYs = quality-adjusted life-years.
[a]Low-cost scenario of Holtgrave and Pinkerton.[34]
[b]A cost-utility ratio less than zero signifies that the intervention is cost-saving.

The base-case cost-effectiveness ratio (cost per HIV infection averted) was about $65 000. Because the lifetime medical care costs associated with HIV and AIDS are even greater—ranging from $71 000 to $119 000 (depending on the discount rate) in the low-cost scenario of Holtgrave and Pinkerton[34]—it would actually be cost-saving to implement this intervention. (Since a cost-saving program is necessarily cost-effective, there was no need to calculate the cost-utility ratio.)

The intervention remained cost-saving at the 3 discount rates considered in Table 2 and under each of the 9 HIV/AIDS medical care scenarios examined by Holtgrave and Pinkerton.[34] The results were not especially sensitive to the particular model used to estimate the number of infections averted or to other parameters, such as the effectiveness of condoms. Although the analysis was moderately sensitive to the per-contact probability of transmission and to the prevalence of infection in the community, the intervention remained cost-effective under all of the scenarios considered in the sensitivity analyses.

Discussion

The community-level HIV prevention intervention described here, in which popular opinion leaders were trained to endorse and model safer sex behavioral norms, is highly cost-effective—even cost-saving—under most reasonable parameter assumptions. The cost per infection averted compares favorably with other HIV behavioral risk reduction interventions for gay men, such as intensive, small-group cognitive–behavioral skills workshops.[20] Moreover, the overall cost of the intervention (about $40 per affected individual) is likely to fall within the budgetary constraints of many community-based AIDS prevention organizations.

Several limitations of this study should be noted, including the retrospective collection of cost data, estimation of key epidemiological parameters, modeling to derive outcome data, and reliance on respondents' self-reports of their sexual behaviors (e.g., if respondents know that an intervention has just been completed, they may respond in a socially desirable manner). However, these concerns are mitigated by the results of the sensitivity analyses, which indicate that the intervention remains cost-effective over a range of reasonable parameter values. It is unlikely that uncertainty in the cost and epidemiological estimate or bias in the self-reporting of sexual behavior data would be sufficient to reverse the overall finding of cost-effectiveness.

External validity is also a critical concern. The intervention was conducted in 1989 among gay men in a small southern city, and the results may not generalize to other populations differing in preexisting risk levels and motivation to change. The costs to implement the intervention, including possible start-up costs, may also differ by geographical location. Additional studies are needed to assess the "real-world" cost-effectiveness of community-level and other HIV prevention interventions, as implemented by AIDS service organizations in the field. Nevertheless, this analysis suggests that interventions that use existing social networks can be highly cost-effective. □

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The Role of Cost-Effectiveness Analysis in Assessing HIV-Prevention Interventions

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INTRODUCTION

HIV-prevention interventions can "work." Multiple studies report that a wide range of interventions reduce individuals' behavior that puts them at high risk of contracting HIV.[1] In certain populations, change in individuals' behavior has contributed to decreases in HIV incidence of as much as 75 percent.[2] This appears to justify renewed and aggressive prevention activities, especially in light of disappointing efforts to identify a vaccine or cure.

Yet, like health interventions in general, prevention is imperfect--no strategy permanently eliminates all high-risk behaviors. Expecting 100 percent effectiveness of an intervention and a quick end to the epidemic leads to frustration and inaction.[3] We argue that if the goal of prevention is to alter the course of the HIV epidemic, perfection is not only unattainable, it is unnecessary. Instead, we must shun absolutism, and "quantify our non-absolutism"; we must apply important and subtle standards, by asking: How much behavioral change is enough to justify a prevention program? How can we use available funding to avert the largest number of infections?

Although traditional behavioral and epidemiologic outcomes are essential in evaluating prevention programs, they cannot be used to answer these questions. Changes in high-risk behavior are relatively easy to document, and can be used to provide compelling *prima facie* evidence of a program's effectiveness. The magnitude of these changes does not necessarily correspond, however, to the number of HIV infections that have been averted. A large change in behavior in members of a population who are at low risk of contracting HIV may avert few infections, while a minor change in behavior in a high-risk population may avert a large number of infections. Change in the incidence of HIV infection is a more direct measure of the number of HIV infections that have been averted, and it is a measure that allows comparison of different prevention strategies and different populations. But changes are directly measurable only in high-risk populations, and for certain interventions; they are expensive to measure; and measuring changes does not address which resources are required to achieve a given prevention goal. Cost-effectiveness analysis integrates these standards. It can be used assess how behavioral change in a specific environment translates into the number of infections that have been averted and at what cost. Thus, it can answer the question, "Given a limited amount of money for prevention--less than enough to fund all possible programs--which strategies will save the most lives?" Ultimately, decisions about prevention programs depend on the constellation of standards that

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COST-EFFECTIVENESS FORMULA

$$\text{Cost-per-HIV-infection-averted that can be attributed to an intervention} = \frac{\text{Cost of the intervention}}{\text{No. of HIV-negative clients} \times \text{Incidence of HIV} \times \text{Effectiveness of the intervention}}$$

Figure 1

go beyond effectiveness (including community participation, cultural appropriateness, equity, and political acceptability). However, cost-effectiveness provides the most comprehensive and consistent scale for rating a program's effect on public health.

Below, we assess three HIV-prevention interventions, using simple cost-effectiveness techniques. We show that using cost-effectiveness techniques can help us to compare the impact of different levels of behavioral change, in specific settings. More importantly, we show that relatively modest change–far less than complete elimination of high-risk activities–can lead to very worthwhile public health benefits. The interventions we consider are (1) providing needle-exchange programs for injection-drug users, (2) training gay community leaders to endorse behavioral change, and (3) testing surgeons for HIV.

PROPOSED STANDARD FOR HIV-PREVENTION INTERVENTIONS

In cost-effectiveness analysis, health outcomes are compared with expenditures for various interventions. In the realm of HIV prevention, where the goal is to prevent new infections by decreasing high-risk behavior, the cost-effectiveness of an intervention can be estimated as shown in figure 1.

In this article, we define *effectiveness* as the reduction in the frequency of high-risk behaviors (for example, needle sharing, unprotected sex) due to the intervention, expressed an a percentage. This assumes that each high-risk episode confers a small and independent incremental probability of transmitting HIV. This also assumes that avoiding the high-risk behavior (for example, not sharing needles, or using a condom) completely or nearly completely eliminates risk. Other definitions of effectiveness (for example, the proportion of individuals who engage in high-risk behavior decreases, an individual reduces the number of his or her sex partners, or an individual reduces the number of high-risk sex partners) can also be used, reflecting theoretically or empirically confirmed predictors of the risk of contracting HIV in specific populations. Also, the formula used can be applied directly only to interventions for HIV-uninfected populations. We discuss the limitations of the formula and the need for other models later in this article.

The public health value of an intervention to prevent the transmission of HIV is a function of the cost-effectiveness ratio. A low cost-per-infection-averted makes an intervention attractive. Interventions that have a cost-per-infection-averted that is less than the cost of treating HIV disease can be justified outright within a broad public health budget: the benefits exceed the costs. An extremely high cost-per-infection-averted (for example, > $500,000 per infection averted) may suggest that funds should be shifted to other population groups, to other treatment programs, or to other diseases.[4] Government budget-making is often compartmentalized, however, and savings that may be found in treatment programs are rarely available to be transferred to fund prevention programs. In the narrower domain of budgeting for prevention programs, cost-effectiveness may also help: to maximize the number of HIV infections that are averted with limited funds, those interventions with the lowest cost-per-infection-averted should be funded first.

ASSESSMENT OF PREVENTION STRATEGIES: THREE EXAMPLES

In this section, we present the data needed to apply the above formula, and estimate the cost-effectiveness for three prevention strategies (see

Table 1
Cost-Effectiveness of Prevention Programs for 1,000 Individuals

Variable	Needle Exchange for Injection-Drug Users, New York City	Training of Community Leaders, Gay Men, Biloxi, Miss.	HIV Testing for Surgeons, U.S.
Cost	$40,000	$12,000	$54,372
Number of HIV-uninfected individuals	500	920	12,600 *
Incidence of HIV Infection	6.0%	1.1%	0.0022%
Effectiveness (reduction in risk behaviors)	50.0%	10.0%	100%
Estimated HIV infections averted	15	1.0	0.28
Estimated cost-per-HIV-infection-averted	$2,667	$12,000	$194,186

*For the column "HIV Testing for Surgeons," the number of uninfected individuals refers to the number of patients operated on by HIV-infected surgeons.

table 1). We also report selected sensitivity analyses–assessments of how uncertainties in data can affect the estimated cost-effectiveness of a program.

NEEDLE-EXCHANGE PROGRAMS

Needle-exchange programs lower the frequency with which IDUs inject with used needles. In New York City, needle-exchange programs require resources that are valued at approximately $40,000 annually per 1,000 clients (to provide 30 syringes per client per year), including the value of volunteers' time.[5] Approximately half of the IDUs in New York are not infected with HIV.[6] The incidence of HIV infection is 5 to 7 percent per year.[7] According to a study conducted in New York City, in which IDUs reported on their use of needles, needle-exchange programs led to a 50 percent reduction in the frequency of injecting with used needles.[8] Thus, in a group of 1,000 clients, 15 new HIV infections could be averted annually (500 uninfected clients x 6 percent incidence x 50 percent reduction in high-risk behavior). The estimated cost-per-HIV-infection-averted is $2,667 ($40,000/15). This is far below the estimated cost of lifetime medical treatment for one HIV-infected individual (prior to protease inhibitors)–$56,000 to $80,000;[9] the net savings per infection averted for a needle-exchange program in New York City could be estimated to be $53,000 to $77,000.

This analysis of the cost-effectiveness of a needle-exchange program includes uncertain data regarding effectiveness, cost, and incidence of HIV. The 50 percent rate of effectiveness is higher than that reported in most studies.[10] At 30 percent effectiveness, the cost-per-HIV-infection-averted is $4,444; at 10 percent effectiveness (less than reported in most other studies),[11] the cost-per-HIV-infection-averted is $13,333. The cost of a needle-exchange program ($40,000 per 1,000 IDUs) is low compared with reports of other needle-exchange programs. If the program were less efficient or distributed more than 30 needles per client annually, the cost could double, leading to a cost-per-HIV-infection-averted of $5,333. Finally, some transmission of HIV among IDUs is sexual. If drug-related incidence is assumed to be only 4 percent, the cost-per-HIV-infection-averted is $4,000. Thus, for a wide range of data values, this needle-exchange program has a cost-per-HIV-infection-averted that is well below the estimated lifetime medical cost of treating one HIV-infected individual.

TRAINING OF COMMUNITY LEADERS

Programs that train leaders in the gay community to endorse behavioral change can lead to a decrease in the incidence of unprotected anal sex.[12] A program like this costs about $12,000 in a small city like Biloxi, Mississippi. This cost estimate includes $6,000 in salary and benefits for intervention staff, $1,600 for workshop facilitators, $2,000 for training incentive payments to the leaders of the gay community, and $2,400 for other expenses (such as training materials, transportation, and lodging).[13] The prevalence of HIV infection in gay men in Biloxi, which is located far from the epicenters of HIV infection, is 8 percent by self-report (for the 60 percent of men who had taken an HIV test).[14] Thus, we estimated that 920 of 1,000 gay men are not infected with HIV. The incidence of HIV infection has not been directly measured in Biloxi, but can be estimated to be 1.1 percent, the incidence needed to maintain a prevalence of HIV of 8 percent, with a median of eight years between infection and cessation of sexual activity (due to migration, morbidity, and mortality). An evaluation of the community leader training in Biloxi reports reductions of approximately 10 percent in a variety of high-risk sexual behaviors, compared to a non-intervention city.[15] Thus, in a group of 1,000 gay men in Biloxi, the number of infections averted has been estimated to be about 1.0 annually (920 uninfected men x 1.1 percent incidence x a 10 percent reduction in high-risk behavior). The cost-per-HIV-infection-averted is estimated to be $11,858.

Analysis of this program to train leaders of a gay community includes uncertain data regarding cost, incidence of HIV, and the number of gay individuals who were not infected in the Biloxi gay community. The actual cost of the program, $12,000, did not include a salary for the leaders of the gay community (beyond an incentive to attend the training program), and thus understated the societal resources required for this strategy. If the cost of the program were doubled to $24,000 (in effect, paying 24 gay leaders to work 50 hours each, at $10 per hour) the cost-per-infection-averted would be approximately $23,715. The second uncertainty is incidence of HIV, estimated, using a simple steady-state model, to be 1.1 percent. If the rate of incidence were really 0.9 percent, the cost-per-HIV-infection-averted would be $14,493; if the rate of incidence were 1.3 percent, the cost would be $10,033. Third, the number of those who were not infected with HIV is uncertain. This number depends on the prevalence of HIV, which was estimated to be 8 percent, based on the report of gay men who had been tested in Biloxi. The cost-per-HIV-infection-averted does not change much if only the prevalence of HIV varies: at 4 percent (960 uninfected men) it is $12,397; at 12 percent (880 uninfected men) it is $11,364. However, if incidence of HIV infection is recalculated based on a different prevalence of HIV infection, there is greater variation in the cost-effectiveness of the program: at a prevalence of 4 percent and an incidence of 0.5 percent, cost-per-HIV-infection-averted would be $25,000; at a prevalence of 12 percent and an incidence of 1.7 percent, cost-per-HIV-infection-averted would be $8,021. Thus, this intervention appears less efficient than needle exchange in New York City, but still costs substantially less than the projected lifetime medical costs averted.

HIV TESTING OF SURGEONS

Testing surgeons for HIV decreases the frequency at which an HIV-infected surgeon might expose his/her patients to infection by reducing how often the surgeon performs high-risk surgical procedures.[16] HIV-testing programs report that an HIV-negative test costs $54 and an HIV-positive test costs $147, which includes counseling.[17] Surgeons in the U.S. are believed to be infected with HIV at a rate similar to that of the overall U.S. population (0.4 percent),[18] so that if 1,000 U.S. surgeon were tested, approximately four would test positive; the cost of such testing would be $54,372. These four surgeons who tested HIV positive could perform as many as 12,600 surgeries before they were disabled by HIV disease (4 surgeons x 450 procedures of all types per surgeon per year x 7 years between detection of infection and disability). We calculated the transmission of HIV from surgeon to patient to be the risk of exposure to infected blood per surgery (0.00768) times the risk of infection, given exposure (0.29 percent), or 0.0022 percent per surgical procedure.[19] Assuming the complete exclusion of infected surgeons from operating, the number of infections averted would be 0.28 (12,600 x 0.0022 percent). Thus, the estimated cost-per-HIV-infection-averted is $194,186 ($54,372/0.28).

The uncertainties in this analysis are cost, transmission of HIV during surgery, and the number of patients who are operated on by HIV-infected surgeons. If the testing of surgeons is 50 percent less expensive than the testing for other populations, assuming that there might be less need for risk-reduction counseling for surgeons, the cost-per-HIV-infection-averted would be $98,079. If, on the other hand, to recruit and train each replacement surgeon costs $50,000,[20] the cost-per-HIV-infection-averted is $917,648. Second, if the risk of transmitting HIV during surgery could be reduced 50 percent by safety training for infected surgeons, the cost-per-HIV-infection-averted would be $392,294. Finally, if testing for HIV were repeated (for example, every six months), the prevalence of infection would be likely lower, because most infected surgeons would be identified in the initial testing.[21] If prevalence of infection on repeat testing were 0.1 percent instead of 0.4 percent, the cost-per-HIV-infection-averted would be $784,588. Thus, over a wide range of scenarios, testing surgeons for HIV is not nearly as cost-effective as needle-exchange programs in New York City or training leaders in the gay community of Biloxi. If other costs are considered (such as lost productivity due to excluding surgeons from practice), the cost-per-HIV-infection-averted might be many millions of dollars.[22]

ADVANTAGES AND LIMITATIONS OF THE FORMULA

The primary advantage of using cost-effectiveness to assess HIV-prevention strategies is its ability to link data and public health goals. The formula that we have presented here translates changes in behavior, epidemiology, and cost into a clear measure of the desirability of an intervention: some prevention strategies are "winners" and some are "losers." When used to allocate funds, this formula provides a compelling tool to answer the question, "How much change in high-risk behavior is enough?" As we have shown in our analysis of the three examples, the answer depends on the particulars given: in the right setting, a minimal amount of behavior change can provide important public health rewards; in the wrong setting, a complete change in behavior may be insufficient to justify the expenditures.

The formula makes the benefits of HIV-prevention interventions more tangible. As health professionals, our goal is to eliminate disease in a population, or at least in some individuals; a diffuse abatement of risk feels unsatisfactory.[23] AIDS prevention is particularly frustrating. Even with excellent behavioral interventions, we won't eradicate AIDS in the near future. The cost-effectiveness formula helps: "15 infections averted" is concrete. We can take pride in this partial solution, knowing that we are saving as many as lives as possible.

Despite its range of inputs, the cost-effectiveness formula still simplifies the dynamics of the HIV epidemic. More elaborate epidemic models include multiple-year projections, portrayals of how HIV is spread between groups who are at high risk of contracting HIV, and detailed descriptions of high-risk behaviors.[24] Such enhancements generally make interventions appear to be more cost-effective by identifying secondary benefits, such as infections averted in sex partners of drug users. However, the refinements generally do not alter policy conclusions: the ranking of interventions usually remains unchanged. There are some exceptions. For example, when high-risk behaviors are extraordinarily frequent, but the prevalence of HIV infection is still in the range of 1 percent to 3 percent (as in New York City in the early 1980s, and in Thailand more recently),[25] a multi-year analysis is needed to show the magnitude of benefit from interrupting an epidemic that is growing exponentially. Careful analysis is also required when effective prevention programs suppress the incidence of HIV infection, and so obscure what the incidence of infection would have been without the prevention (as in the case of gay men in San Francisco).[26] In this setting, cost-effectiveness analysis of *existing* prevention programs must use the incidence of HIV infection as it would have been in the absence of those programs. Reasonable diligence and thoughtful "back-of-the-envelope" calculation can identify when the dynamics of the epidemic will require more complex analysis.

This simple cost-effectiveness formula also glosses over some important economic issues. For example, the way in which costs are defined will dictate the way results should be interpreted. A determination of societal costs should include all of the resources that are required to mount a prevention strategy. The best way to determine societal costs is to assign a market value for each required resource, even if it has been donated. The accounting costs (from a program's ledger) may be more readily available, and, if used cautiously, may be used to determine approximate true costs, excluding donated resources. The economic perspective is a larger issue: if an agency is deciding how to allocate its prevention budget, it may choose to consider only actual costs and not volunteers' efforts. Finally, our analysis uses averages of programs' costs. In reality, programs may have high start-up costs and lower marginal costs, so that the analysis is more accurate if it reflects such operational factors.[27] The goal is to portray enough of the economic and epidemic factors for the model to assist in making budgeting decisions. As with prevention programs, a cost-effectiveness model need not be perfect to be valuable.

The key to the accuracy of a simple cost-effectiveness model is its ability to capture the most important determinants of cost-effectiveness. The formula that we present works best when it is used to assess an intervention that averts infections in the group that is to receive the intervention (for example, a needle-exchange program for a community of drug users). Other prevention strategies may require different approaches. For example, prevention interventions that focus on HIV-infected individuals actually benefit the offspring of these individuals, or their drug or sex partners.[28] Thus, a simple formula may need to integrate information on the costs for one group and the benefit to another group. Further, sometimes it may be difficult to quantify the size of the population that is affected by an intervention, for example, street outreach programs that are intended to widely diffuse an HIV-prevention message. The simple formula must then reasonably estimate the number of individuals who will be affected by the message. How one chooses to simplify cost-effectiveness analysis is of critical importance. Simple formulas other than the one proposed here can and should be developed to assess the variety of prevention strategies that exist.

No matter how well it is done, cost-effectiveness analysis cannot resolve competing agendas. It does not address broad issues of distributing resources, such as empowering communities by funding HIV-prevention programs, allotting funds in proportion to the size of a population, rectifying a history of neglect of underserved communities, or counterbalancing a lack of funds for other services (for example, healthcare services). For example, society may choose to implement HIV-prevention strategies for hard-to-reach poor minority women because of ethical and human rights considerations, even if it appears that such prevention is not cost-effective when compared with other expenditures.

Cost-effective analysis cannot reconcile contrasting moral viewpoints. The cost-effectiveness analysis emphasis on averted infections implicitly endorses harm reduction, the principle of minimizing the ill-health effects of risky behaviors–such as drug injection–when they cannot be eliminated. Consequently, those who advocate abstinence on moral or religious grounds are unlikely to be comfortable with cost-effective analysis, because it can be seen as supporting a perspective they oppose. Modeling the cost-effectiveness of abstinence programs, although technically possible, would fail to address the moral and ethical considerations underlying the advocacy of abstinence.

Cost-effectiveness analysis, as we present it here, adopts the perspective of a society. The formula describes the average benefit of a program, and does not consider whether an intervention responds to every concern of every individual. To the contrary, eliminating risk for any one person is explicitly subordinated to maximizing the social benefit of a program.[29] Thus, cost-effectiveness analysis insures that "perfect prevention"–always protecting everyone–does not become the enemy of "optimal prevention"–doing the best that is possible with limited resources.

THE ROLE OF COST-EFFECTIVENESS ANALYSIS IN REAL-WORLD DECISIONS

We believe that the critically important role of cost-effectiveness analysis in planning HIV-prevention interventions is to guide how resources are allocated. Cost-effectiveness analysis can help policy makers to divide prevention resources among populations, according to variations in the incidence of HIV, the cost of the programs, and the effectiveness of the interventions. Cost-effectiveness analysis can also help policy makers to select among HIV-prevention programs for a specified population, based on the relative cost and effectiveness of the various HIV-prevention strategies that are tailored to serve this population. As the epidemic moves to new locations, groups, and behaviors, and as we learn more about preventing its spread, decisions about allocating resources can be revisited. Cost-effectiveness analysis has great potential as a tool in the "prevention kit." We have identified three substantial challenges to using this tool, and now will propose approaches to address them. The challenges are to build acceptance of cost-effectiveness analysis, to improve the collection of data, and to provide funding and technical assistance.

BUILDING ACCEPTANCE

Recently, cost-effectiveness analysis has been endorsed for use in planning HIV-prevention programs. For example, the Centers for Disease Control and Prevention (CDC) includes cost-effectiveness as an evaluative standard in its *Supplemental Guidance on HIV Prevention Community Planning for Noncompeting Continuation of Cooperative Agreements for HIV Prevention Projects* for national HIV-prevention community planning,[30] and the Office of AIDS Research at the National Institutes of Health has established an objective to evaluate the cost-effectiveness of HIV-prevention programs.[31] There have been at least 25 methodologically sound studies of the cost-effectiveness of HIV-prevention programs.[32] Nevertheless, cost-effectiveness analysis remains a tool that is little used and poorly understood in public health. The CDC, the primary federal public health agency for HIV prevention, initiated a formal program of cost-effectiveness research and teaching only in 1991; few of CDC's professional staff have participated in cost-effectiveness studies. In the HIV-prevention community planning process, cost-effectiveness analysis has been only rarely used, despite its inclusion in the CDC guidance, and has elicited controversy regarding its complexity and ethical implications in at least one location.[33] Public health researchers, program managers, and policy makers will need to personally observe the value of cost-effectiveness analysis in decision making before cost-effectiveness analysis will receive broader support. Familiarity will build acceptance, by lessening confusion about methods and applications. Toward this end, more studies are needed. Some can be carried out with existing data, particularly using simplified methods such as those we present in this article. Widespread use of cost-effectiveness techniques, however, will require new and better data.

IMPROVED COLLECTION OF DATA

Some of the data that are necessary for cost-effectiveness analysis are already widely available, but they are not standardized; other important data have rarely been collected. The resources the programs require and their costs are usually readily available from grant and contract budgets and from accounting records. Numbers of clients are routinely monitored; additional documentation regarding the intensity and duration of interventions will assist analysis in the future. The prevalence of HIV infection, which is relatively inexpensive to measure, can be incorporated more often into behavioral studies. To assess the incidence of HIV infection, which is often too expensive to assess empirically, rough approximations are adequate (for example, < 0.5 percent or 3 percent to 5 percent), and can be derived from the prevalence of HIV infection, as discussed in this article. Finally, behavioral evaluations can focus on detailed descriptions of high-risk behaviors and on how programs have changed individuals' behavior, and, when the goal is to change behavior throughout a community, changes in a community's behavior can be assessed. For behavioral studies, the norm should be the prevalence and frequency of several basic high-risk behaviors (for example, injecting with a used syringe, using a shooting gallery, sharing needles with sexual partners). Improvements in the collection of data will require additional financial and technical support.

FUNDING AND TECHNICAL ASSISTANCE

Much of the data that is needed to perform cost-effectiveness analysis can come from evaluation of programs that are already in operation. Yet, program funds are rarely sufficient to pay for research or evaluation, and research awards are infrequently made to evaluate programs or to provide technical assistance for evaluation.[34] Further, program managers often fear that they may lose financial support if deficiencies are identified by an evaluation. Those who allocate funds are in the best position to alter this climate by (1) insisting on, and budgeting for, the appropriate collection of data; (2) identifying or developing the technical expertise to assist programs in performing evaluations; and (3) rewarding rigorous evaluation. Those who allocate funds to programs could explicitly add the expense of cost-effectiveness analysis when they make funding decisions. Those who allocate funds for research could require cost-effectiveness analysis as part of the evaluation of interventions, and could issue RFPs (requests for proposals) for the cost-effectiveness analysis of programs that are already in operation, of demonstration projects (such as the CDC's Prevention Marketing Initiative), and of interventions that have already been funded.

In order to phase cost-effectiveness analysis into the decision-making process--overcoming these various challenges–several misconceptions will need to be refuted. First, cost-effectiveness analysis does not devalue human life, or the lives of any group of individuals. To the contrary, the focus of cost-effectiveness analysis is to maximize the number of lives saved, rather than to choose a program based on the race, gender, or lifestyle of the population it will serve. Second, cost-effectiveness analysis is not prohibitively complex. We demonstrate in this article that cost-effectiveness analysis can provide a straightforward structure to quantify the lessons that we already know about the prevention of HIV, without slipping into a sinkhole of absolutism. Third, a lack of precise data does not negate the value of this kind of analysis. Rather, uncertainty in the data used helps us focus on important, large distinctions, rather than on subtle and relatively inconsequential ones. It also helps us to hone in on policy questions, rather than on arcane facts: How much behavior change must a program deliver to be worthwhile? Fourth, the importance of politics in preventing HIV does not preclude a role for public health science, but instead means that such science must be compelling enough to influence a process that includes many actors and many aims. Finally--and most importantly–a failure to adopt rigorous standards is bought at the cost of wasting scarce resources on ineffective programs, and missing the opportunity to save lives.

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