Estimated Future HIV Prevalence, Incidence, and Potential Infections Averted in the United States: A Multiple Scenario Analysis

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Objectives: To estimate the potential future burden of HIV in the United States under different intervention scenarios.

Methods: We modeled future HIV incidence, prevalence, and infections averted using 2006 estimates of HIV incidence (55,400 new infections per year), prevalence (1,107,000 persons living with HIV), and transmission rate (5.0 per 100 persons living with HIV). We modeled 10-year trends for 3 base-case scenarios (steady incidence, steady transmission rate, declining transmission rate based on the 2000–2006 trend) and 2 intensified HIV intervention scenarios (50% reduction in transmission rate within 10 and 5 years).

Results: Base-case scenarios predicted HIV prevalence increases of 24%–38% in 10 years. Reducing the transmission rate by 50% within 10 years reduces incidence by 40%; prevalence increases 20% to an estimated 1,329,000 persons living with HIV. Halving the transmission rate within 5 years reduces incidence by 46%; prevalence increases 13%, to 1,247,000. Although in year 10 incidence is similar regardless of the intervention time frame, more infections are averted when halving the transmission rate within 5 years.

Conclusions: HIV prevalence will likely increase creating additional demands for health care services. These analyses are instructive for setting HIV prevention goals for the nation and assessing potential cost savings of intensified HIV prevention efforts.

Key Words: costs, HIV, incidence, policies, prevalence

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Understanding potential future trends in the HIV epidemic in the United States has important implications for establishing realistic public health goals and planning for the anticipated needs of people living with HIV and those at risk for HIV infection. The Centers for Disease Control and Prevention (CDC) estimated that the number of people living with HIV in the United States increased about 4% per year (30,000–40,000 cases annually) between 1996 and 2006, bringing the number of adolescents and adults who were living with HIV in 2006 to about 1.1 million.[1,2] This increase is the result of reduced mortality after the introduction of highly active antiretroviral therapy and relatively stable HIV incidence in the past decade—approximately 48,200 to 64,500 new infections were estimated to have occurred in 2006.[3] Stable HIV incidence in the context of growing prevalence reflects a reduction in the HIV transmission rate per persons living with HIV. The estimated transmission rate declined substantially from 1984 to the mid 1990s and has continued to decline, albeit at a slower pace, in recent years.[4] Recent reductions in state and local funding for prevention,[5] medical care, and supportive services, coupled with the growing number of people living with HIV who need prevention and medical services, raise questions about the feasibility of continuing to reduce the HIV transmission rate in the United States without further expanding and improving the efficiency and impact of HIV prevention and treatment.

Despite these challenges, we considered what could be achieved if current prevention efforts were to be significantly expanded and HIV incidence and transmission rate were to be reduced substantially. At a Congressional hearing in 2008, 2 proposals for reducing HIV transmission were presented.[6,7] Both emphasized significant expansions of HIV testing to reduce undiagnosed HIV infections, improved linkage to medical care for people with HIV, and provision of effective risk reduction interventions for people living with and those at increased risk for HIV. However, a key difference between the proposals was how quickly new activities could be scaled up to achieve a 50% reduction in HIV transmission rate: one proposed meeting this goal in about 10 years and the other in 5.

To estimate the potential future burden of HIV in the United States under different intervention situations, we developed 3 base-case scenarios using published HIV incidence and transmission rates. These scenarios were compared over a 10-year time horizon with the 2 intensified

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HIV intervention proposals in terms of estimated HIV prevalence, incidence, and infections averted.

METHODS

We modeled future HIV incidence, prevalence, and infections averted in the United States using current estimates of HIV incidence and prevalence from national HIV surveillance data and methods previously published.[1–3] In brief, since 1982 all 50 US states and the District of Columbia have reported AIDS cases to CDC using a standardized case report form. In 1994, CDC implemented data management for national surveillance of diagnoses of HIV infection integrated with AIDS case surveillance, at which time 25 states with confidential name-based HIV surveillance started submitting case reports to CDC. Over time, additional states implemented name-based HIV surveillance, and all states had implemented such surveillance in 2008. These advances in HIV surveillance now allow the estimation of HIV incidence and prevalence using extended back-calculation models.[1,3]

Using the most recent incidence (number of new infections) and prevalence (number of persons living with HIV) estimates available (2006), and the transmission rate based on these,[4] as the baseline, we modeled trends in incidence and prevalence for a 10-year period under 3 base-case scenarios and 2 intensified HIV intervention scenarios. We assumed, based on the back calculation method, that at the outset, 55,400 new infections occur each year[3] with a prevalence of 1,107,000 persons living with HIV[2] and an annual HIV transmission rate of 5.0 per 100 persons living with HIV.[4] For the base-case scenarios, we examined the effects of (1) steady incidence, (2) a steady transmission rate, and (3) a declining transmission rate based on extrapolating trends estimated for 2000–2006 (observed decline 2000–2006 from 6.2 to 5.0; with modeled decline to 3.1 in year 10). The period 2000–2006 was chosen because the trend in transmission rates was linear during these years. Including years before 2000 would introduce nonlinearity in the transmission rate trend. The death rate was assumed to remain constant, using the estimated 2005 death rate (deaths/prevalence) rather than the estimated 2006 death rate to account for reporting delays in deaths and less stable reporting delay adjustment in the most recent year. For the 2005 deaths, we used the cumulative incidence through 2005 and subtracted both the prevalence in 2005 and the cumulative deaths through 2004.

We modeled a reduction of 50% in the transmission rate from 5.0 to 2.5 within a 10-year and 5-year time frame (intervention scenarios) according to the 2 proposals presented to Congress. A target transmission rate of 2.5% (annual rate of transmissions per 100 persons) allows for a small proportion of persons infected with HIV that would not be diagnosed. By comparison, we estimated that currently those diagnosed and aware of their infection have an estimated HIV transmission rate of 3.3%, compared with a rate of 11.4% among those not aware (derived from 2006 incidence and prevalence using the formula by Marks et al[8]). Although the 2 scenarios were similar in fundamental ways, they allocated prevention resources differently and were based on different assumptions about how quickly prevention efforts could be expanded, and the resources needed to reduce and sustain the transmission rate at the target level. Both scenarios included the rapid expansion of HIV testing and behavior change interventions for persons living with HIV or at increased risk for HIV infection. The proposal to halve the HIV transmission rate in 10 years also included increased resources for surveillance, research, capacity building, and other public health activities. The other proposal called for a more rapid scale up of prevention efforts and aimed to halve HIV transmission rates in 5 years. This scenario assumed that the transmission rate would remain stable at this reduced level in 6–10 years. Both proposals assumed that annual funding would increase in the first 5 years and remain fixed at year-5 levels thereafter.

Estimates for the scenarios with varying transmission rates were calculated as follows. In the first year of our projections, the beginning prevalence was our baseline estimate of 1,107,000 persons living with HIV. The prevalence at the end of the first year was determined by dividing the prevalence at the beginning of the year by 1 + [death rate from 2005 (the 2005 death rate includes both deaths due to AIDS, and mortality among HIV-seropositive persons who have not yet progressed to AIDS) − (projected transmission rate for this first year)]. Incidence was then derived from the number of persons living with HIV at the end of the year multiplied by the projected transmission rate for that year. The number of deaths in that year was estimated by multiplying the prevalence at the end of the year by the 2005 death rate. Incidence and prevalence of subsequent years were estimated in much the same way, using the estimated prevalence at the end of the previous year and the projected transmission rate for the current year as input parameters.

Similarly, prevalence and transmission rates were calculated with constant incidence (55,400 per year) by adding incidence to the estimated prevalence from the prior year and deriving the transmission rate by dividing incidence (constant at 55,400) by the prevalence at the end of the year and expressing the rate per 100 persons living with HIV.

We estimated the number of additional HIV infections averted by subtracting the estimated number of infections from the 2 intervention scenarios from the base case scenarios; that is, each intervention scenario (50% reduction in transmission rate within 10 or 5 years) was compared with 3 base-case scenarios. The cumulative number of infections averted was calculated by adding the number of infections averted in each year to the sum of infections averted in prior years.

RESULTS

In the base-case scenario assuming steady incidence (55,400 new infections per year) over 10 years, the transmission rate decreases to 3.9 in year 10 and prevalence increases 29% to 1,427,000 people living with HIV by the end of year 10 (Table 1). A constant transmission rate would increase incidence and prevalence by about 38% in year 10 with 1,530,000 people living with HIV—the highest in any of the scenarios. Projecting a course of decreases in the transmission rate similar to the years 2000–2006 would result in decreases in incidence, with about a 24% reduction in incidence in year 10 and a prevalence that increases about

TABLE 1. Ten-Year Projections of New HIV Infections With 50% Reduction in TR Within 5 and 10 Years and Base Case Scenarios, Unites States

	Base 1			Base 2			Base 3		
	Stable Incidence			Constant TR			TR trend 2000-06 continued		
Year	TR	Incidence	Prevalence	TR	Incidence	Prevalence	TR	Incidence	Prevalence
1	4.9	55,400	1,142,000	5.0	57,200	1,143,000	4.8	54,900	1,141,000
2	4.7	55,400	1,176,000	5.0	59,100	1,181,000	4.6	54,200	1,174,000
3	4.6	55,400	1,209,000	5.0	61,100	1,220,000	4.4	53,400	1,206,000
4	4.5	55,400	1,242,000	5.0	63,100	1,260,000	4.2	52,300	1,235,000
5	4.3	55,400	1,274,000	5.0	65,100	1,302,000	4.0	51,100	1,263,000
6	4.2	55,400	1,306,000	5.0	67,300	1,344,000	3.9	49,700	1,290,000
7	4.1	55,400	1,337,000	5.0	69,500	1,389,000	3.7	48,100	1,314,000
8	4.1	55,400	1,367,000	5.0	71,800	1,434,000	3.5	46,300	1,336,000
9	4.0	55,400	1,397,000	5.0	74,100	1,482,000	3.3	44,400	1,356,000
10	3.9	55,400	1,427,000	5.0	76,600	1,530,000	3.1	42,300	1,373,000
	Intervention 1			Intervention 2					
	50% Reduction in TR in 10 years			50% Reduction in TR in 5 years					
Year	TR	Incidence	Prevalence	TR	Incidence	Prevalence			
1	4.8	54,200	1,140,000	4.5	51,200	1,138,000			
2	4.5	52,800	1,172,000	4.0	46,600	1,163,000			
3	4.3	51,100	1,201,000	3.5	41,400	1,183,000			
4	4.0	49,200	1,228,000	3.0	35,900	1,197,000			
5	3.8	47,000	1,252,000	2.5	30,200	1,205,000			
6	3.5	44,600	1,274,000	2.5	30,400	1,214,000			
7	3.3	42,000	1,292,000	2.5	30,600	1,222,000			
8	3.0	39,300	1,308,000	2.5	30,800	1,230,000			
9	2.8	36,300	1,320,000	2.5	31,000	1,239,000			
10	2.5	33,300	1,329,000	2.5	31,200	1,247,000			

TR, transmission rate.

24% with 1,373,000 people estimated to be living with HIV by the end of year 10.

Reduction of the transmission rate by 50% within 10 years results in about a 40% reduction in incidence; from the baseline incidence of 55,400 new infections to 33,300 infections per year in year 10 (Table 1). In this scenario, prevalence increases about 20% with an estimated 1,329,000 persons living with HIV by the end of year 10. Reduction of the transmission rate by 50% within 5 years results in a reduction in the annual number of new infections of about 46%, from the baseline incidence of 55,400 new infections to 30,200 infections per year in year 5, with subsequent constant transmission rate in years 6–10 and a similar incidence in year 10 to the year 10 incidence in the scenario with 50% reduction within 10 years. Prevalence would increase about 13%, to 1,247,000.

Although at the end of 10 years the annual number of new HIV infections is similar regardless of the timeframe of the intervention (50% reduction in transmission rate in 10 vs. 5 years), reducing the transmission rate sooner (within 5 years) rather than later (within 10 years) has markedly different results on the cumulative number of infections averted (Fig. 1) and prevalence (Fig. 2). More infections are averted at the end of 10 years with a 50% reduction in the transmission rate within 5 years and a stable transmission rate from then on. However, the number of infections averted depends on the assumptions regarding the base case. The most infections are averted if we compare the interventions to the constant-transmission-rate base case, followed by the comparison to constant incidence. The fewest infections are averted if we compare the interventions to a reduction in the transmission rate according to the decrease during 2000–2006. With a 50% reduction in transmission rate within 10 years, the cumulative number of additional new HIV infections averted ranges from 47,000 to 215,000. With a 50% reduction in transmission rate within 5 years, the cumulative number of infections averted ranges from 137,000 to 306,000.

Similarly, reductions in transmission rates have the most impact on prevalence if attained in fewer years, with a marked flattening of the curve by year 4 with a 50% reduction in the transmission rate in 5 years (Fig. 2). There is a small difference in prevalence between 50% reduction in transmission rate within 10 years (1,329,000; 20% increase above baseline) compared with the assumption of continued transmission rate decrease according to years 2000–2006 (1,373,000; 24% increase above baseline).

DISCUSSION

The modeling of these hypothetical scenarios has important implications for planning for public health and

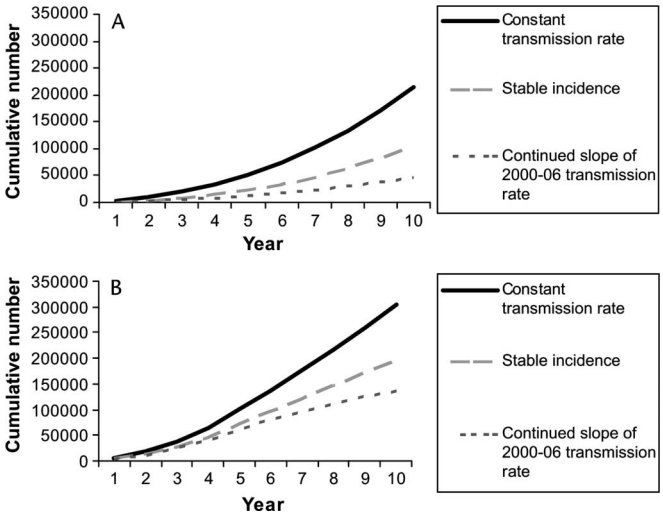

FIGURE 1. A, Cumulative number of infections averted, 50% reduction in transmission rate in 10 years compared to 3 baseline scenarios. B, Cumulative number of infections averted, 50% reduction in transmission rate in 5 years compared to 3 baseline scenarios.

health care in the United States. The base case scenarios indicate that the number of persons living with HIV in the United States would increase in the next 10 years by 24% to 38% to a total of 1,373,000 to 1,530,000. Even in the most optimistic expanded intervention scenario, the number of people living with HIV increases to 1,247,000 (13% increase). In the coming decade, already strained health care systems will likely experience substantial increases in the numbers of people living with HIV who need on-going medical care, treatment, and supportive services.

Interventions to reduce transmission rates would have the most impact if scaled up in a rapid manner, with an earlier reduction in the transmission rate resulting in more infections averted and a quicker stabilization of prevalence. Although in both scenarios presented additional infections were averted compared with base case assumptions, the magnitude of the effects achieved should be considered in light of (1) costs and benefits to society, (2) the feasibility of achieving the proposed target rates, and (3) the ability to scale up expanded interventions in a short period.

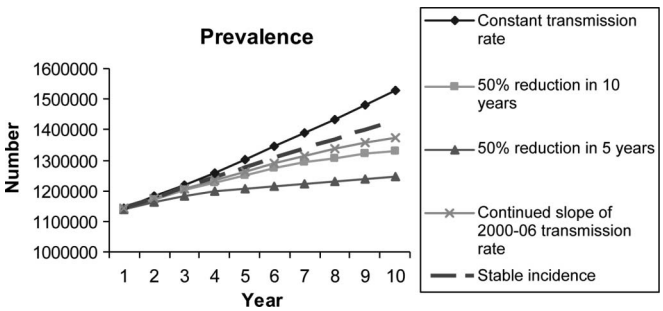

FIGURE 2. Ten-year projections of HIV prevalence with 50% reduction in transmission rate within 5 and 10 years, and base case scenarios, Unites States.

The proposed costs of intensifying prevention efforts to further reduce HIV transmission in the United States are substantial, but the potential cost savings are even greater. Assuming an average cost of $355,847 USD for life-time medical costs per new infection,[9] the baseline scenarios suggest that it will cost $128 billion (continued decline in transmission rate) to $237 billion (constant transmission rate) to treat those who become newly infected in this 10-year period. Over this 10-year timeframe, the additional costs of the proposals were $4 billion USD for the 5-year plan and $10 billion USD for the 10-year plan.[6,7] Compared against the 3 base-case scenarios, the 10-year plan would result in an estimated saving of $6.6 to 66.4 billion USD, and the 5-year plan would result in $44 to 104 billion USD of estimated savings in medical costs alone.

We have provided 3 base case scenarios that are based on different assumptions about the future of the epidemic. A stable incidence rate is plausible in light of the continued high HIV transmission among men who have sex with men (MSM), who make up the majority of persons infected with HIV, and declining incidence among other risk groups.[3,10] However, some US cities now experience more generalized epidemics that may shift HIV incidence trends within risk groups over time.[11] Continued declines in transmission rates are plausible given a growing proportion of HIV-infected persons who know their status and on-going prevention efforts that encourage HIV testing, link HIV-infected persons to medical care, and motivate reduced risk behavior among people living with and at-risk for HIV. However, continued declines in transmission rate may not be sustainable given the growing number of people living with HIV who will need prevention services and medical care. This means that more HIV-infected persons may not receive prevention and care services, which may adversely affect the future transmission rate. Our third base-case, steady transmission rate, may reflect reduced intervention efforts as a result of recent cuts in state and local funding for prevention and shifts in some communities to a more generalized epidemic. An assumption of a continuation of current prevention and care efforts may not be accurate in the current economic situation in the United States. Reduced budgets of state and local governments have resulted in cuts to HIV prevention, medical care, and treatment services. Furthermore, the economic downturn in the United States may have an impact on HIV transmission by affecting socioeconomic factors, such as poverty and homelessness,[12–14] that are associated with increased HIV risk, decreased health care utilization, and poorer health outcomes among people living with HIV.

To reduce HIV transmission to the target rate of 2.5 transmissions per 100 persons living with HIV would require a multipronged approach. The foremost intervention to attain decreased HIV transmission rates is HIV testing—coupled with ongoing prevention services and linkage to and retention in care—as those who are not aware of their infection have a transmission rate 3.5 times that of those who are aware of their infection.[8] However, currently an estimated 79% of persons living with HIV are aware of their infection[2] and we estimate the transmission rate is 3.3% among these. With a current estimated transmission rate of 3.3% among those aware of their infection, even the base case scenario assuming

a continuing slope similar to that for 2000–2006 would require intensified interventions to reduce the transmission rate below the current rate for those aware of their infection. Prevention programs will need to provide effective interventions to a larger population of people living with HIV, especially persons who currently engage in any transmission risk behavior (which is a minority of all persons living with HIV), to promote the adoption and maintenance of risk reduction practices. An earlier estimate suggests that about a 90% HIV status awareness level could be achieved among persons with HIV.[6] Therefore, additional interventions need to be in place for all persons whose behaviors place them at risk, whether infected or not.

Essential health and mental health services (in addition to those assumed to exist at current levels in the base case and expanded prevention scenarios) need to remain in place to ensure the health and well being of people living with HIV. The current scenarios are based on an assumption that people diagnosed with HIV are able to access health and mental health services and other critical supportive services, including supportive housing services, at the same levels as currently exist. If these services become more difficult to access due to increased demand or budget limitations, the ability of prevention programs to limit HIV transmission and the health of people living with HIV likely will be negatively affected.

Both enhanced prevention scenarios included expanded HIV testing, prevention with people living with HIV, and prevention for HIV-negative persons who are at risk for infection. Proven behavioral interventions for people living with HIV and many high-risk populations exist[15] and have been shown to significantly reduce HIV risk behavior.[16,17] However, although many of these interventions have been implemented in prevention programs across the country, they have not been implemented on a sufficient scale nor sufficiently targeted to those at greatest risk. Over a 1-year period only about 15% of MSM participated in individual-level and 8% in group-level interventions, which are among the most effective behavioral interventions available.[18] Further accelerating reductions in HIV transmission will require the substantial expansion of HIV testing and existing effective interventions for persons with HIV and those at risk. Improving the effectiveness of behavioral interventions, developing biomedical interventions such as antiretroviral prophylaxis or a vaccine, and further expanding HIV treatment access, including to people with higher CD4 cell counts as recently recommended,[19] all have the potential to further accelerate HIV prevention in the United States.

Both scenarios place considerable emphasis on the rapid expansion of HIV testing and prevention interventions for people living with HIV.[6,7] They differ, however, in terms of how quickly they assume prevention efforts can be expanded, the amount of capacity building needed to expand prevention programs, the allocation of resources to preventing other sexually transmitted infections that facilitate HIV transmission, and the resources allocated to surveillance, research, and prevention with uninfected persons. A separate effort to model HIV prevention resource allocations has shown that the largest impact would be gained by increasing behavioral interventions for diagnosed positives, increasing resources for interventions with high-risk groups (MSM, injection drug users, and blacks/African Americans), and increasing testing specifically among MSM and injection drug users.[20] This model supports the general approach taken in both expanded prevention scenarios, but it is not known whether either could be scaled up as quickly as proposed or whether they would achieve their goals in the specified time frames. Effects of any scaled up intervention would be delayed by the time required for capacity building and implementation at the national and local levels.

Our analyses are subject to several limitations. We have discussed the assumptions for our base case analyses above. In addition, our input parameters for modeling—the 2006 US HIV prevalence and incidence—are point estimates, with confidence intervals ±5% to 10% of the estimates. Further, we applied a constant death rate (2005) to our estimates; future death rates may differ because of better treatments for HIV, reduced services due to budget constraints, or changes in the demographic profile, such as the aging of the HIV-infected population. As such, these estimates are not precise and are highly dependent upon the quality and accuracy of these assumptions and data.

These analyses are instructive for planning for the future health care needs of a growing population of people living with HIV. This analysis shows that even in the most optimistic scenario, the number of people in the United States living with HIV who need prevention, medical care, and supportive services will increase. These data also provide needed information for setting prevention goals. In the past, some plans have called for reductions in incidence by 50%, and 1 Presidential Advisory Council on HIV/AIDS plan called for HIV incidence to be reduced to 0.[21,22] These scenarios illustrate that achieving such goals, even with intensified prevention efforts, would be challenging at best and will be affected by HIV prevalence and transmission rates. Here, we see that even a 22% reduction in the transmission rate still results in a flat incidence (and no change in the transmission rate results in a substantial increase in incidence). Hence, planning efforts that set HIV incidence goals should also set transmission rate goals so that it can be made transparent how much improvement is needed in the transmission rate to achieve a specified reduction in incidence. Further, such goal setting efforts should include analyses such as those provided here so that it can be clear whether or not the stated goals are even epidemiologically feasible given anticipated growth in HIV prevalence.

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