Annals of Internal Medicine

ARTICLE

Cost-Effectiveness of HIV Screening in Patients Older than 55 Years of Age

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Background: Although HIV infection is more prevalent in people younger than age 45 years, a substantial number of infections occur in older persons. Recent guidelines recommend HIV screening in patients age 13 to 64 years. The cost-effectiveness of HIV screening in patients age 55 to 75 years is uncertain.

Objective: To examine the costs and benefits of HIV screening in patients age 55 to 75 years.

Design: Markov model.

Data Sources: Derived from the literature.

Target Population: Patients age 55 to 75 years with unknown HIV status.

Time Horizon: Lifetime.

Perspective: Societal.

Intervention: HIV screening program for patients age 55 to 75 years compared with current practice.

Outcome Measures: Life-years, quality-adjusted life-years (QALYs), costs, and incremental cost-effectiveness.

Results of Base-Case Analysis: For a 65-year-old patient, HIV screening using traditional counseling costs $55 440 per QALY compared with current practice when the prevalence of HIV was 0.5% and the patient did not have a sexual partner at risk. In sexually active patients, the incremental cost-effectiveness ratio was $30 020 per QALY. At a prevalence of 0.1%, HIV screening cost less than $60 000 per QALY for patients younger than age 75 years with a partner at risk if less costly streamlined counseling is used.

Results of Sensitivity Analysis: Cost-effectiveness of HIV screening depended on HIV prevalence, age of the patient, counseling costs, and whether the patient was sexually active. Sensitivity analyses with other variables did not change the results substantially.

Limitations: The effects of age on the toxicity and efficacy of highly active antiretroviral therapy and death from AIDS were uncertain. Sensitivity analyses exploring these variables did not qualitatively affect the results.

Conclusion: If the tested population has an HIV prevalence of 0.1% or greater, HIV screening in persons from age 55 to 75 years reaches conventional levels of cost-effectiveness when counseling is streamlined and if the screened patient has a partner at risk. Screening patients with advanced age for HIV is economically attractive in many circumstances.

Ann Intern Med. 2008;148:889-903. www.annals.org
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Recently revised HIV screening guidelines from the Centers for Disease Control and Prevention (CDC) recommend that all patients age 13 to 64 years in health care settings be tested (1). Previous work by our group (2) and others (3–5) has demonstrated that screening for HIV in younger patients is cost-effective even in relatively low-prevalence settings. For example, we found that screening 40-year-old persons costs less than $50 000 per quality-adjusted life-year (QALY) when the prevalence of undiagnosed HIV infection is 0.05% (1 in 2000 persons) or higher (2). Although screening is cost-effective in younger age groups, approximately 19% of all people with AIDS in the United States were age 50 years or older when disease was diagnosed (6). The cost-effectiveness of screening older patients has not been evaluated and is uncertain.

There are several reasons that screening patients older than age 55 years may be less cost-effective than screening younger persons. First, the prevalence of HIV, a major determinant of cost-effectiveness, is lower in older than in younger age groups (7). Second, treatment of HIV will be less cost-effective in older persons because the competing risk for death from other causes diminishes the absolute benefits of therapy. Third, if older patients have fewer sex partners, screening will be less economically attractive because reduction of HIV transmission is an important benefit of screening, and hence a determinant of cost-effectiveness (2). Finally, neither the effectiveness nor toxicity of highly active antiretroviral therapy (HAART) in patients age 55 to 75 years has been well studied; both could be less favorable than in younger patients (8). To assess the importance of these factors, we modified our previous cost-effectiveness model to assess the cost-effectiveness of HIV screening in persons older than age 55 years.

METHODS

We estimated the health and economic effects of a program of voluntary HIV screening in patients age 55 to

See also:

Print

Web-Only

Context

Although many HIV infections occur in older adults, national guidelines recommend screening only for persons age 13 to 64 years.

Contribution

This analysis suggests that screening persons age 55 to 75 years is reasonably cost-effective under the following circumstances: HIV prevalence is 0.1% or greater; a streamlined counseling process is implemented; and the person has a partner at risk for HIV infection.

Implication

This information on the cost-effectiveness of screening in older adults should inform decisions about expanding screening recommendations to older people.

—The Editors

75 years by using a decision model, following the recommendations of the Panel on Cost-Effectiveness in Health and Medicine. We did the analysis by using a societal perspective on health benefits and costs and applying a 3% annual discount rate (9).

Decision Model

We adapted a Markov model (10, 11) that was developed to assess the cost-effectiveness of voluntary HIV screening in health care settings (2) by using Decision Maker software, version 2007.0.1 (Pratt Medical Group, Boston, Massachusetts). The model tracked a cohort of older patients during their lifetime. Patients with prevalent HIV infection (asymptomatic or symptomatic HIV or AIDS) or those who were not infected could enter the model. Each month, patients who are not infected are at risk for HIV infection. Patients who have asymptomatic disease may progress to symptomatic HIV or remain in the asymptomatic health state. Patients who have symptomatic HIV infection may progress to an AIDS-defining condition or remain with symptomatic HIV. Patients with AIDS may either die from infection or remain with AIDS. Patients either were screened through a one-time voluntary HIV screening program or were followed without routine screening. Each month, the model assessed the patients' HIV status, whether their HIV status was identified, the clinical course of HIV disease, the costs and consequences of HIV transmission, and the costs and consequences of HAART for patients identified with HIV and eligible for treatment (**Figure 1**). Persons were also at risk for age- and sex-specific death not related to HIV. Probability estimates were based on high-quality published literature and expert clinical judgment (**Table 1**) (2, 9, 12–156).

Patient Sample

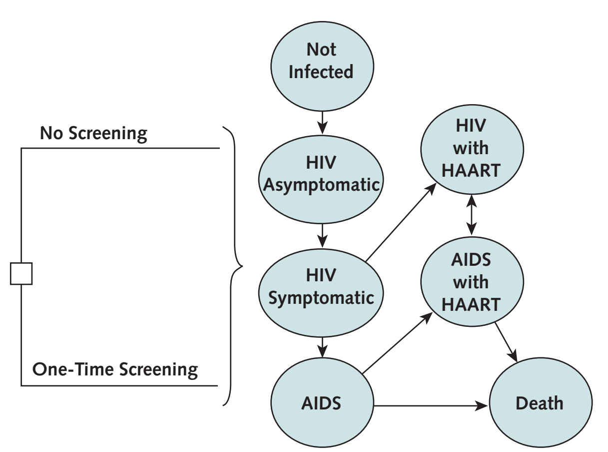
We assessed the cost-effectiveness of screening patients age 55 to 75 years who had an unknown HIV status in populations with a prevalence of unidentified HIV infection that varied from 0.1% to 1% (157). We estimated the incidence of HIV in age- and sex-specific strata based on previous models (18, 19).

HIV Testing

Patients who were not tested through an HIV screening program or who tested negative through screening could be selected for future testing through symptom-based case findings. We assumed that such case findings occurred only in patients with a CD4 count of 0.350×10^9 cells/L or less and that the probability of identifying and testing for HIV increased as the CD4 count decreased. We incorporated standard HIV testing by using a serum enzyme-linked immunosorbent assay followed by confirmatory Western blot analysis.

In our base-case analysis, patients received comprehensive pretest and posttest counseling with HIV testing. We explored the effects of streamlined counseling (abbreviated pretest counseling requirements) as recommended by the CDC (1) on HIV screening in sensitivity analyses. The benefits of testing and counseling accrued only to patients who received their test results and entered care.

Figure 1. **The Markov model.**



The square node at the left represents the decision to screen or not to screen for HIV. The patient's health thereafter is simulated by a Markov model shown on the right. Patients may enter the model with prevalent HIV infection (asymptomatic or symptomatic HIV or AIDS) or they may not be infected. Each month, patients who are not infected are at risk for HIV infection. Patients who have asymptomatic disease may progress to symptomatic HIV or remain in the asymptomatic health state. Patients who have symptomatic HIV infection may progress to an AIDS-defining condition or remain with symptomatic HIV. Patients with AIDS may either die of infection or remain with AIDS. Each month, all patients may be identified either through a voluntary screening program in the HIV screening group or through symptom-based case findings in the symptomatic HIV and AIDS health states in both the HIV screening group and the no-screening group. Throughout the patients' lifetime, all patients are at risk for non–HIV-related death. Health states are further characterized by viral load level, CD4 count, and antiretroviral treatment history (not shown). HAART = highly active antiretroviral therapy.

Table 1. **Input Variables and Sources***

Variable	Base-Case Value (Range)	Source
Demographic characteristics		
Patient age in HIV screening program, *y*	(55–75)	
Prevalence of unidentified HIV among patients, %	(0.1–1.0)	
Proportion of prevalent unidentified HIV, %		
Asymptomatic	75 (50–100)	Estimate based on references 12–17
Symptomatic	15 (0–30)	Estimate based on references 12–17
AIDS	10 (0–20)	Estimate based on references 12–17
Annual incidence, %	(0.0003–0.02)	18, 19
Proportion of sample that are women without a diagnosis of HIV, %	60 (50–70)	20
Proportion of sample that are men with a diagnosis of HIV, %	75 (50–90)	21
Proportion of sample that are men who have sex with men with a diagnosis of HIV, %	50 (25–75)	21
Relative risk for age-specific death of patients age >55 y with a diagnosis of HIV	1.0 (1.0–1.5)	22
Natural history		
CD4 count when HIV is diagnosed, $\times 10^9$ *cells/L*	0.900	23
CD4 count when symptoms start occurring, $\times 10^9$ *cells/L*	0.350 (0.250–0.500)	23
Case findings		
CD4 count when maximum case-finding rate is reached, $\times 10^9$ *cells/L*	0.050 (0–0.350)	Assumed
Maximum annual symptom-based case-finding rate, %	80 (50–100)	Assumed
HIV testing		
Adherence to HIV screening program, %	100 (50–100)	24–26
Sensitivity of screening test, first 3 mo after diagnosis, %	60 (11–83)	27–29
Sensitivity of screening test, established disease, %	99.5 (98–99.9)	27, 29, 30
Specificity of entire sequence of screening tests, %	99.9994 (99–100)	27, 29, 31
Probability that a patient returns to receive HIV test results, %	80 (70–100)	25, 32–40
Time before false-positive HIV diagnosis is discovered, *mo*	2 (0–12)	Assumed
Frequency of CD4 testing after HAART is discontinued, *mo*	3 (3–6)	41
Treatment		
CD4 count when HAART begins, $\times 10^9$ *cells/L*	0.350	41–46
Viral load when HAART begins, log_{10} *copies/mL*	4.6	41–46
Frequency of CD4 and viral load testing during HAART treatment, *mo*	3 (2–6)	41–46
Increase in CD4 count when starting HAART	110 + (535 [cdstart$^{0.98}$]/ [cdstart$^{0.98}$ + 260])†	47–51
Decrease in CD4 count with detectable viral load	−79.2 + 33.5 $\log_{10}$ viral load	52, 53
Viral load, log_{10} *copies/mL*		
Set point	4.6 (3.0–6.0)	15, 54
During virologic suppression	1.3 (1.0–2.7)	55
During virologic rebound	4.1 (3.6–4.6)	56, 57
Incremental increase above set point‡		
After suppressive therapy failed	0.8 (0–1.5)	58–66
After suppressive therapy failed and AIDS	1.0 (0–2.0)	58–66
Decrease with nonsuppressive therapy	1.0 (0–2.0)	67–71
Relative hazard of AIDS per:		
1-$\log_{10}$ copies/mL decline in plasma viral load	0.43 (0.28–0.65)	63, 65, 66, 72–88
1-$\log_{10}$ $\times 10^9$ cells/L increase in CD4 count	0.0154 (0.0002–1.0)	
Relative hazard of death from AIDS per:		
1-$\log_{10}$ copies/mL decline in plasma viral load	0.64 (0.55–0.75)	
1-$\log_{10}$ $\times 10^9$ cells/L increase in CD4 count	0.118 (0.064–0.329)	
Probability of achieving virologic suppression		
First regimen %	80 (30–98)	12, 66–72, 77, 79, 90, 91, 108–144
Second regimen, %	65 (20–80)	
Third regimen, %	30 (5–40)	
Relative risk for achieving suppression in patients age >55 y	1.0 (0.5–1.0)	89–98
Rates of virologic rebound		
First rebound at 2 y, %	15 (6–30)	55, 68, 98–114
Per subsequent regimen (relative hazard)	2.0 (1.0–6.0)	100, 109, 115, 116
Intolerance requiring discontinuation (relative risk), %		
First regimen	25 (5–40)	67–69, 98, 102, 103, 107, 111, 112, 115, 117–126
Second regimen	1.0 (1–4)	
Third regimen	1.4 (1–4)	
Patients age >55 y	1.0 (1.0–1.50)	91, 94, 96

Continued on following page

Table 1—Continued

Variable	Base-Case Value (Range)	Source
Transition rate, *events/100 patient-years*		
From HIV to AIDS	6 (2–12)	52, 77, 84
From AIDS to death	3 (1–10)	84
Transmission		
Age of patients' sexual partners, *y*	(55–75)	Assumed to be the same as the patient with HIV
Susceptible partners at risk, *n*	1 (0–10)	127, 128
Annual probability of transmitting HIV to a sexual partner, %		
Men who have sex with men	4 (1–5)	103, 129–131
Heterosexual men	3 (0.5–5)	132–136
Heterosexual women	1 (0.5–4)	132–135
Relative risk for infectivity given 1-$\log_{10}$ copies/mL change in viral load	2.45 (1–3)	137
Effectiveness of testing and counseling in reducing the number of sexual transmissions (reduction in infectivity), %	20 (0–50)	138–140
Costs, $		
HIV test, negative result	12.41 (1–20)	Cost of ELISA test at VA Palo Alto Health Care System based on Medicare pricing
HIV test, positive result	51.87 (40–60)	Cost of ELISA and Western blot tests at VA Palo Alto Health Care System based on Medicare pricing
HIV pretest counseling	35 (5–60)	Estimate based on references 2 and 27 and VA Palo Alto Health Care System time–cost analysis (unpublished data)
HIV posttest counseling after a negative test result	10 (2–30)	Estimate based on references 2 and 27 and VA Palo Alto Health Care System time–cost analysis (unpublished data)
HIV posttest counseling after a positive test result	35 (10–100)	Estimate based on references 2 and 27 and VA Palo Alto Health Care System time–cost analysis (unpublished data)
CD4 count, per test	96 (65–120)	141
Viral load, per test	127 (90–200)	141
Annual cost for HIV infection while receiving HAART§		
CD4 count $>0.500 \times 10^9$ cells/L	3112 (2228–5000)	142, 143
CD4 count $0.200–0.50 \times 10^9$ cells/L	5324 (3821–6369)	142, 143
CD4 count $<0.200 \times 10^9$ cells/L	7937 (5697–12 000)	142, 143
Annual cost for AIDS while receiving HAART§	11 491 (8251–25 000)	142, 143
3-drug antiretroviral therapy	14 369 (251–16 307)	41, 144–147
Incremental cost for 4-drug antiretroviral therapy	2588 (1540–12 579)	41, 144–147
Annual cost for salvage therapy	16 957 (0–28 885)	41, 144–147
HAART side effects, per episode	155 (98–733)	148–150
Age-specific medical costs unrelated to HIV	(2672–4210)	Based on age-specific health care expenditures‖
Quality of life		
Current health		Sex- and age-specific utilities for current health from reference 151
Asymptomatic HIV infection, unknown	0.91 (0.85–1.0)	156
Asymptomatic HIV infection, diagnosed		
First year	0.84 (0.80–1.0)	156
Subsequent years	0.89 (0.80–1.0)	156
Symptomatic (untreated) HIV	0.79 (0.45–1.0)	152–156
HIV infection while receiving HAART	0.83 (0.45–1.0)	152–156
AIDS	0.73 (0.24–0.80)	152–156
Quality-of-life loss with HAART side effects (multiplier)	0.53 (0.44–0.62)	2, 149, 150
Other		
Discount rate (annual), %	3 (0–5)	9
Cycle length, *mo*	1	Assumed

* All probabilities are annual unless otherwise noted. Monthly transition probabilities were estimated where needed on the basis of annual probabilities using the relationship of $P = 1 - e^{-rt}$. All costs are in 2007 U.S. dollars. ELISA = enzyme-linked immunosorbent assay; HAART = highly active antiretroviral therapy; VA = Veterans Affairs.
† The term "cdstart" denotes the initial CD4 count. We assumed that all patients had an increase of at least 0.060×10^9 cells/L.
‡ Maximum viral load was 6.0 $\log_{10}$ copies/mL.
§ Treatment costs are listed exclusive of HAART cost.
‖ Data from www.bls.gov/cex/csxann05.pdf.

HIV Disease Progression and Treatment

We modeled HIV disease progression by using HIV viral load copy number and CD4 count and drawing on natural history data (**Table 1**) (52, 77, 84). We assumed that treatment of HIV infection would adhere to published treatment guidelines, including appropriate prophylaxis and immunization (41, 42). We assumed that HAART was initiated when an identified HIV-infected patient's CD4 count decreased to 0.35×10^9 cells/L or less. Once HAART was initiated, we modeled the possible increase in CD4 count, virologic suppression, treatment-related toxicity, and virologic rebound. We assumed that patients with drug-related adverse effects switched to a new regimen and had the same probability of achieving suppression as they did with the initial regimen. In contrast, we assumed that patients who had virologic failure and were identified through viral load testing were switched to a new regimen with a reduced likelihood of achieving virologic suppression (**Table 1**). We assumed that after being treated with 3 successive antiretroviral regimens, a patient could achieve only partial virologic suppression because of multidrug resistance. We assessed varying assumptions about the efficacy of treatment of such patients in sensitivity analysis.

Effectiveness and Toxicity of HAART in Patients Older Than Age 55 Years

Substantial uncertainty exists about the effectiveness of HAART and the course of HIV infection among older patients. Although patients older than age 55 years may have higher rates of virologic suppression (perhaps because of better adherence or altered pharmacodynamics), the evidence about immunologic effects in patients in this sample is inconsistent. Although several studies have suggested that older patients have a longer time to CD4 reconstitution after starting HAART (89–91, 94, 98), other studies have found no differences or differences in the first year only (8, 92, 93, 95–97). Studies have similarly differed about whether older age is an independent risk factor for disease progression (90, 158). The evidence about the toxicity of antiretrovirals in older patients is even more limited. Although there are many reasons to suspect that older patients do not tolerate antiretrovirals as well as younger patients (such as cardiovascular and hepatic events), the evidence for this assertion is still weak (8, 91, 94, 96).

We approached the modeling of HAART effectiveness and toxicity in patients older than age 55 years, recognizing that the evidence for age effects is generally based on observational studies that are often small and with considerable potential for residual confounding. To address the uncertainty around these age effects and explore their potential impact, our base-case model assumed no difference in antiretroviral efficacy for older patients, but we included specific scenarios in which we modeled 3 effects that may be related to older age: greater failure rates with HAART, greater treatment-limiting toxicities, and greater age-specific death not related to AIDS.

Transmission of HIV

We included the potential costs and health benefits associated with transmission of HIV from an infected individual to their sexual partners in our analysis. Transmission depended on the infected patient's sex, type of sexual activity, number of sexual partners, knowledge of HIV status, and viral load (**Table 1**). We assumed that a sexually active patient age 55 to 75 years would have, on average, 1 partner at risk for infection. In addition, we tested the situation in which patients had no sexual partners or several partners (**Appendix**, available at www.annals.org).

Quality of Life

The model incorporated adjustments for the quality of life associated with age-specific current health, HIV disease (asymptomatic HIV, symptomatic HIV, and AIDS), and HAART (**Table 1**). Utilities measure the patient's quality of life and were rated on a scale from 0 to 1, in which 0 represents death and 1 represents ideal health. We multiplied utilities on the basis of HIV-related health status and knowledge by using age-specific utility weights derived from the Beaver Dam Health Outcomes Study (151).

Costs

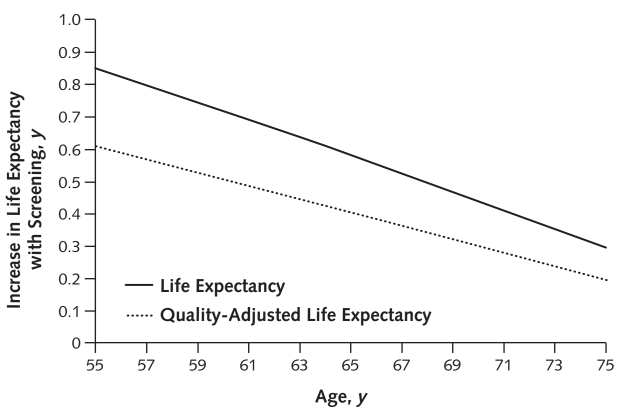
Our analysis included the direct costs of medical care associated with HIV testing and counseling, follow-up, and treatment of patients identified with HIV infection through a screening program or through a symptom-based case finding (**Table 1**). We included age-specific medical expenditures unrelated to HIV care (www.bls.gov/cex/csxann05.pdf) and updated all costs to 2007 dollars by using the gross domestic product deflator (159). Although some economists consider the gross domestic product deflator a more robust estimate of inflation than the consumer price index, it generally yields similar or slightly more conservative estimates of current costs.

Sensitivity Analyses

We did 1-way and multiway sensitivity analyses to account for important model assumptions and uncertainties. For clinical variables, our ranges for sensitivity analyses represent our judgment of the variation likely to be encountered in clinical practice on the basis of both the literature and discussion with experts.

To estimate the uncertainty in our findings, we did a probabilistic sensitivity analysis. We assigned distributions to 20 variables that described the natural history of HIV and effectiveness of HAART in older patients (**Appendix**, available at www.annals.org). We selected distributions appropriate to the type of variable (for example, we modeled probabilities using a β-distribution) and selected corresponding measurements by using the method of moments. For variables that represented alternative scenarios rather than uncertain estimates, we sampled from discrete distributions, reflecting our belief that the likelihood of each scenario is true. We did a second-order Monte Carlo simulation with 1000 iterations over the sampled distributions.

Figure 2. **Effect of early identification of HIV infection on life expectancy.**



The solid line represents the effect on undiscounted life expectancy and the dotted line represents the effect on undiscounted quality-adjusted life expectancy of identifying asymptomatic HIV infection compared with symptom-based case findings.

Model Calibration and Validation

Calibration and validation of the decision model and its outputs occurred as an iterative process throughout its development. To assess the output of the model, we compared our predicted time from infection until death for untreated patients (10.3 years to 13.4 years) with published estimates (12.1 years) (103). To assess our long-term estimates of treatment efficacy, we compared the estimated proportion of patients with multidrug-resistant virus at 10 years (7.2%) with published estimates (9.2% [95% CI 5.0% to 13.4%]) (66). Finally, we compared our model's estimate of life expectancy for patients with identified HIV receiving HAART (varying from 14.9 to 18.5 years) with modeled estimates by King and colleagues (160) and Paltiel and colleagues (4).

Role of the Funding Source

This research is supported in part by the Department of Veterans Affairs, the National Institute on Drug Abuse (R01 DA15612-01), the National Institute of Aging through the Stanford Center on the Demography and Economics of Health and Aging (P30-AG017253), the Ontario HIV Treatment Network, and the Ontario Ministry of Health and Long-Term Care. The funding sources had no role in the design or implementation of the study or in the decision to seek publication.

RESULTS

Benefit of Screening: Early Identification of HIV

We estimated the increase in survival that resulted from early identification of asymptomatic HIV and initiation of HAART through a screening program compared with identification on the basis of case finding. The benefit varied depending on age and decreased for older patients. For a 65-year-old HIV-infected patient, early identification and treatment increased life expectancy by 0.58 year or 0.41 QALY. For a 75-year-old HIV-infected patient, the benefit was 0.30 year or 0.20 QALY (**Figure 2**). The **Appendix** (available at www.annals.org) shows how increases in life expectancy from a one-time HIV screening program in the U.S. population age 55 to 64 years could save more than 120 000 life-years attributed to almost 170 000 persons. In the cohort of persons age 65 to 74 years, almost 92 000 persons would gain an additional 40 000 life-years.

Cost-Effectiveness of HIV Screening

The costs and benefits of voluntary one-time HIV screening for patients age 55 to 75 years depended on the prevalence of unidentified HIV, the age of the patient, and whether the patient has a sexual partner at risk for infection.

Benefit of HIV Screening for Patients with a Sexual Partner at Risk

If a patient has an uninfected partner at risk for infection and the prevalence of unidentified HIV was 0.5%, a voluntary one-time screening program improved life expectancy in 65-year-old patients by 1.56 days or 1.31 quality-adjusted life-days, at a cost of $107 relative to current practice (incremental cost-effectiveness, $30 020 per QALY) (**Figure 3**). For a 75-year-old patient, the incremental cost was $90, whereas incremental life expectancy was 0.95 day or 0.79 quality-adjusted life-day (incremental cost-effectiveness, $41 520 per QALY). At a lower HIV prevalence of 0.1%, the incremental cost-effectiveness of screening a 65-year-old with a sexual partner at risk was $91 410 per QALY. At this prevalence, HIV screening exceeds $100 000 per QALY for patients age 70 years or older (**Table 2** and **Figure 3**) if traditional pretest (estimated cost, $35) and posttest (estimated cost, $10 for negative test results and $35 for positive test results) counseling is used.

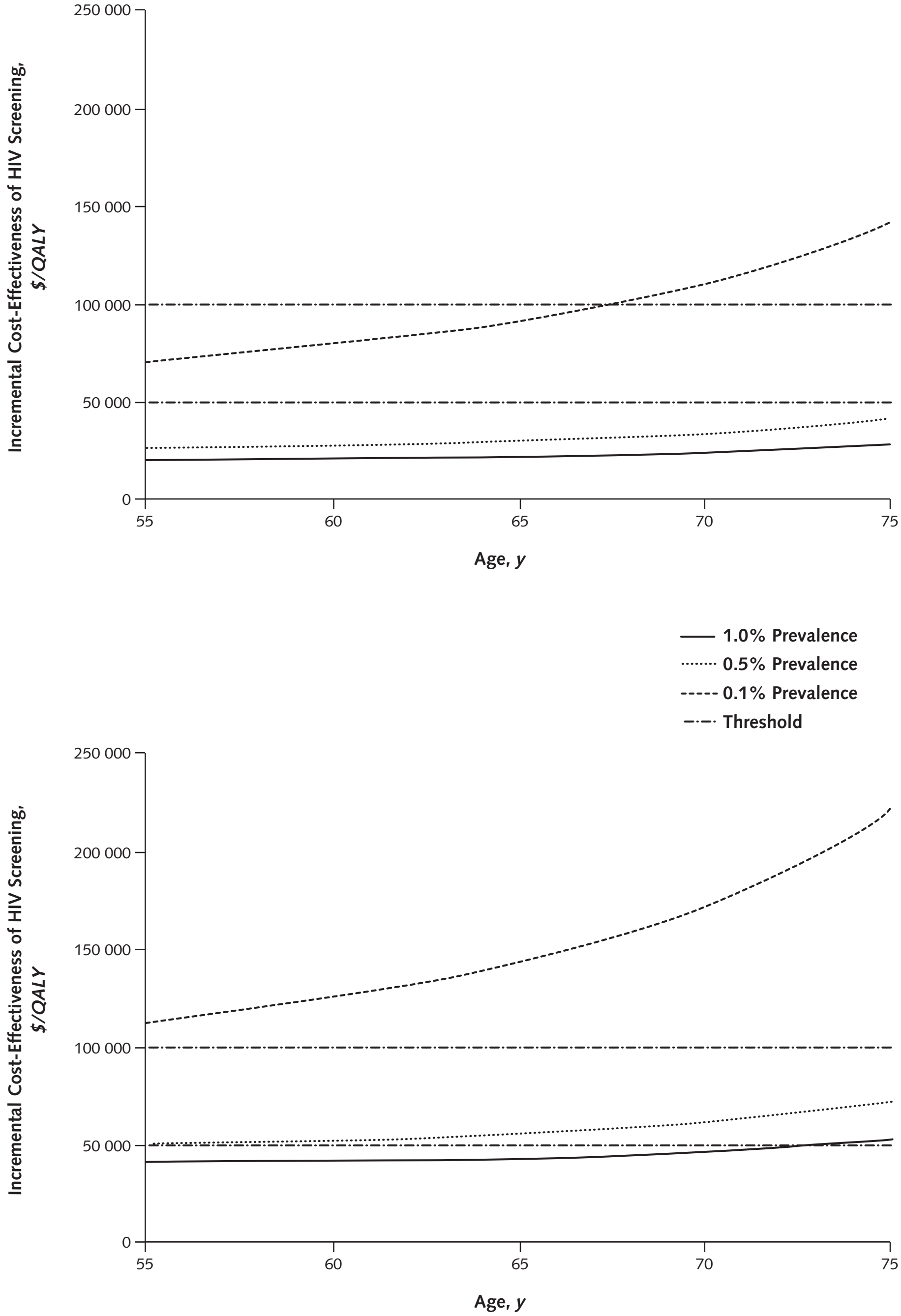
Benefit of HIV Screening for Patients without a Partner at Risk

If a patient does not have a partner at risk for infection, HIV screening costs less than $100 000 per QALY for all patients (age ≤80 years) if the prevalence of unidentified HIV is greater than 0.5% (**Figure 3**). For a 65-year-old patient, HIV screening using traditional counseling costs $55 440 per QALY compared with current practice when the prevalence of HIV is 0.5%. At an HIV prevalence of 0.1%, however, screening a patient (age ≥50 years) without a sexual partner increases costs to more than $100 000 per QALY (**Table 2** and **Figure 3**) with traditional counseling.

Effect of Streamlined Counseling on Cost-Effectiveness of HIV Screening

Current CDC guidelines for HIV screening recommend streamlined counseling, which reduces the time and costs associated with pretest counseling and, for those who test negative, posttest counseling (1). On the basis of a

Figure 3. **Incremental cost-effectiveness of HIV screening in patients older than age 55 years who receive traditional counseling.**



QALY = quality-adjusted life-year. **Top.** Patients with a sexual partner at risk. **Bottom.** Patients without a partner at risk. Each part represents the incremental cost-effectiveness of HIV screening (assuming implementation of traditional counseling) compared with current practice for patients of varying ages with differing underlying prevalence of unidentified HIV. The dashed-and-dotted line indicates a cost-effectiveness threshold of $50 000 and $100 000 per QALY.

recent time–cost analysis by the Veterans Affairs Quality Enhancement Research Initiative for HIV and Hepatitis, we assumed that pretest counseling costs would be reduced (from $35 to $5) relative to comprehensive counseling, posttest counseling for patients who tested negative would be reduced (from $10 to $2), and posttest counseling for patients who tested positive would remain unchanged ($35). We further assumed that streamlined counseling did not affect either adherence with screening or modification of risk behaviors. Under these assumptions, the incremental cost-effectiveness of HIV screening was more economically attractive at all

Table 2. **Health and Economic Outcomes with Traditional Counseling***

Screening Strategy	Cost, $	Incremental Cost, $	Life Expectancy, y	Incremental Life Expectancy, d	Incremental Cost-Effectiveness, $/LY	Quality-Adjusted Life Expectancy, QALYs	Incremental Quality-Adjusted Life Expectancy, QALDs	Incremental Cost-Effectiveness, $/QALY
Patients with a sexual partner at risk								
Age 55 y, no screening	47 646	–	16.847	–	–	14.276	–	–
Age 55 y, HIV screening	47 716	70	16.846	0.44	59 230	14.277	0.36	71 060
Age 60 y, no screening	44 297	–	14.872	–	–	12.466	–	–
Age 60 y, HIV screening	44 365	68	14.873	0.38	65 850	12.467	0.31	78 910
Age 65 y, no screening	40 242	–	12.857	–	–	10.607	–	–
Age 65 y, HIV screening	40 308	66	12.858	0.33	76 570	10.608	0.26	91 410
Age 70 y, no screening	35 499	–	10.808	–	–	8.853	–	–
Age 70 y, HIV screening	35 563	64	10.808	0.25	93 010	8.854	0.21	110 630
Age 75 y, no screening	30 344	–	8.815	–	–	7.135	–	–
Age 75 y, HIV screening	30 406	62	8.816	0.18	119 820	7.135	0.16	143 060
Patients without a partner at risk								
Age 55 y, no screening	47 561	–	16.851	–	–	14.280	–	–
Age 55 y, HIV screening	47 640	79	16.852	0.37	81 200	14.281	0.26	112 180
Age 60 y, no screening	44 244	–	14.874	–	–	12.469	–	–
Age 60 y, HIV screening	44 320	76	14.875	0.31	89 010	12.469	0.22	124 680
Age 65 y, no screening	40 212	–	12.858	–	–	10.608	–	–
Age 65 y, HIV screening	40 285	72	12.859	0.26	101 240	10.609	0.18	142 700
Age 70 y, no screening	35 481	–	10.808	–	–	8.854	–	–
Age 70 y, HIV screening	35 550	69	10.809	0.21	121 090	8.855	0.15	172 090
Age 75 y, no screening	30 333	–	8.816	–	–	7.135	–	–
Age 75 y, HIV screening	30 398	65	8.816	0.15	154 880	7.136	0.11	222 920

* Prevalence of HIV is 0.1%. Costs and life expectancy estimates are discounted at 3% annually. LY = life-year; QALD = quality-adjusted life-day; QALY = quality-adjusted life-year.

ages and prevalences of HIV (**Figure 4**). For patients with a sexual partner at risk, HIV screening incorporating streamlined counseling would cost less than $60 000 per QALY compared with current practice for patients age 75 years or younger, even if the prevalence of unidentified HIV was as low as 0.1% (**Figure 4**). For patients without a partner at risk, HIV screening that incorporates streamlined counseling costs less than $100 000 per QALY for patients from populations in which the HIV prevalence is 0.1% if patients were age 75 years or younger (**Figure 4**) and costs less than $50 000 per QALY at a prevalence of 0.5%.

Sensitivity Analysis

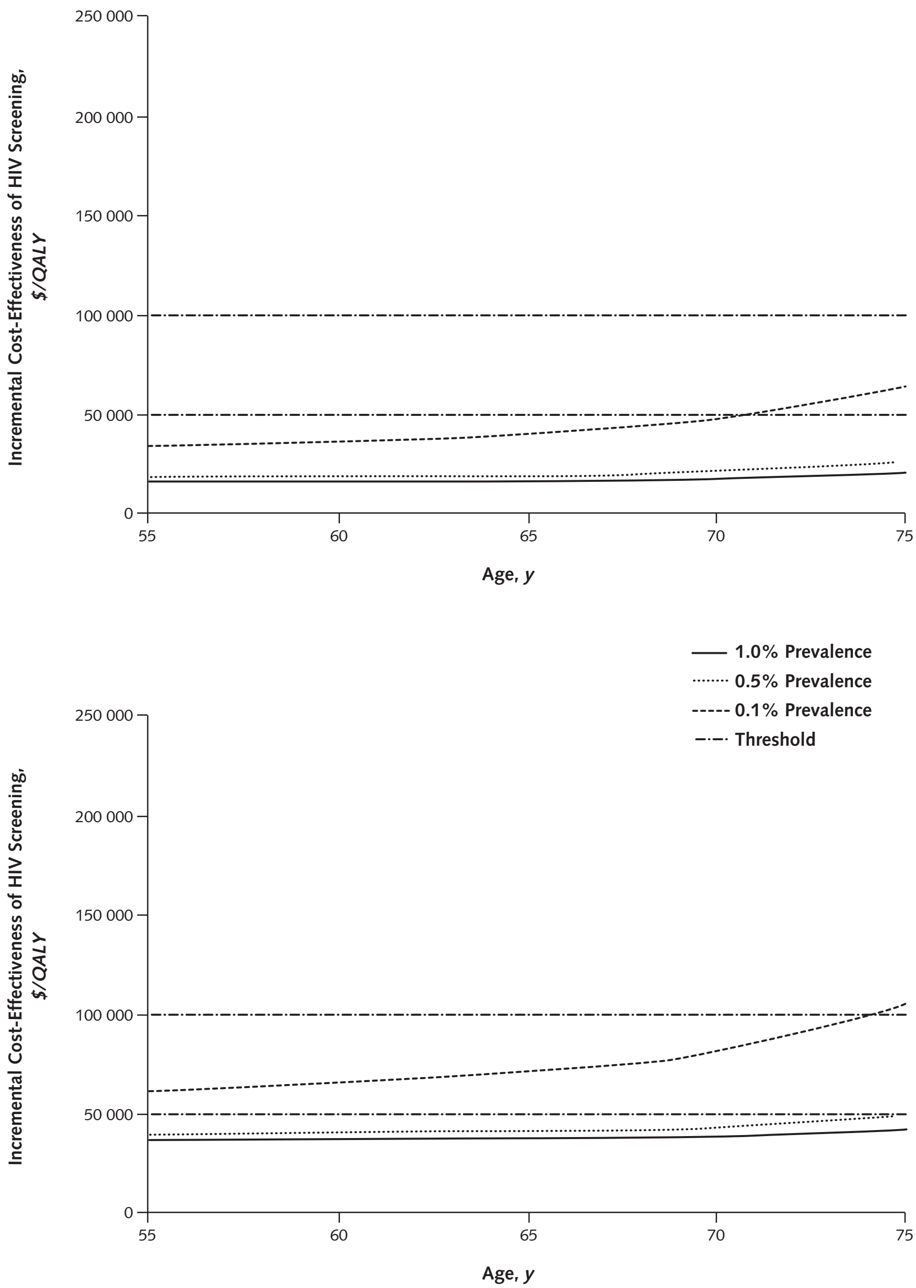
We evaluated scenarios in which HAART was less effective or more toxic in older patients. After assuming that the failure rate of HAART was increased by 20% in patients older than age 55 years, HIV screening with traditional counseling costs less than $60 000 per QALY for patients of all ages if they had a sexual partner at risk and the unidentified HIV prevalence in the sample was greater than 0.5%. If the unidentified prevalence of HIV was 0.1%, HIV screening costs less than $65 000 per QALY for patients age 75 years or younger with streamlined counseling.

The assumption that HAART-related toxicity requiring treatment change increased by 25% in patients older than age 55 years had minimal effects on the analysis and did not qualitatively change our results. It is also uncertain whether the non-AIDS, age-specific death of HIV-positive patients is increased compared with uninfected patients. We therefore evaluated the effect of HIV screening if we assumed that HIV-positive patients had an age-specific death 25% greater than that of an uninfected cohort. Again, these assumptions did not qualitatively affect the results of our analysis. Finally, when we varied all 3 of these assumptions simultaneously for patients with a partner at risk, HIV screening with traditional counseling cost less than $65 000 per QALY if the unidentified prevalence of HIV was 0.5% or greater. If the unidentified prevalence of HIV was 0.1%, HIV screening cost less than $70 000 per QALY for patients age 75 years or younger with streamlined counseling.

We did a probabilistic sensitivity analysis in which we simultaneously varied the values of variables defining the natural history of HIV and effectiveness of HAART in older patients. Assuming traditional counseling costs for patients age 65 to 74 years with a sexual partner at risk from a population with the prevalence of unidentified HIV ranging from 0.2% to 1.2%, the probabilistic sensitivity analysis estimated a median and mean incremental cost-effectiveness ratio of $36 980 per QALY and $44 530 per QALY, respectively. A cost-effectiveness acceptability curve (**Appendix**, available at www.annals.org) demonstrated that, at a willingness-to-pay threshold of $50 000 per QALY, the probability that HIV screening in this sample was cost-effective was 75%. The probability that HIV screening with traditional counseling costs was cost-effective with a willingness-to-pay threshold of $100 000 per QALY was 96%.

With streamlined counseling, the probabilistic sensitivity analysis predicted a median and mean incremental cost-effectiveness ratio of $22 460 per QALY and $24 420 per QALY, respectively. The cost-effectiveness acceptability curve (**Appendix**, available at www.annals.org) with streamlined counseling demonstrates that, at a willingness-to-pay threshold of $50 000 per QALY, the probability

Figure 4. **Incremental cost-effectiveness of HIV screening in patients older than age 55 years who receive streamlined counseling.**



QALY = quality-adjusted life-year. **Top.** Patients with a sexual partner at risk. **Bottom.** Patients without a partner at risk. Each part represents the incremental cost-effectiveness of HIV screening (assuming implementation of streamlined counseling) compared with current practice for patients of varying ages with differing underlying prevalence of unidentified HIV. The dashed-and-dotted line indicates a cost-effectiveness threshold of $50 000 and $100 000 per QALY.

that HIV screening in this sample with streamlined counseling is cost-effective was 97%.

The **Appendix** (available at www.annals.org) includes results of additional sensitivity analyses. Sensitivity analyses with other model variables (**Table 1**) did not change our results substantially.

DISCUSSION

We found that the cost-effectiveness of screening in patients age 55 to 75 years compares favorably with that of other interventions that are accepted as good uses of resources, particularly if providers implement screening with streamlined counseling and if the person being screened has a sexual partner at risk. Under these circumstances, screening costs less than $60 000 per QALY gained, even with an unidentified prevalence as low as 0.1%. Screening at age 64 years, as recommended by the CDC, costs about $41 000 per QALY gained with streamlined counseling and a partner at risk. Screening is more expensive for patients who do not have a partner at risk or if traditional counseling is used.

Although evidence about the prevalence of HIV in the older age groups is sparse, the limited available data suggest that the prevalence is sufficiently high for screening to be cost-effective. In a blinded serologic survey of 8627 inpatients and outpatients at 6 Department of Veterans Affairs health care systems, we found the prevalence of undocumented HIV infection to be 0.7% (CI, 0.2% to 1.7%) in outpatients age 55 to 64 years, 0.5% (CI, 0.2% to 1.2%) in outpatients age 65 to 74 years, and 0.1% (CI, 0.0% to 0.06%) in outpatients age 75 years or older (157). Because the Veterans Affairs sample differs from other health care settings, evidence about the prevalence of undocumented HIV in the groups with patients older than age 55 years from other populations would be useful to help guide screening decisions. We note, however, that among outpatients age 65 to 74 years, the prevalence in other settings could be only one fifth as high as we found, and screening with streamlined counseling would still be cost-effective for patients who are sexually active.

As noted, an important determinant of the cost-effectiveness of screening is whether the screened person has a sexual partner at risk. A recent study used a probability sample of 3005 U.S. adults and found that 73% of people age 57 to 64 years, 53% of people age 65 to 74 years, and 26% of people age 75 to 85 years were sexually active (161). The National Health and Social Science Survey in 1992 studied 3492 members of the U.S. general population and found that 84% of persons age 50 to 54 years and 69% of those age 55 to 59 years had at least 1 sexual partner in the past year. The National AIDS Behavioral Surveys administered from 1991 to 1992 estimated that the prevalence of having at least 1 risk factor for HIV infection was approximately 10% among persons age 50 years or older. In addition, a small percentage of those persons with a known risk for HIV infection used condoms during sex or had undergone testing and were much less likely to have adopted these prevention strategies than younger persons who engaged in the same behavioral risks (162). These studies suggest that a significant number of people older than age 50 years have risk factors for HIV and that most persons age 75 years or younger have a partner at risk for infection.

On the basis of the results of our cost-effectiveness analyses, the data available on prevalence, and the relatively high rates of sexual activity in people older than age 55 years, we recommend one-time voluntary HIV screening with streamlined counseling on a routine basis for all persons age 55 to 64 years and one-time screening on a targeted basis to sexually active persons age 65 to 74 years if the HIV prevalence is greater than 0.1%. For people age 65 to 74 years who do not have a partner at risk, screening costs between $50 000 and $100 000 per QALY gained with prevalence between 0.1% and 0.5%. Thus, screening is more expensive if the person is not sexually active, but it is still a reasonable option, particularly if prevalence approaches 0.5%.

One approach that providers can use to estimate the prevalence of HIV is to begin a screening program and assess the number of positive test results in the screened population. If approximately 4000 persons are screened without a positive result, a prevalence of 0.1% can be excluded with 95% confidence, and the sample would fall outside the prevalence threshold (0.1%) recommended for screening by the CDC (1).

The cost-effectiveness of screening remained favorable if HAART was modestly less effective or led to modestly higher rates of adverse events than in younger patients. An increase in age-specific death of 25% in infected patients did not substantively change the cost-effectiveness of screening. This finding would not hold for patients whose life expectancy was substantially shortened by diseases with a high mortality rate, such as cancer or congestive heart failure. In general, however, our findings support the usefulness of screening older persons who do not have comorbid conditions with high mortality rates if the prevalence of HIV is greater than 0.1% to 0.5%. Our analysis included 3 suppressive antiviral regimens before beginning nonsuppressive therapy. With the approval of new antiretrovirals, a fourth suppressive regimen may be feasible; thus, we may have underestimated the benefit from antiretroviral therapy in elderly persons.

In conclusion, we found that routine HIV screening is cost-effective in the age range (age ≤64 years) and prevalence (>0.1%) recommended by the CDC. If the screened sample has an unidentified prevalence of 0.1% or greater, HIV screening in older persons (age 65 to 75 years) can also reach conventional levels of cost-effectiveness if screening can be done inexpensively, such as by using streamlined counseling. Our analyses suggest that screening decisions in patients older than age 64 years should consider whether partners are at risk, cost, and whether the patient has life-threatening comorbid conditions. Advanced age alone should not preclude screening for HIV. Rather, for many people in this age group, the cost-effectiveness of screening is within the range of that of other accepted interventions.

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Disclaimer: The views expressed in this publication are the views of the authors and do not necessarily reflect the views of the Ontario Ministry of Health and Long-Term Care.

Grant Support: This research is supported in part by the Department of Veterans Affairs, the National Institute on Drug Abuse (R01 DA15612-01); the National Institute of Aging through the Stanford Center on the Demography and Economics of Health and Aging (P30-AG017253); the Ontario HIV Treatment Network; and the Ontario Ministry of Health and Long-Term Care.

Potential Financial Conflicts of Interest: None disclosed.

Reproducible Research Statement: *Study protocol:* Available from Dr. Sanders (e-mail, gillian.sanders@duke.edu). *Statistical code:* Not available. *Data set:* Available from Dr. Sanders (e-mail, gillian.sanders@duke.edu).

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APPENDIX

Public Health Benefit of HIV Screening

To estimate the public health benefit of HIV screening within the current U.S. population, we used the results of a blinded serologic survey of HIV within the Veterans Affairs sample (157), the impact of HIV screening and early identification on life expectancy (**Figure 2**), and the current population of the United States. These data were used to estimate the life expectancy gain in the current U.S. population from early HIV identification through a one-time, voluntary HIV screening program. **Appendix Table 1** shows that under these assumptions, a one-time HIV screening program in the current U.S. population (age 55 to 64 years) would save more than 120 000 life-years attributed to almost 170 000 persons. In the cohort of persons age 65 to 74 years, an additional 40 000 life-years would be gained by almost 92 000 persons (**Appendix Table 1**).

HIV Screening Frequency

In our main analyses, we focused on the incremental cost-effectiveness of a one-time voluntary HIV screening program and compared it with current practice. In sensitivity analyses, however, we wanted to explore the incremental costs and benefits of a repeated HIV screening program—especially in populations in which the incidence of HIV may be increased. **Appendix Figure 1** demonstrates the impact of screening frequency on the incremental cost-effectiveness of screening at various HIV incidence rates, assuming that patients are 55 years of age and the prevalence of HIV is 1% in the cohort. The incremental cost-effectiveness ratio compares screening every A years with screening every B years, in which B refers to the screening frequency directly to the left of A on the x-axis (that is, comparing screening every 3 years with screening every 5 years). Recurrent screening becomes more economically favorable as the incidence increased, yet one-time screening seems to be the best use of limited health care resources in these older cohorts. We found similar findings in older cohorts and at varying prevalences.

Efficacy of Nonsuppressive Therapy

To explore the effect of additional regimens or increased efficacy of nonsuppressive therapy, we varied the decrement in viral load that patients received while receiving nonsuppressive therapy. Under our base-case assumptions (1-$\log_{10}$ copies/mL decrement with nonsuppressive therapy), screening a 55-year-old individual with a sexual partner at risk for HIV cost $71 060 per QALY compared with current practice if the prevalence of unidentified HIV was 0.1%. Under these same assumptions, screening a 75-year-old individual for HIV cost $143 060 per QALY compared with current practice. If the decrement in viral load realized through nonsuppressive therapy was increased to 2 $\log_{10}$ copies/mL, the incremental cost-effectiveness of HIV screening became more favorable at $56 250 per QALY and $118 480 per QALY in persons age 55 and 75 years with a partner at risk. Similarly, if the decrement in viral load was increased to 4 $\log_{10}$ copies/mL, the incremental cost-effectiveness ratios of HIV screening was further reduced in the 55- and 75-year-old cohorts (to $43 780 per QALY and $110 980 per QALY).

Cost and Efficacy of Streamlined Counseling

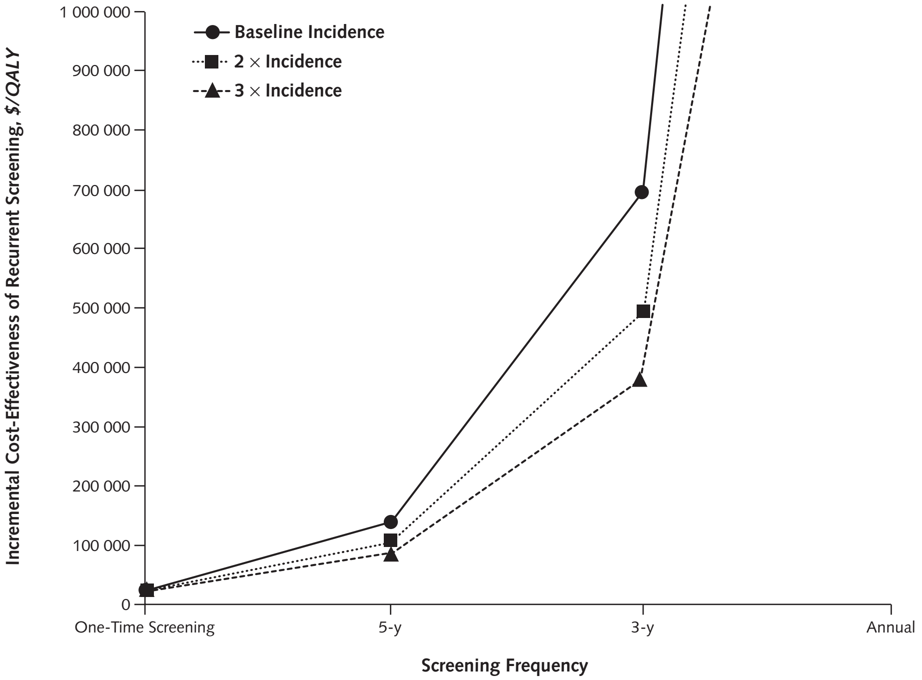
Because the cost and feasibility of streamlined counseling in elderly patients with competing comorbid conditions and previous testing is uncertain, we explored the effect of a more expensive streamlined counseling scenario in sensitivity analyses. In this analysis, we assumed that a pretest counseling session cost $15 (base-case value of $5 in our streamlined analysis), and that posttest counseling for a negative test result cost $5 (base-case value of $2 in our original streamlined analysis). In our original anal-

Appendix Table 1. **Estimated Public Health Benefit of HIV Screening**

Variable	Age Cohort	
	55–64 Years	65–74 Years
U.S. population, *n**	24 274 684	18 390 986
Prevalence of unidentified HIV (95% CI), %†	0.7 (0.2–1.7)	0.5 (0.2–1.2)
Estimated number of HIV-infected persons unaware of their HIV status (range), *n*	169 923 (48 549–412 670)	91 955 (36 782–220 692)
Estimated life expectancy gain per person from early HIV identification, *y*	0.7227	0.4391
Estimated life expectancy gain in current U.S. population from early HIV identification (range), *y*	122 805 (35 087–298 242)	40 374 (16 150–96 899)

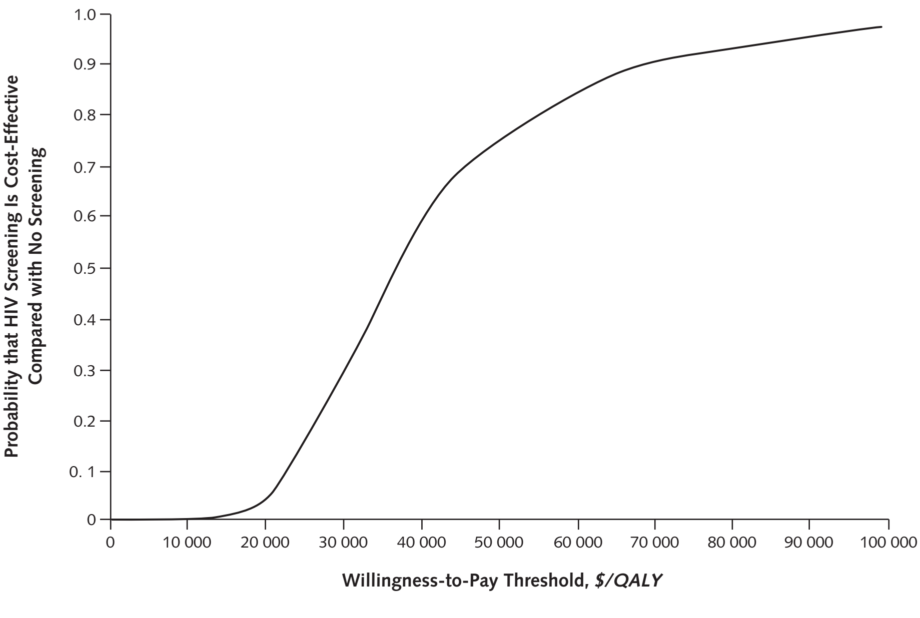
* Based on 2000 U.S. census data.
† Estimated from blinded serologic survey of 8627 inpatients and outpatients at 6 Department of Veterans Affairs health care systems (157).

Appendix Figure 1. **Effect of screening frequency on the incremental cost-effectiveness of screening at various HIV incidence rates.**



The solid line marked with solid circles represents the baseline incidence, the dotted line marked with solid squares represents the cost-effectiveness of recurrent screening when the incidence of HIV is twice the baseline rate, and the dashed line marked with solid triangles represents the cost-effectiveness of recurrent screening when the incidence of HIV is 3 times the baseline rate.

Appendix Figure 2. **Cost-effectiveness acceptability curve of HIV screening, assuming traditional counseling.**



Appendix Table 2. **Parametric Distributions Used in Probabilistic Sensitivity Analysis***

Variable	Mean (±SE)	Selected Distribution
Prevalence of HIV, %†	0.5 ± 0.27	β
Decrease in viral load during virologic rebound	0.5 ± 0.5	γ
Decrease in viral load with nonsuppressive therapy	1 ± 0.5	γ
Increase in viral load after failed therapy (with AIDS)	1 ± 0.5	γ
Increase in viral load after failed therapy	0.8 ± 0.4	γ
Viral load during virologic suppression	1.3 ± 0.6	γ
Probability of not achieving virologic suppression during first regimen	0.20 ± 0.20	β
Probability of not achieving virologic suppression during second regimen	0.35 ± 0.21	β
Probability of not achieving virologic suppression during third regimen	0.7 ± 0.15	β
Probability of intolerance to HAART requiring discontinuation	0.25 ± 0.13	β
Relative risk for discontinuation of HAART during second regimen	1.4 ± 0.84	Log normal
Relative hazard of AIDS per increase in CD4 count	0.0154 ± 0.12	Log normal
Relative hazard of AIDS per increase in viral load	0.43 ± 1.25	Log normal
Relative hazard of death from AIDS per increase in CD4 count	0.118 ± 1.43	Log normal
Relative hazard of death from AIDS per increase in viral load	0.64 ± 0.92	Log normal

* HAART = highly active antiretroviral therapy.
† The prevalence distribution was estimated from the blinded serologic survey of 8627 inpatients and outpatients at 6 Department of Veterans Affairs health care systems (157).

ysis, if the prevalence of unidentified HIV was 0.1%, then screening patients age 75 years who had a partner at risk cost $83 680 per QALY compared with current practice. Under our assumptions of a more costly streamlined counseling scenario, this incremental cost-effectiveness ratio increased marginally to $88 120 per QALY. Although the incremental cost-effectiveness ratio increased for all age and prevalence combinations, these increases did not change our qualitative results or our clinical recommendations.

We also explored a scenario in which the efficacy of streamlined counseling was reduced. Under streamlined counseling, patients who test positive for HIV infection receive the same counseling (for both costs and efficacy) as those who receive traditional counseling, and therefore the true reduction of streamlined counseling effects on behavior modification is small. If we assumed that streamlined counseling reduced the efficacy of counseling from our base-case value of 20% reduction in transmission to a 10% reduction, then the incremental cost-effectiveness of HIV screening increases to $19 800 per QALY, $23 090 per QALY, and $45 550 per QALY in a cohort of 65-year-old cohort with prevalence of unidentified HIV of 1%, 0.5%, and 0.1%, respectively. If we assumed that streamlined counseling completely eradicated any benefit from counseling on transmission, the incremental cost-effectiveness of screening increased, although the effects again are minimal ($23 050 per QALY, $26 700 per QALY, and $50 730 per QALY in a 65-year-old cohort with 1%, 0.5%, and 0.1% prevalence of HIV, respectively).

Finally, in our exploration of the effects of streamlined counseling, we assume that persons who are sexually active have 1 partner at risk for transmitting infection. In a sensitivity analysis, we varied this assumption to explore the effects on our results if persons who were sexually active had 2 partners at risk. As expected, if persons had a greater number of sexual partners at risk, this increased the benefits of HIV screening and early identification. For example, if the prevalence of unidentified HIV in a population was 0.05%, HIV screening for persons age 75 years who had 1 partner at risk would cost $21 560 per QALY if streamlined counseling was used. If, however, these persons had 2 partners at risk, such HIV screening would become more favorable with an incremental cost-effectiveness ratio of $10 100 per QALY compared with current practice.

Probabilistic Sensitivity Analysis

To estimate the uncertainty in our findings, we did a probabilistic sensitivity analysis. We assigned distributions to 20 variables that described the natural history of HIV and effectiveness of HAART in older patients. For 15 variables, we used parametric distributions described further in **Appendix Table 2**. **Appendix Table 3** shows how we sampled from discrete values for 5 variables. We evaluated the incremental cost-effectiveness of HIV screening for a patient age 65 to 74 years with a sexual partner in a population in which the unidentified prevalence of HIV ranged from 0.2% to 1.2%. **Appendix Figures 2** and **3** show the results of our Monte Carlo simulation under assumptions of either traditional or streamlined counseling as an acceptability curve. Cost-effectiveness acceptability curves allow decision makers to determine the probability that HIV screening in the given population is cost-effective at various willingness-to-pay thresholds (the highest incremental cost-effectiveness ratio that people would be willing to accept as reasonable value for their health care dollar).

Appendix Table 3. **Samples of Discrete Values in Probabilistic Sensitivity Anaylsis***

Variable	Discrete Values Sampled†
Age, *y*	65, 66, 67, 68, 69, 70, 71, 72, 73, 74‡
Multiplier on age-specific death for HIV-infected patients age >55 y	1.0, 1.5
Relative risk for achieving suppression in patients age >55 y	0.5, 1.0
Relative risk for HAART discontinuation in patients age >55 y	1.0, 1.5
Relative risk for discontinuation of HAART during third regimen	1.0, 2.0, 3.0, 4.0§

* HAART = highly active antiretroviral therapy.
† When not specified, the probability of each value was assumed to be equal.
‡ The distributions of ages represented those of the U.S. population based on U.S. census data.
§ Corresponding probabilities are 0.5 (1.0), 0.25 (2.0), 0.25 (3.0), and 0.25 (4.0).

Appendix Figure 3. **Cost-effectiveness acceptability curve of HIV screening, assuming streamlined counseling.**