The Optimal Age for Screening Adolescents and Young Adults Without Identified Risk Factors for HIV

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ABBREVIATE

Purpose: To assess the optimal age at which a one-time HIV screen should begin for adolescents and young adults (AYA) in the U.S. without identified HIV risk factors, incorporating clinical impact, costs, and cost-effectiveness.

Methods: We simulated HIV-uninfected 12-year-olds in the U.S. without identified risk factors who faced age-specific risks of HIV infection (.6–71.3/100,000PY). We modeled a one-time screen ($36) at age 15, 18, 21, 25, or 30, each in addition to current U.S. screening practices (30% screened by age 24). Outcomes included retention in care, virologic suppression, life expectancy, lifetime costs, and incremental cost-effectiveness ratios in $/year-of-life saved (YLS) from the health-care system perspective. In sensitivity analyses, we varied HIV incidence, screening and linkage rates, and costs.

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Results: All one-time screens detected a small proportion of lifetime infections (1%–10.3%). Compared with current U.S. screening practices, a screen at age 25 led to the most favorable care continuum outcomes at age 25: proportion diagnosed (77% vs. 51%), linked to care (71% vs. 51%), retained in care (68% vs. 44%), and virologically suppressed (49% vs. 32%). Compared with the next most effective screen, a screen at age 25 provided the greatest clinical benefit, and was cost-effective ($96,000/YLS) by U.S. standards (<$100,000/YLS).

Conclusions: For U.S. AYA without identified risk factors, a one-time routine HIV screen at age 25, after the peak of incidence, would optimize clinical outcomes and be cost-effective compared with current U.S. screening practices. Focusing screening on AYA ages 18 or younger is a less efficient use of a one-time screen among AYA than screening at a later age.

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The U.S. Centers for Disease Control and Prevention (CDC) estimate that 22% of new HIV diagnoses occur in adolescents and young adults (AYA) aged 13–24 years, and that nearly 61,000 AYA are now living with HIV in the U.S. [1,2]. In 2006, CDC recommended routine HIV screening at least once between the ages of 13 and 64, regardless of risk factors [3]. However, HIV screening rates among AYA remain low: 12% of U.S. high school students reported ever being screened in 2005, increasing only to 13% by 2012 [4]. Among older youth aged 18–24, the proportion who had ever been screened declined over a similar period, from 37% reported in 2000 to 30% in 2010.

Of all AYA aged 13–24 living with HIV, 51% are estimated to be unaware of their HIV status, substantially higher than the 13% of HIV-infected U.S. adults estimated to be unaware of their status [2]. People unaware of their HIV infection miss opportunities for treatment and improved individual health, as well as contribute disproportionally to HIV transmission [5]. CDC recommends that people at high risk for HIV infection, including people who have had sex with more than one partner since their last HIV screen, sexually active men who have sex with men, and injection drug users, be rescreened at least annually [3]. For youth without identified risk factors, however, uptake of CDC guidelines for routine screening may be limited by differing recommendations among national professional organizations, as well as lack of evidence that 13 is the optimal age at which to initiate HIV screening in AYA [6,7]. Although many youth with unknown risk factors may be at higher risk of HIV infection than either they or their healthcare providers perceive [8], we hypothesized that offering a one-time screen at a younger age may cause harm by missing infections that occur later. Additionally, offering an HIV test to a 13-year-old without identified risk factors might take the place of potentially higher priority health considerations such as catch-up immunizations or assessing safety and counseling on injury prevention [9]. Our objective was to identify the age at which the CDC recommendation for one-time HIV screening should begin. We thus assessed the clinical impact, cost, and cost-effectiveness of one-time HIV screening strategies for AYA aged 13–24 in the U.S. without identified HIV risk factors.

Methods

Analytic overview

We used the Cost-Effectiveness of Preventing AIDS Complications microsimulation model to evaluate the cost-effectiveness of alternative strategies for routine one-time HIV screening in youth aged 13–24, in addition to current HIV screening and testing practices in the U.S. (13% ever screened by age 18, and 30% by age 24) [4]. We simulated HIV-uninfected 12-year-olds without identified risk factors (Table 1). We modeled five screening strategies: a one-time screen at age 15, 18, 21, 25, or 30 years; each one-time screening strategy was performed in addition to current practice. Screens at age 25 and 30 were included to determine the value of screening after the AYA period. Model outcomes included CD4 cell count at diagnosis, life expectancy, and HIV-related lifetime costs from the health-care system perspective. In the base case, life expectancy was not quality-adjusted due to limited data among AYA [22]. To compare the marginal cost for an additional unit of health benefit when choosing between these different strategies, we report incremental cost-effectiveness ratios (ICERs) [23]. We calculated ICERs for each strategy compared with the next most costly alternative (Δ cost/Δ life expectancy), using outcomes for HIV-infected and HIV-uninfected people. Results were discounted at 3%/year to convert future costs and health outcomes [23]. We defined a strategy as “cost-effective” if its ICER fell below a willingness-to-pay threshold of $100,000/year-of-life saved (YLS) [24]; we examine a range of ICER thresholds in sensitivity analyses.

Model structure, population, and data parameters

The Cost-Effectiveness of Preventing AIDS Complications model is a patient-level simulation model of HIV infection, screening, disease progression, and treatment calibrated to clinical data with and without antiretroviral therapy (ART) in the U.S. (http://web2.research.partners.org/cepac) [25]. Youth enter the model at age 12 without HIV infection, and are simulated through their lifetimes until death.

HIV incidence and diagnosis. Simulated patients face monthly risks of HIV infection, based on age-stratified incidence rates (Table 1 and online Appendix Table S1). For patients who become infected, diagnosis can occur via current practice of HIV detection (e.g., HIV screening and testing already occurring in health-care settings), or testing after presenting to care with an opportunistic infection (OI) or the one-time HIV screening program.

The model includes age-stratified monthly probabilities of detection under current practice HIV screening. Current practice screening rates were derived from Youth Risk Behavior Survey data for 13- to 17-year-olds (% ever tested) and the National Health Interview Survey for people >18 years (% tested within 12 months)
Table 1

| Input parameters for a model of routine HIV screening in U.S. adolescents and young adults |
|----------------------------------|---------------------------|
| General U.S. population          | Source                    |
| Population characteristics      |                           |
| Age (years)                      | 12                        | Modeled population |
| Male sex (%)                     | 51.2                      | [10]               |
| HIV prevalence at age <12 (%)    | 0                         | Modeled population |
| Annual HIV incidence by age, rate/100,000PY\* |                           |
| <13 years                        | 0.6                       | [11,12]            |
| 15                               | 1.8                       | [11,12]            |
| 18                               | 22.9                      | [11,12]            |
| 21                               | 59.1                      | [11,12]            |
| 24                               | 71.3                      | [11,12]            |
| 25                               | 54.3                      | [11,12]            |
| 26–30                            | 46.3                      | [11,12]            |
| 31–35                            | 38.3                      | [11,12]            |
| 36–40                            | 32.6                      | [12]               |
| 41–45                            | 32.1                      | [12]               |
| >45                              | 8.6                       | [12]               |
| Current HIV screening practice (annual probability) |                        |
| 12–17 years                      | 0.1                       | [4]                |
| 18–34                            | 0.16                      | [4]                |
| 35–44                            | 0.10                      | [4]                |
| 45–64                            | 0.06                      | [4]                |
| ≥65                              | 0.02                      | [4]                |
| Probability of linkage to care (%) | 75.6                     | [13]               |
| HIV screening program costs (USD 2013)\* |                           |
| HIV screen                       | 35.92                     | [14]               |
| Completed positive screen        | 72.23                     | [14,15]            |
| Antiretroviral therapy (range, first through sixth available regimen)\* |            |
| Efficacy (%)                     | 93.81                     | [16–18]            |
| Cost/month (USD 2013)            | 2,170–5,370               | [19,20]            |
| Return to care (rate/100PY)      | 18.1                      | [21]               |

Additional references for inputs are noted in the Appendix (Table S1). PY = person-years; USD = U.S. dollars.

\* Incidence estimates presented incorporate rates of new diagnoses in 2013 from the National HIV Surveillance System (NHSS) and undiagnosed incidence. (See Appendix Table S1 and Figure S1 for complete age-stratified incidence rates.)

\* HIV screen cost was derived from an average of reported costs with and without counseling at sexually transmitted infection clinics [14]. The cost of completing a positive screen was based on average reported costs at hospitals [15]. Costs include costs of reagents and controls, laboratory equipment costs, specimen collection, transport and process, quality control, counseling and personnel time at national wage and fringe labor rates.

\* Antiretroviral efficacy is defined as the rate of suppression of HIV RNA <400 copies/ml at 48 weeks.

In sensitivity analyses, we first varied HIV incidence from 5- to 100-fold the base case inputs. The fivefold increase approximated 2013 rates of new diagnoses reported among African-American males (Appendix Figure S1) [11,12]. We next shifted the age distribution of HIV incidence, ranging peak age from 15 to 28 (Appendix Figure S2), and varied rates of current practice HIV screening from .5- to 2-fold the base case. We also varied parameters of the HIV screening program, CD4 cell count at infection, loss to follow-up, virologic suppression, and HIV-related health-care costs. We examined HIV screening and HIV care costs up to 5-fold the base case to understand where the ICER threshold was crossed. In multiway sensitivity analyses, we varied the most influential of these parameters simultaneously, including costs of HIV screening and HIV care, and linkage.

**HIV care continuum.** The model also generates HIV care continuum outcomes (proportions HIV-diagnosed, linked to care, retained in care, and virologically suppressed). Monthly risks of becoming lost to follow-up and returning to care reflect movement within the care continuum (Table 1).

**Sensitivity analyses and additional analyses**

In sensitivity analyses, we first varied HIV incidence from 5- to 100-fold the base case inputs. The fivefold increase approximated 2013 rates of new diagnoses reported among African-American males (Appendix Figure S1) [11,12]. We next shifted the age distribution of HIV incidence, ranging peak age from 15 to 28 (Appendix Figure S2), and varied rates of current practice HIV screening from .5- to 2-fold the base case. We also varied parameters of the HIV screening program, CD4 cell count at infection, loss to follow-up, virologic suppression, and HIV-related health-care costs. We examined HIV screening and HIV care costs up to 5-fold the base case to understand where the ICER threshold was crossed. In multiway sensitivity analyses, we varied the most influential of these parameters simultaneously, including costs of HIV screening and HIV care, and linkage.

Because of limited data in AYA, we excluded quality-of-life adjustments in the primary analysis. In sensitivity analysis, we used quality-of-life weights from adults, generating ICERs in $/quality-adjusted life-year ($/QALY), a more common unit for ICERs. We also calculated the proportion of one generation of HIV transmissions/100 person-years (PY) that would be averted by each strategy to estimate the impact on the optimal age for a one-time screen. The likelihood that a person will transmit HIV to others is modeled as a function of the HIV RNA level; HIV RNA-stratified transmission rates ranged from .16 to 9.03 transmissions/100PY, with higher rates for those within 3 months of infection and for those with advanced infection (Appendix Table S1). Further, we examined one-time screens at every age between 13 and 35 years to determine whether clinical and cost differences at similar ages were meaningful.

Base case results are reported according to cost-effectiveness convention, in order of increasing costs; ICERs are calculated comparing each strategy to the next most costly strategy after eliminating “dominated” strategies, which are strategies that are either more costly or less cost-effective than other strategies that produce greater benefits [23]. For sensitivity analyses, we report ICERs comparing the most effective strategy to current practice because of variation in the comparator strategies when calculating ICERs. Details of additional model parameters can be found online in the Appendix.

**Disease progression and treatment.** In the month of HIV infection, simulated patients are assigned a CD4 cell count and HIV RNA level from defined distributions (Table 1 and Appendix Table S1). ART is initiated in all patients who link to care, per U.S. guidelines [27]. After ART initiation, simulated patients face a probability of virologic suppression and a resulting increase in CD4 cell count stratified by adherence [28]. Patients on suppressive ART experience a monthly probability of virologic failure after 48 weeks, also stratified by adherence [21,29]. Monthly risks of OIs and mortality are determined by age, current CD4 cell count, and prior disease history. The model tallies time in each health state and associated costs, including clinical care, laboratory screening, and medications [25,28].

**Appendix Table S1.**

| HIV screening program costs (USD 2013)\* |
|----------------------------------|---------------------------|
| HIV screen                       | 35.92                     | [14]               |
| Completed positive screen        | 72.23                     | [14,15]            |

**Appendix Figure S1.**

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Results

Base case results: clinical outcomes

Among 12-year-olds in the U.S. without identified HIV risk factors, the projected number of new HIV infections peaked at age 24, although more than 75% of lifetime infections were projected to occur afterward (mean age: 37.3 years [SD 16.9 years] (Appendix Figure S1). Among AYA who became HIV-infected at any point in their lifetime, current practice led to a projected mean CD4 cell count at diagnosis of 324 cells/μL and an undiscounted life expectancy from age 12 of 585.05 months (48.75 years) (Table 2).

When projected for the entire cohort (including those becoming and never becoming HIV-infected), life expectancy from age 12 was 810.90 months (67.58 years) (344.49 months [28.71 years] discounted).

Any evaluated one-time screen in addition to current practice increased projected CD4 cell count at diagnosis and life expectancy among HIV-infected people. Of the one-time-screening strategies, a screen at age 25 led to the highest projected mean CD4 cell count at diagnosis (345 cells/μL) and the greatest gains in undiscounted HIV-infected life expectancy from age 12 (589.82 months, an increase of 4.8 months over current practice). The impact of any one-time screen on discounted life expectancy for the total population (HIV-infected and HIV-uninfected people) was very small (current practice: 810.90 months [344.49 months discounted]; additional screen at age 25: 810.97 months [344.52 months discounted]).

All one-time screening strategies identified a small proportion of total lifetime HIV infections (.1%–10.3%) (Figure 1A) because most infections occurred after age 25 (Appendix Figure S1). Screen at age 25 provided the lowest proportions never diagnosed (10.6%) and diagnosed via OI (34.8%) (Appendix Figure S3A). Even a perfect screen at age 25 (100% test offer and acceptance, result return, and linkage) would detect only 13% of lifetime infections. When limited to people infected before age 25, one-time screening strategies identified a larger proportion of HIV infections (.4%–33.8%), and results were still optimized with screen at age 25 (Figure 1B, Appendix Figure S3B).

Table 2
Modeled outcomes of 5 HIV screening strategies for U.S. adolescents and young adults

<table>
<thead>
<tr>
<th>Age of one-time screening in addition to current practice, years</th>
<th>Mean CD4 at diagnosis (cells/μL)</th>
<th>Life expectancy (months from age 12)</th>
<th>Population per-person cost, population ($)ab</th>
<th>ICER ($/YLS)c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HIV-infected (undiscounted)</td>
<td>Population (undiscounted)</td>
<td>Population (discounted)a</td>
<td></td>
</tr>
<tr>
<td>Current practice</td>
<td>324</td>
<td>585.05</td>
<td>810.90</td>
<td>344.49</td>
</tr>
<tr>
<td>15</td>
<td>325</td>
<td>585.10</td>
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<td>344.52</td>
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<tr>
<td>25</td>
<td>345</td>
<td>589.82</td>
<td>810.97</td>
<td>344.52</td>
</tr>
</tbody>
</table>

ICER = incremental cost-effectiveness ratio; YLS = year-of-life saved.

d Results are discounted at 3% per year.

e Results are rounded to the nearest $10.

c Cost-effectiveness is the difference in cost divided by the difference in life expectancy for each strategy compared with the next most costly strategy. When comparing three or more strategies, if a strategy has a higher ICER than a competing strategy with a higher lifetime cost (as is the case here), then the strategy is said to be “dominated,” reflecting an inefficient use of health-care resources, and the ICERs of all strategies are recalculated with that strategy omitted[23]. ICERs are calculated from unrounded model output and then rounded to the nearest $100. Of note, an ICER with the same life expectancy and increased cost would also be dominated. ICERs are graphically represented in the Appendix (Figure S5).

HIV detection
Our objective was to assess whether the CDC recommendation for one-time HIV screening between the ages of 13 and 64 should begin at age 13. We determined the value of one-time HIV screening, in addition to current screening practices, in AYA aged...
13–24 without identified risk factors for HIV infection in the U.S. We had three principal findings. First, although an additional one-time screen at any age between 15 and 30 led to important gains in HIV diagnosis rates and life expectancy for HIV-infected people, a screen at age 25 provided the most favorable clinical outcomes and the best value for money. Compared with current practice, an additional one-time screen at age 25 led to a substantial gain in HIV-infected life expectancy of 4.8 months and was cost-effective in the U.S. (ICER compared with a screen at age 30: $96,000/YLS) [23,24,30]. These results align with other analyses that have found HIV screening to be cost-effective in the U.S. in all but the lowest-risk populations [25,31,32]. CDC recommends screening for HIV infection at least once for all people aged 13–64 years [3]. Our results suggest that if a one-time screen is offered to AYA without identified risk factors, it would provide greater clinical benefit and economic value if offered later, in the mid-20s, than if offered in early adolescence. In this analysis, a screen at age 18 or 21 was only superior to a screen at age 25 if HIV incidence peaked at earlier ages. Diagnoses of new HIV infections among persons aged 13–29 years peaked between ages 22 and 25 from 2009 to 2013 [11]. Although the timing of peak HIV incidence among persons aged 13–29 is unknown, it is unlikely that the population peak of HIV incidence in youth without identified risk factors occurs before age 18.

Second, although gains in life expectancy and the number of AYA detected by the one-time screen were small (because most infections occurred after age 24), a screen at age 25 substantially improved care continuum outcomes for those who became HIV-infected by age 25. With a one-time screen at age 25, the proportion of HIV-infected youth diagnosed by age 25 increased markedly compared with screening at other ages (77% vs. 51%–53%); the proportion with virologic suppression also increased (51% vs. 34%–36%). These projections depend on data about rates of linkage and retention in AYA after routine screening, which vary by setting. Linkage to care rates for AYA, for example, range from 30% in Miami, FL to 92% in an emergency department in Bronx, NY (base case 76%) [13,33,34]. The current practice scenario projected more optimistic virologic outcomes than were reported in a recent review or in the CDC Medical Monitoring Project (80% vs. 55% and 68% virologic suppression among those retained, respectively) [35,36]. Our sensitivity analyses using lower rates of retention and suppression suggest that the benefits of an additional one-time screen are markedly attenuated if AYA are screened but subsequently do not remain in care and on ART. HIV-infected AYA have poorer outcomes compared with adults at every step of the HIV care continuum; interventions to support linkage and retention will therefore be critical to any HIV screening program for AYA [13,37].

Third, any combination of current practice and an additional one-time screen among AYA without identified risk factors will detect only a small proportion of lifetime HIV infections, most of which occur after age 25. Even a perfect one-time screen at age 25 would detect only 13% of lifetime infections, and in our less optimistic base case scenario, this value was 10%. Despite these modest contributions to HIV detection, a one-time screen at age 25 substantially improved clinical and cost-effectiveness outcomes compared with other one-time screening strategies. A screen at age 30, for example, led to lower CD4 cell count at diagnosis compared with a screen at age 25 because those infected at young ages experienced substantial CD4 cell count decline by age 30. Combinations of routine HIV screening strategies for AYA, along with repeat screening in high-risk youth at appropriate intervals, will be needed to curb the rising epidemic of HIV in U.S. AYA [37].

There are several limitations to this model-based analysis. First, incidence inputs were estimated from rates of new diagnoses because the true number of new infections is unknown [38]. To address this uncertainty, we adjusted these values by age-stratified CDC-estimated proportions of infections that are undiagnosed, and then calibrated the model to National HIV Surveillance System data on CD4 cell count at diagnosis and total incidence rates. Second, current practice HIV screening inputs were derived from reported rates of HIV screening which likely do not capture barriers to HIV screening for all AYA (e.g., the Youth Risk Behavior Survey only samples students in grades 9 through 12) [4]. Third, because of limited data in AYA, we assume HIV-related health-care utilization was constant over the age group. We also excluded utility adjustments in the primary analysis. AYA aged 18–30 comprise only a small fraction of participants in HIV-specific health-related quality-of-life studies, and emerging data suggest that youth may attach different values to specific health states compared with adults [22]. When adult quality-of-life utility weights were applied to calculate ICERs with QALYs, all ICERs remained below $150,000/QALY; ICER thresholds ranging from $50,000 to 200,000/QALY have been recommended for use in the U.S. [24]. We additionally used adult values when the rates reported in AYA seemed too extreme; for example, for test acceptance we used 80.0% instead of 95% reported among 13- to 21-year-olds, and varied this parameter in sensitivity analysis [34]. Fourth, we did not explore multiple generations of HIV transmission. The small (0.5%–3.8%) proportion of primary HIV transmissions averted would likely make a one-time screen at all ages slightly more cost-effective; however, among AYA without identified risk behaviors, HIV prevalence by age 25 is so low that this impact is likely minimal.

Designed to assess routine one-time screening in AYA without identified HIV risk factors, this analysis did not examine the impact of repeat screening later in adulthood. Additionally, the results do not apply to AYA with identified risk factors. The peak HIV incidences (3.6/100PY and 7.2/100PY) examined in our sensitivity analyses mirrored that of higher risk populations (e.g., Adolescent Trials Network study 110: 3.1/100PY; PROUD study: 9.0/100PY), but we lacked data to derive age-specific incidence rates for these groups [39,40]. Age-based, sexual identity- and orientation-based, racial/ethnic, and regional disparities have been described in both HIV screening and incidence [2,4,13,33]. Risk factor assessment should be performed by health-care practitioners and optimal screening strategies for known high-risk subgroups of AYA will be different from those presented in this analysis [41].

In summary, for AYA without identified HIV risk factors in the U.S., one-time routine HIV screening at age 25, shortly after the peak of HIV incidence, in addition to current screening practice, would improve clinical outcomes and be cost-effective compared with current U.S. screening practices alone. Focusing screening on AYA ages 18 or younger is a less efficient use of a one-time screen among AYA than screening at a later age.

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Supplementary Data

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