Cost-Effectiveness of Universal Compared With Voluntary Screening for Human Immunodeficiency Virus Among Pregnant Women in Chicago

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ABSTRACT. *Objectives.* **To determine and compare the cost-effectiveness of implementing 3 screening strategies to detect human immunodeficiency virus (HIV) infection among pregnant women in Chicago, Illinois: no screening, voluntary screening, and universal screening.**

Methods. **A decision-analysis model was developed, using standard cost-effectiveness analysis from a societal perspective. Reference case estimates were derived from a surveillance project conducted by the Illinois Department of Public Health and studies were published in the medical literature. Costs included direct and indirect medical costs associated with identification of pregnant women infected with HIV and identification, prevention, and treatment of perinatally HIV-infected newborns. Specifically, for each screening option, the cost per pregnant woman screened, the resulting number of pediatric HIV infections, and the number of newborn life-years were calculated. All costs were adjusted to the 1997 dollar value and discounted at 3%. Sensitivity analyses were determined for all variables included in the decision model.**

Results. **The estimated prevalence of HIV infection among pregnant women in Chicago is .41%. For every 100 000 pregnant women, it is estimated that 104.6 children would be infected with HIV if no screening strategy were implemented and 44.8 children would be infected if voluntary HIV testing (assuming a 92.7% acceptance rate) were available. In comparison, if universal HIV testing was performed, the number of children infected with HIV would decrease to 40 cases. Sensitivity analysis across a maternal HIV prevalence rate of .01% to 2.2% found that universal screening would be cost-saving in communities where the seroprevalence is .21%. In Chicago, it would take an estimated 5.2 months of screening pregnant women to avert 1 case of pediatric HIV. Taking into consideration the lifetime costs of treating a child with HIV infection, universal HIV testing of 100 000 pregnant women would result in a cost-savings of $3.69 million when compared with no screening, and $269 445 when compared with voluntary screening. We estimated that it would cost $11.1 million to screen 100 000 pregnant women in Chicago. The cost-savings produced with increased screening are the direct result of reduced cases of newborns infected with HIV. A 2-way sensitivity analysis was performed to examine how costs vary as a function of the voluntary rates for HIV-positive and HIV-negative women. When screening falls below 50% for HIV-positive mothers, universal screening becomes cheaper than voluntary screening even if no HIV-negative mothers were screened.**

Conclusion. **Reference case analyses showed that universal HIV screening of pregnant women in Chicago would both decrease the number of HIV-infected newborns and save money in comparison to voluntary or no testing strategies. Sensitivity analysis was robust across all variables for the conclusion that universal screening was more effective than voluntary screening. For many communities that have HIV prevalence rates for mothers of >.21%, universal screening would also save money in comparison to voluntary screening. For communities with prevalence rates <.21%, the benefits of universal screening may outweigh the costs for screening as we found that desirable incremental cost-effectiveness ratios were found for prevalence rates as low as .0075%.** *Pediatrics* **2000;105(4). URL: http://www.pediatrics.org/cgi/content/full/105/4/e54;** ***cost-effectiveness, human immunodeficiency screening.***

ABBREVIATIONS. HIV, human immunodeficiency virus; AIDS, acquired immunodeficiency syndrome; CDC, Centers for Disease Control and Prevention; ACTG, AIDS Clinical Trials Group; AZT, zidovudine; ELISA, enzyme-linked immunosorbent assay; WB, Western blot; PCR, polymerase chain reaction.

Nearly all human immunodeficiency virus (HIV)-infected infants and children acquire their infection from their mothers either during pregnancy or around the time of delivery. Thus, the epidemiology of pediatric HIV reflects maternal infection. Worldwide, the percentage of those with HIV or acquired immunodeficiency syndrome (AIDS) who are women has increased from 7% in 1985 to 43% in 1998.[1,2] The Centers for Disease Control and Prevention (CDC) estimates that over 7000 HIV-infected women give birth in the United States each year.[2,3] Specifically, in Chicago, it is estimated that 94% of pediatric AIDS cases are the result of perinatal transmission.[4,5]

In February 1994, the AIDS Clinical Trials Group (ACTG) Protocol 076, a double-blind, placebo-controlled study of the use of the anti-retroviral agent, zidovudine (AZT) during and after pregnancy, demonstrated a reduction in the maternal–fetal transmission of HIV from 25.5% in the placebo group to 8.3% in the AZT-treated group.[6] More recently, perinatal transmission rates of 6.1% when AZT prophylaxis began prenatally, 9.3% when AZT prophylaxis began within the first 48 hours of life, and 26.6% when no prophylaxis was given have been found.[7] However, rates as low as 1% to 2% have been reported in women receiving AZT prophylaxis who have elec-

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tive cesarean delivery.[8–10] Currently, in Illinois, the state public health department recommends that all pregnant women be offered voluntary and confidential HIV antibody testing. Because of the stigma attached to high-risk behaviors, previous studies have shown that only a small percentage of HIV-positive women are identified by those programs in which testing is targeted to individuals acknowledging these actions.[11] Consequently, some investigators argue that introducing universal screening programs to provide screening by default without requiring written consent, thereby giving patients the right to informed refusal, would de-emphasize the HIV test and the stigma attached to it and also reduce the burden on physicians to categorize patients according to their risk level.[12] Moreover, recently the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists recommend universal HIV testing with patient notification as a routine component of prenatal care.[13] Even so, since the ACTG 076 Study, there have been few cost-effectiveness studies on targeted screening of pregnant women identified to have risk-associated behaviors and despite the increasing evidence of the benefits of early detection of HIV infection in women and their infants, few studies on the effects of a universal screening program.[14–17]

We analyze and compare the costs from a societal perspective of a universal versus a voluntary screening program for HIV among pregnant women in a major urban city, taking into account the potential benefits to newborns of mothers who may have had abbreviated or no AZT treatment during pregnancy or the intrapartum period. The results of these analyses will provide information and direction for setting guidelines for HIV-screening strategies in Chicago and other urban communities.

METHODS

Overview

A decision-analysis model was developed to compare voluntary to universal screening for HIV among pregnant women in Chicago. Outcomes assessed include the cost per pregnant woman screened, the number of pediatric HIV cases, and the number of newborn life-years expected for each screening option. Standard cost-effectiveness analysis was used to compare the various options for screening.[18] We also compared these screening options with a no screening strategy. All costs were calculated from a societal perspective. Sensitivity analyses using ranges based on published studies and experts' opinions were performed for all variables included in the decision-analysis model. Table 1 summarizes the baseline variables and sensitivity ranges used in the analyses.

Costs

Costs include direct and indirect medical costs associated with identification of pregnant women infected with HIV and identification, prevention, and treatment of perinatal HIV infection (Table 1). Guidelines for HIV testing for both mother and infant are based on the recommendations provided by the CDC and the American Academy of Pediatrics' Committee on Pediatric AIDS.[19,20] All costs for HIV testing, including the enzyme-linked immunosorbent assay (ELISA), Western blot (WB), and HIV DNA polymerase chain reaction (PCR) are based on 1997 costs at the University of Illinois Hospital. The direct costs for medical care of children with AIDS are based on published data.[21–24] These costs are adjusted to 1997 dollar value. The estimated health care costs include costs associated with hospitalizations, outpatient visits, including emergency department visits, home health care, and prescribed medications. Recognizing that children infected with HIV may not incur the degree of costs incurred by children with full blown AIDS, we derived our total lifetime costs for treatment of perinatally HIV-infected children from costs for children with HIV infection with

TABLE 1. Summary of the Probability and Cost Variables Used in the Decision Analysis*

Variable	Baseline Value	Range of Values	References
Cost variables			
ELISA test	$ 22	$ 10–$40	14, Δ
WB test	$ 54	$ 30–$75	14, Δ
HIV DNA PCR test	$ 250	$ 100–$400	14, Δ
Mother's AZT	$5646.30	$ 1200–$7000	25
Infant's AZT (per wk)	$ 3.08	$ 1–$5	25
Post-test counseling for HIV-negative mother	$ 14.87	$ 10–$40	21, 23
Post-test counseling for HIV-positive mother	$ 35.46	$ 30–$100	21, 23
Lifetime cost for direct health care of perinatally HIV-infected child	$ 171 373.51	$65 000–$250 000	12, 15, 21, 22
HIV tests			
ELISA sensitivity	1.0	.9–1.0	28, 29
ELISA specificity	.99	.95–1.0	28, 29
WB sensitivity	.99	.8–1.0	24, 28, 29
WB specificity	.99	.8–1.0	24, 28, 29
PCR sensitivity	.99	.95–1.0	†
PCR specificity	1.0	.9–1.0	†
Probability variables			
Prevalence of HIV in pregnant women	.0041	.0001–.022	27
Vertical transmission rate without AZT	.255	.20–.40	6
Vertical transmission rate with maternal and infant AZT	.083	0–.13	6
Vertical transmission rate with only infant AZT within 48 h of birth	.127	.127–.255	7
Acceptance of HIV testing under voluntary screening	.927	.3–1.0	14, 31–37
Probability of accepting AZT	.7	.5–1.0	52, 53
Other variables			
Average life span of HIV-infected child (y)	9.4	5–25	21, 40
Average life span of adult in the United States (y)	76.1	55–85	41
Discount rate	.03	0–.08	18

* Baseline case variables, their ranges and references are given in 1997 dollars.
† No published data on sensitivity. Results based on figures given by Roche, Inc. Specificity for DNA PCR obtained from technical services at Roche Pharmaceutical and is based on inferences from published information for specificity of viral RNA quantitative test.

and without AIDS and performed sensitivity analysis over a range of costs that has been reported in the literature.[12,15,21,22] In the reference case, we assumed children infected with HIV would live 7.4 years without AIDS and 2 years with AIDS. We used $11 056 for the cost per year of life for the child with HIV without AIDS and $44 780 for the child with AIDS.[22] It follows then that 52.3% of total treatment costs would accrue in the last 2 years of life and were divided equally between these last 2 years.[15,18] The indirect medical costs include costs associated with counseling pregnant women after HIV testing. The savings that result from prevention of pediatric HIV infections are limited to the 1997 dollar value of medical care that would have incurred in the future. These costs are discounted at 3%.

The maternal costs included in the analysis are limited to only those costs associated with testing and posttest counseling and initiation and maintenance of AZT during pregnancy and through delivery. The cost of AZT for both mother and infant is based on 1997 costs listed at the University of Illinois Hospital for parenteral therapy and Red Book Pricing for oral therapy.[25] We did not consider any additional costs of treating HIV-infected women after delivery or any additional benefits that may have resulted from the screening, eg, direct medical benefits to a newly identified HIV-positive mother. We also did not include the costs involved with labor and delivery of the newborn. It is presumed that mothers would be screened at 14 weeks of gestation; thereby, we limited the time frame and analytic horizon for maternal costs to the duration of an uncomplicated pregnancy at 40 weeks of gestation. We also limited the maternal medications to AZT and did not differentiate the costs for pregnant women at different stages of their HIV infection. We include the cost of treatment for false-positive detection of HIV infection in both mother and infant. We also take into account the economic impact of medical costs incurred when HIV testing results in a false-negative result.

The cost of counseling considered in the decision-analysis model was limited to posttest counseling because it was assumed that the cost for pretest counseling would be the same for voluntary and universal screening. Posttest counseling was considered an additional service in an existing health care facility. The fixed costs of the facility were excluded. The value of a pregnant mothers' time was determined from data on the median earnings of all workers.[23,26] We make the distinction that posttest counseling costs would be greater for those who tested positive compared with those who tested negative. Counseling costs are based on published reports and adjusted to 1997 dollar value.[21,23]

Probability Estimates

Estimates of the seroprevalence rate of HIV infection in pregnant women reflect 1996 data collected by the Illinois Department of Public Health, through a cooperative agreement with the CDC.[27] The reference case uses prevalence data specifically for the city of Chicago. The maternal–infant transmission rates are based on the results from the ACTG 076 study.[6] The rate reduction reflects the effect of AZT alone in reducing infant transmission. The base case maternal–infant transmission rate for mothers refusing AZT treatment is based on results from an abbreviated treatment regimen providing AZT to the newborn within 48 hours of delivery.[7] The sensitivity and specificity of all tests for HIV detection reflect assays that are currently available.[24,28–30] The acceptance rate for HIV testing among pregnant women under the voluntary testing strategy is based on data collected from pregnant women during their prenatal visit. This information is based on an intra/postpartum survey conducted by the University of Illinois Perinatal Network in cooperation with the Illinois Department of Public Health. These women delivered at the University of Illinois Hospital during the months of October 1997 and April 1998 and reflect 91% and 96% of the total deliveries at that hospital, respectively.[31] To determine the range of acceptance rates for the sensitivity analysis, we used acceptance rates from women who came for services to the Chicago Department of Public Health Sexually Transmitted Disease Clinics and were offered HIV testing[32] and acceptance rates from other published reports in the medical literature.[33–37] The acceptance of AZT by pregnant women after they are told their HIV status is based on estimates from published studies and results obtained from the University of Illinois Women's Health Clinic[14,38,39] (M. Vajaranant, personal communication, August 1998).

Median Life Expectancy

The median life expectancy of children infected with HIV was used in calculating the direct costs of treating infected children per year.[21,40] Based on the most recent publication available, we estimate that the average life expectancy of a child infected with HIV is 9.4 years[21,40] (R. Yogev, personal communication, 1998). However, given the recent availability of new antiretroviral medications for children with the anticipated prolongation of their life expectancy, we conducted sensitivity analysis of the life expectancy of newborns infected with HIV to survival into their early 20s. The average life expectancy of a noninfected newborn is estimated to be 76.1 years in the United States.[41]

Screening Strategies

The testing strategies analyzed reflect 3 major policy options: 1) universal screening of all pregnant women; 2) voluntary testing; or 3) no screening. For mothers who are pregnant, HIV testing involves an ELISA and if positive, a confirmatory WB. For infants born to HIV-infected mothers, testing includes an initial ELISA, and if positive, a follow-up WB. HIV DNA PCR is also included at <48 hours of life and then repeated in 1 month.[19] Table 1 lists the tests for HIV, their reference costs, and their respective sensitivities and specificities.

Decision Analysis

All calculations were performed using DATA 3.0 (Tree Age Software Inc, Boston, MA), a decision-analysis software program. A summary of the decision tree is depicted in Fig 1. Sensitivity analysis was performed on all variables listed in Table 1. The ranges used were based on published reports listed in Table 1 and experts' opinions as noted.

In conducting the analysis, we made the following additional assumptions: 1) The screening was limited to pregnant women and all pregnant women screened for HIV were <14 weeks of gestation. 2) Regardless of whether they received voluntary or universal screening, all pregnant women would receive pretest counseling. Posttest counseling would be more costly and time consuming for those women who tested positive. 3) Universal testing does not result in increased numbers of women without prenatal care nor would HIV screening affect reproductive decision-making. 4) Acceptance of and compliance with AZT is the same for pregnant women screened under the voluntary and universal arms of the decision tree for the reference case. 5) The rates of complications during pregnancy (miscarriage, congenital anomalies, and preterm labor) for women on AZT are the same as those for normal pregnancy without AZT and are no different between voluntary and universal arms.[6]

RESULTS

Using the reference values listed in Table 1, our analysis indicates that universal screening both lowers the incidence of newborn HIV infections and produces a lower average cost per pregnant woman screened than either no screening or voluntary screening. Under the universal option, it would cost approximately $11.1 million to screen 100 000 pregnant women and treat the 40 cases of pediatric HIV that would result under such a strategy (Table 2). In comparison, under the voluntary strategy (based on a voluntary acceptance rate of 92.7%), it would cost $11.35 million to screen 100 000 pregnant women and treat the 44.8 cases of pediatric HIV that would result. Thus compared with voluntary screening, universal screening would avert 4.8 cases of pediatric HIV and save $269 445 dollars for every 100 000 pregnant women screened. Moreover, in comparison to no screening, universal screening would result in net cost-savings of $3.69 million dollars for every 100 000 pregnant women screened in Chicago and avert 64.6 more cases of pediatric HIV infection. Alternatively, the benefit of universal screening in

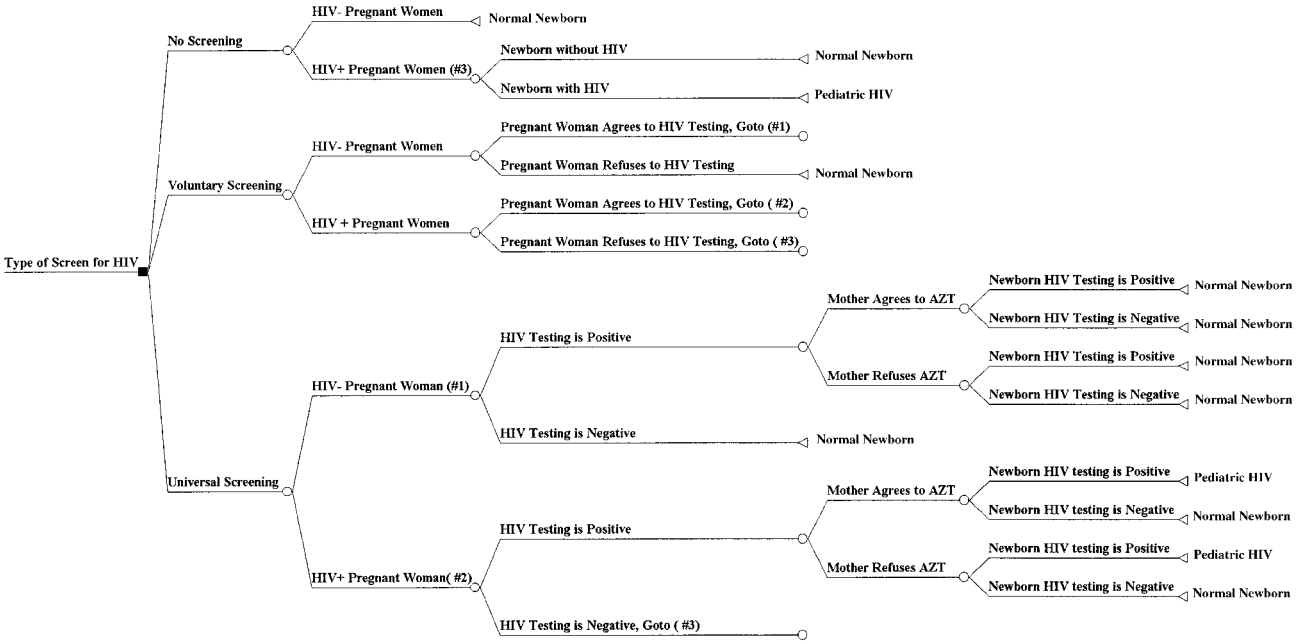

Fig 1. Decision-analysis tree summary: screening strategies for HIV among pregnant women. Square indicates decision branch node, circles indicate chance branch node, and triangles indicate terminal node or outcome. Baseline reference variables are listed on branches; branches for each node sum to 1.00.

TABLE 2. Outcomes Measured for Different Screening Options*

Type of Screening	No Screening	Voluntary Screening	Universal Screening
Expected costs	$14 772 184	$11 350 608	$11 081 163
Cases of pediatric HIV	104.6	44.8	40
Expected life-years of newborn (y)	7 603 027	7 607 015	7 607 329

* The expected costs for each strategy, number of cases of perinatally HIV-infected children, and the number of life-years saved reflect costs, cases, and years per 100 000 pregnant women screened. Voluntary screening is set at 92.7% acceptance rate.

years of life to the newborn would be 314 more years for every 100 000 pregnant women screened compared with voluntary screening. Figure 2 isolates the amount of total costs that are attributable to screening compared with treatment across a wide range of HIV-screening rates. No screening is represented by 0% and universal screening is represented by 100%. At 100%, the largest amount of money is being spent on the screening component, yet the overall costs are the lowest. This demonstrates the disproportionately large impact that treatment costs have on the total costs, and highlights the potential value of universal screening. The cost savings produced with increased screening are the direct result of reduced cases of newborns infected with HIV.

The claim that universal screening is cost-saving compared with voluntary screening was examined for a range of maternal HIV infection prevalence rates, using sensitivity analysis (Fig 3). Based on data obtained from HIV antibody testing on 12 053 blood samples from heel sticks of all newborns delivered in Chicago hospitals over a 3-month period, the prevalence of HIV among pregnant women was estimated in Chicago to be .41%.[27] We conducted a sensitivity analysis across a prevalence range from .01% to 2.2%[11,42,43] and determined that wherever the seroprevalence for HIV is ≥.21%, it would be cost-saving to implement a universal strategy. Below this point, communities must decide whether the reduction in HIV cases is worth the additional costs associated with universal screening. However, even at .01%, universal screening remains cost-effective. We calculated that if a community has this prevalence rate, it would cost $32 512.50 for each year of life saved.

Table 3 combines the HIV prevalence rates with the expected birth rates for the city of Chicago, the state of Illinois, and the country as a whole to compare the respective cost per life-year saved and the time needed to avert 1 case of pediatric HIV infection across different locations. Extrapolating the total number of deliveries that occurred in Chicago over a 3-month period, the approximate annual number of live births in Chicago is 48 212. For the city of Chicago, it would take 5.2 months of screening pregnant women in Chicago to avert 1 case of pediatric HIV. For the state of Illinois, it is estimated that ~.15% of pregnant women are HIV-positive (this is based on 42 728 newborn heel stick samples taken over a 3-month period). Although at this prevalence rate it is not cost-saving, it remains cost-effective at a cost of $649.57 for each life-year saved. Across this time, universal screening would save the city $56 292 dollars. Finally, according to a national population based serosurvey conducted by the CDC from 1989 through 1994, it is estimated that nationwide, the seroprevalence of HIV among pregnant women is 1.5

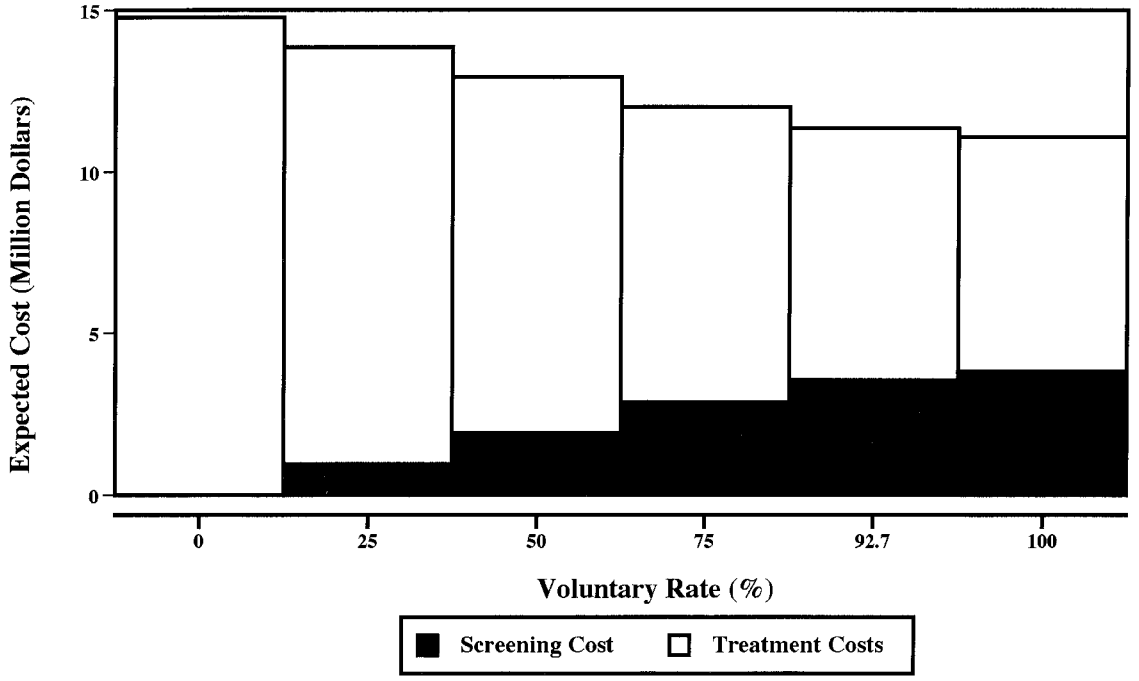

Fig 2. Percentage of pregnant women who accept HIV testing on a voluntary basis and the expected costs (in millions of dollars) per 100 000 pregnant women. Universal screening is represented by 100% voluntary rate and no screening is represented by the 0% voluntary rate. Costs are divided between screening costs (filled areas) and treatment costs (empty areas).

to 1.7 per 1000.[44] For the country, it would take .15 months to avert a single case of pediatric HIV at a cost of $368.35 per life-year saved.

Voluntary Rate Assumption

The voluntary screening rates used in the current analyses assumed that HIV-negative and HIV-positive pregnant women, who are unaware of their HIV status at the time of screening, were equally willing to be screened. It is possible that, in taking a patient's history, physicians identify certain HIV risk-related behaviors and use this information to encourage screening for some patients rather than others. These physicians would in effect target some patients for HIV screening. Attempts to better differentiate low-risk from high-risk mothers or targeted screening could conceivably produce less cost than universal screening. A 2-way sensitivity analysis was performed to examine how costs vary as a function of the voluntary rates for HIV-positive and HIV-negative women (Fig 4). A perfect targeted screening program would screen 100% of the HIV-positive mothers and 0% of the HIV-negative mothers. This point is represented in the lower right hand corner of Fig 4. Here voluntary screening is less costly than universal screening. When the rate for HIV-positive mothers falls beneath 50%, universal screening becomes cheaper than voluntary screening even if no HIV-negative mothers were screened because of the high costs associated with missed chances to treat HIV-positive mothers and to prevent some newborn HIV transmissions. If we use our reference case of 92.7% for the voluntary rate among HIV-positive mothers and 0% for the voluntary rate of HIV-negative mothers, then this targeted screening program would be cost-effective but not cost-saving. At this point, $10 148.86 would be spent for every life-year saved. When the rate for HIV-positive mothers falls beneath 50%, universal screening is always cost-saving even if no HIV-negative mothers were screened. Accordingly, a targeted screening program would need to be very specific to be cheaper than universal screening, and unless the program maintained 100% screening for HIV-positive mothers, the cost-savings also would be accompanied by an increase in HIV transmissions to newborns.

Sensitivity Analyses

Separate 1-way sensitivity analyses were conducted for effectiveness and for cost for all variables listed in Table 1. The ranges of values that we used are also listed in Table 1. The conclusion that universal screening was more effective than voluntary screening was robust across all variables. The conclusion that universal screening was less costly than voluntary screening also was robust for all variables, with the exception of prevalence for HIV among pregnant women (as noted above) and the total direct costs for treatment of perinatally HIV-infected children. Based on our estimate of pediatric HIV survival to 9.4 years old, it would be cost-saving to have universal screening as long as the lifetime costs for medical care exceeds a threshold of $105 000. Between this $105 000 threshold and the lower limit of $65 000, universal screening is not cost-saving but it remains cost-effective. At the lower limit of $65 000, universal screening would cost $457.23 per life-year saved.

DISCUSSION

Our study finds that in comparison to no screening or voluntary screening, universal screening is cost-

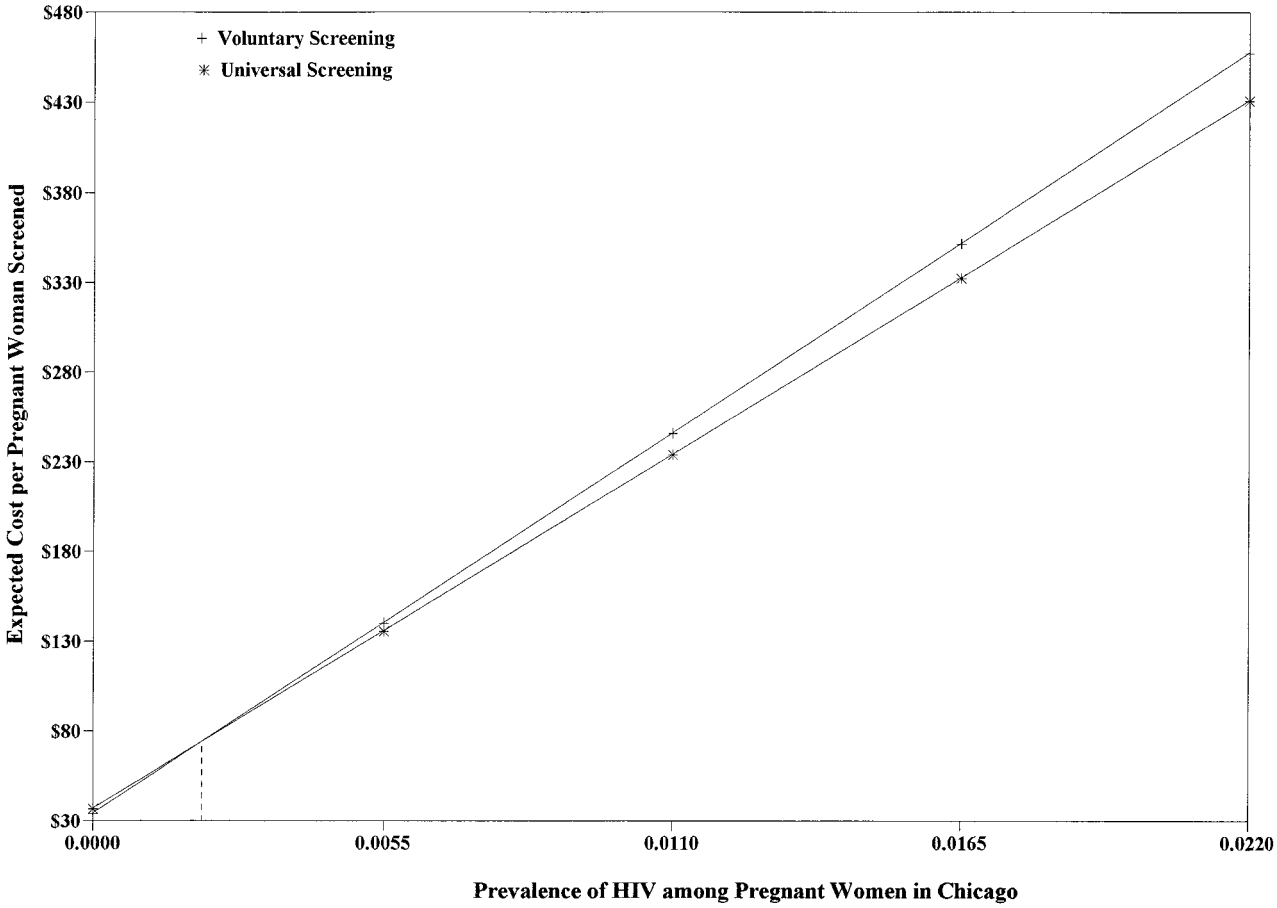

Fig 3. Sensitivity analysis of the prevalence rate of HIV among pregnant women and the expected costs per pregnant woman screened for HIV. Cross bars represent the voluntary screening option and asterisks represent universal screening. Voluntary screening is more costly than universal screening unless the prevalence for HIV among pregnant women is ≤.21%. At .21%, the expected cost for screening under either strategy is estimated to be $74.00 per pregnant woman screened.

TABLE 3. The HIV Prevalence Rate for Pregnant Women, Birth Rate, and Time Needed to Avert a Case of Pediatric HIV Infection*

Geographic Area	HIV Prevalence (%)	Number of Live Births/Year	Time Needed to Avert Single Case of Pediatric HIV Infection (Months)
Chicago	.41	48 212	5.2
Illinois	.15	170 912	3.9
United States	.17	3 914 953	.15

* Data reflect results under universal screening option only.

saving as long as the estimated prevalence of HIV seropositivity among pregnant women is >.21%. This finding differs from that of Myers et al.[15] In that study, they concluded that from a health care system perspective, universal screening would prevent more cases of pediatric AIDS but at a somewhat higher cost than voluntary screening. We found that no matter how low the HIV prevalence rate (as long as it is above zero) is for a specific community, the number of pediatric HIV cases averted and life-years saved are greater for universal screening. We did not determine a specific prevalence rate for which we would no longer recommend universal screening. Communities with a prevalence rate below .21% must determine if the additional effectiveness of universal screening outweighs the additional cost. Using a threshold of $50 000 per life-year saved,[45,46] universal screening would remain cost-effective for all communities with a prevalence rate >.0075%.

Although this study is based on the results of the ACTG 076 study in which pregnant women and their infants received only AZT, our study results would support greater cost-saving with universal screening as improvements in the treatment regimen for children infected with HIV occur. In fact, as the vertical transmission decreases, which will likely occur as more and more HIV-positive pregnant women are placed on multiple antiretroviral therapy during their pregnancies, the difference between the costs for universal and voluntary screening increases even more because more cases of HIV in newborns will be averted. In addition, based on a recent meta-analysis study by the International Perinatal HIV Group, elective cesarean section of HIV-infected pregnant women would reduce the risk of transmission of HIV from mother to child.[9] In this situation, the difference between the costs for universal and voluntary screening increases further. Thereby, even greater cost-savings for universal screening would result.

Although we used 92.7% as the voluntary rate, there is considerable variability in the percentage of

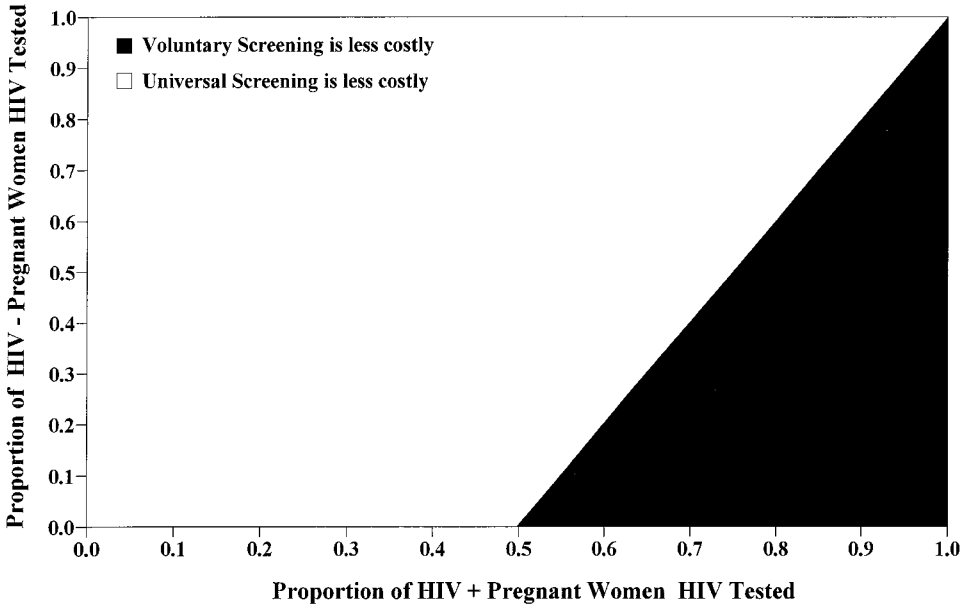

Fig 4. Two-way sensitivity analysis of the percentage of women screened depending on whether they are considered high-risk or low-risk for HIV infection. The *x*-axis represents women who are HIV-positive who are screened. The *y*-axis represents women who are HIV-negative who are screened. The area shaded represents areas where voluntary screening is less costly and the unshaded region represents areas where universal screening is less costly. An ideal targeted screening program is represented by the lower right hand corner in which 100% of the HIV-positive women are HIV screened and 0% of HIV-negative women are screened.

women volunteering to be tested for HIV that has been reported in the literature.[14,33–37] In fact, many of the communities report a volunteer rate that is lower than what is seen in Chicago. Therefore, the savings would be expected to be greater for these communities where the voluntary rate is less than our reference value.

Our assumption that costs for pretest counseling would be the same for voluntary and universal strategies is conservative, because it would be more likely that less time and counseling would occur for each pregnant woman screened under the universal plan. This would increase the overall costs of the voluntary screening option and widen the difference between the voluntary and universal screening costs.

The seroprevalence rate for Chicago is based on unlinked anonymous screening of newborn infants born in all Chicago hospitals. Therefore, the seropositivity rate reflects infants born to mothers with known and unknown HIV infections. This reference case may be an overestimate of the prevalence of HIV-positivity among pregnant women not previously identified. Screening pregnant women whose HIV status is already known would not contribute to any of the outcomes measured in our analysis but merely contribute to the screening costs. Thus, it is presumed that whatever strategy is implemented, it would not include screening HIV-positive women who have disclosed their status.

This model can also be applied toward those pregnant women who present late or not at all for prenatal care, ie, in labor and delivery. The costs of treating the mother with AZT would decrease. Universal screening would still be cost-effective because presumably, the HIV status of the mother could be determined sometime during labor and delivery or before her infant reached 48 hours of life. As a result, the infant born to the HIV-positive mother could still be started on AZT. This would still decrease the number of potentially infected infants.[7] In their cost-effectiveness analysis, Stringer and Rouse[47] addressed the potential effectiveness and costs of a program to prevent vertical transmission of HIV in women without prenatal care. When they compared a no testing scheme to rapid HIV testing to women who present in active labor, they concluded that rapid testing followed by AZT if seropositive would be cost-saving. We do not consider universal screening of all newborns in this study, which would be another alternative to capturing the population of pregnant women who received no prenatal care. However, this strategy of universal newborn screening would obviously not avert as many cases of pediatric HIV, because treatment for HIV could not begin until after the birth of the newborn.

Many women may be uncertain about their risk factor for infection, eg, they may be unaware of partner risk factors for HIV infection. As a result, they may not elect to be screened. This lack of awareness may be more prominent in the pregnant adolescent population as has been noted in previous studies.[14,48,49] Pregnant teenagers who are HIV-positive would be an important population to identify because not only can we decrease the prevalence of HIV infection among their infants but we can potentially improve the quality and survival of these young adults. Other studies have shown that women may not acknowledge risk factors and not agree to testing to ensure their privacy or they may simply be in denial of their risk-taking behaviors.[11] In addition, universal screening could potentially identify the partners of women who are screened to be HIV-positive and prevent infections (increase life expectancy and decrease costs for medical care) in future children and partners.

Our results may also have underestimated the effectiveness of a universal screening program because we did not adjust newborn life expectancy based on the quality of those years. The burdensome medication regimen, the social stigma attached with HIV infection, and the eventual complications from HIV infection would undoubtedly lower the expected

quality of life for newborns contracting HIV. Accordingly, the benefits of preventing transmission may be somewhat greater than we have estimated.

Our model also may have underestimated the total costs for treatment of a perinatally HIV-infected child in that we assigned only the last 2 years of life as survival with AIDS. If the number of years an HIV-infected child spends with AIDS increases, obviously the total costs for treatment would increase accordingly. In this case, it would become cost-saving to implement a universal strategy and the threshold HIV prevalence for cost-saving and cost-effectiveness would be even lower.

Finally, if we had included newborns' future consumption and earning patterns in the model, as some researchers advocate,[50,51] universal screening would also save more money from a societal perspective than we estimated. Newborns without HIV, would generally go through 3 periods of life: childhood when they consume only, working age when they produce more than they consume, and older age when they again consume more than they produce. In comparison, newborns with HIV generally will not reach an age where they can generate financial resources, and their resource consumption would occur in the relatively near future, which is not discounted as much as later consumption. Thus, if it is assumed that people generally produce more than they consume across a life span, the financial savings associated with each HIV transmission prevented may be larger than we have estimated.

Limitations of Study

This study does not address the economic impact as more medications become available on the market for individuals infected with HIV. It is presumed that as survival increases, the costs for keeping viral loads to a minimum would increase dramatically. We also did not address the maternal costs associated with prevention of HIV infection in infants whose mothers are known to have HIV before pregnancy. Depending on the pregnant mother's immune status and the complications that may arise from her HIV infection, the maternal costs associated with keeping her viral infection under control and preventing or treating complications could be tremendous. Given recent findings that cesarean sections reduce the risk for perinatal infection, it would be interesting to further investigate the cost-effectiveness of universal screening taking into account that this mode of delivery is much more costly than vaginal delivery.[9] We also did not include in our analysis the impact of universal screening on delaying maternal prenatal care. Myers et al[15] found that delays in prenatal care reduced the incremental cost-effectiveness. In their analysis, they assumed the overall proportion of women with no prenatal care to be relatively low. As a result, the reduction in net costs is greater than the relative decrease in cases prevented.

Our study also does not address the ethical considerations relating to the pregnant woman's right to privacy. We do not address the impact of a known HIV status and the potential negative consequences to the pregnant woman or her infected infant, eg, ability to obtain subsequent health and life insurance coverage. Our study is from a societal perspective, so the analysis considers everyone affected by the interventions of universal or voluntary screening not just the pregnant woman.[18]

CONCLUSION

Our analyses suggest that universal screening for HIV among pregnant women would avert many cases of pediatric HIV transmission if adopted. For many communities, such as Chicago, that have HIV prevalence rates for mothers of >.21%, universal screening would also save money in comparison to voluntary screening. For communities with prevalence rates <.21%, the benefits of universal screening still may outweigh the costs for screening, as desirable incremental cost-effectiveness ratios were found for prevalence rates as low as .0075%. Furthermore, the benefits of universal screening may be larger for communities where mothers are less likely to volunteer for HIV testing. Universal screening may also ease the burden on physicians to encourage patients to be screened.

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