POLICY BRIEF 20 | AUGUST 2009

Estimating the Impact of an AIDS Vaccine in Developing Countries

Almost 30 years into the pandemic, more than 25 million people have died from AIDS, 33 million people are living with HIV worldwide and about 3 million become newly infected each year (UNAIDS, 2008). Even as countries expand programs to prevent and treat HIV and AIDS, the 7,400 new infections each day speak to the ever-growing humanitarian, social and economic burden the world faces, and the pandemic continues to outpace currently available interventions. While the global community works to expand treatment and care services to those infected by HIV, there is an urgent need to strengthen HIV prevention activities to stem the tide of new infections.

Vaccines are consistently among the best tools for fighting infectious diseases. As part of an integrated prevention and treatment strategy, vaccines could potentially end the spread of HIV. However, questions persist:

- Would a vaccine still be needed if existing prevention programs and antiretroviral treatment (ART) are significantly expanded while a vaccine is being developed?
- What will be the impact of first-generation vaccines if they provide only partial protection against HIV?
- Would a vaccine be cost-effective?

To address these questions, the International AIDS Vaccine Initiative (IAVI), with support from the Futures Institute, has been modeling the future epidemiology of the AIDS epidemic in key countries and the impact that a vaccine could have (IAVI, 2006a). An analysis of global vaccine impact was initially published in 2006, but UNAIDS estimates of the magnitude and trends of the epidemic have been modified downward since then, reflecting increased availability of country-level data, methodological refinements and growing knowledge about the disease's history (Kaiser Family Foundation, 2008). This brief updates the earlier analysis with the latest epidemiological information. The updated analysis confirms that including vaccines as part of a comprehensive response can make a significant impact in ending the pandemic in the coming decades. Additionally, a vaccine would not have to be 100% effective or reach 100% of at-risk populations to yield significant benefits. A vaccine that is 50% effective, given to just 30% of the population could reduce the number of new HIV infections in the developing world by 24% over 15 years.

Estimating Global Impact

IAVI and the Futures Institute developed an AIDS vaccine impact model as part of the Spectrum Policy Modeling System, which has been used to explore the impact of other AIDS prevention and treatment scenarios (IAVI, 2005a; IAVI, 2005b; and IAVI, 2005c). The model is intended to be an easy-to-use tool for researchers to explore the impact of AIDS vaccines on the pandemic by applying country-specific demographic, epidemiological, and vaccine uptake data (Futures Institute, 2009 and Stover, et al, 2008). The model also allows policy-makers to analyze different vaccine delivery scenarios, from broad coverage of the adult population to more targeted vaccination of high-risk groups, including injecting drug users, sex workers and men who have sex with men.

IAVI's epidemiological impact modeling project is part of a larger effort to analyze the impact of an AIDS vaccine and to estimate the health and economic benefits that are likely to result from widespread vaccination in countries affected by the disease. Results from this exercise can assist policy-makers to better assess the potential impacts and benefits of an AIDS vaccine and AIDS vaccine R&D, and assist decision-makers in thinking about the challenges and issues they are likely to face in the coming decades.

The UN has set coverage targets for prevention, treatment and care services, depending on whether the epidemic is low-level, concentrated or generalized in each country (UNAIDS, 2007). Based on these guidelines, countries have set their own goals and have committed to try to reach them as soon as possible.

The baseline scenario described here optimistically assumes that the UN universal access goals will be met by 2015, when a vaccine is also assumed to be introduced. The model reinforces findings from other studies showing that although the ambitious targets set by the UN would lower the number of new infections and reduce cases of AIDS-related disease and deaths, achieving these goals will not be sufficient to end the pandemic (Stover, et al, 2006). We estimate that there would still be 1.5 million new infections in the year 2015, indicating that an AIDS vaccine would have an important role to play in slowing and ultimately ending the pandemic.

The analysis described here used the following seven countries (in four regions) to build an estimate of the epidemiological impact of vaccines for the developing world as a whole: Nigeria and South Africa (sub-Saharan Africa), Brazil and Mexico (Latin America), China and India (Asia), and Russia (Eastern Europe). These countries were selected because they are representative of the epidemic in their regions and because they are among the countries with the greatest absolute numbers of infections. Collectively, they contain almost 40% of people living with HIV and almost 50% of all new adult HIV infections in the developing world.

Using readily available data, such as the UNAIDS country projections, estimates of the HIV epidemic to 2030 were made for each of the selected countries, reproducing the key dynamics of the HIV epidemic in each country (IAVI, 2006a). The country-specific results for each indicator of vaccine impact (prevalence, incidence, deaths averted) were extrapolated to the regional level based on the countries' proportional contribution to their respective region's epidemic in 2007. The regional totals were added together to obtain a global total for the developing world.

Potential Vaccine Scenarios

Although the exact level of protection that will be conferred by first generation vaccines is still unknown, scientists believe they may only be partially effective in protecting against HIV (IAVI, 2006b). Based on the leading vaccine candidates currently being tested in clinical trials, an AIDS vaccine could have a combination of the following effects:

- Protect the vaccinated individual against HIV infection (i.e., reduced susceptibility);
- Reduce the probability that a vaccinated individual who later becomes infected will transmit his or her infection to others, (i.e., reduced infectiousness); and/or
- Slow the rate of progression from HIV infection to death in vaccinated individuals (i.e., increase in average survival time after infection).

All three of these effects are included in the four main scenarios (Low, Medium, High and Very High) that were tested using the HIV vaccine impact model. Plausible ranges were chosen to reflect current understanding of AIDS vaccine science. Coverage levels were based on previous work that indicates uptake of a partially effective vaccine in the general population would be modest (Esparza, 2003 and IAVI, 2007).

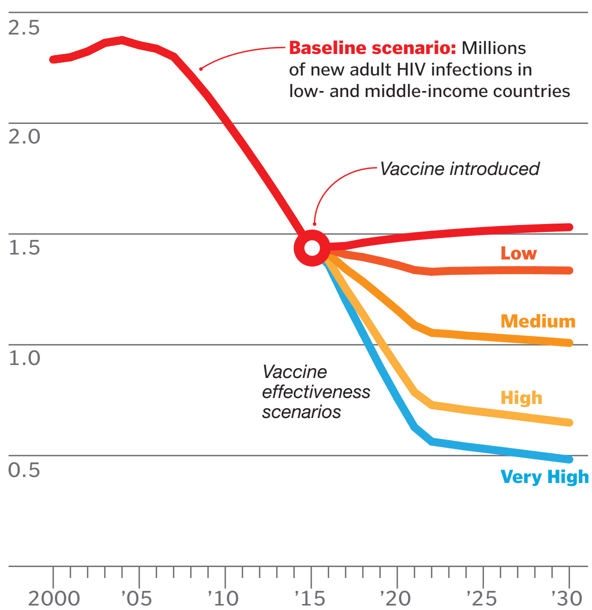
In addition to the five scenarios detailed at right, several other possiblities were examined:

- *More optimistic coverage rates:* Higher levels of coverage yield dramatic results. For example, a vaccine with 70% efficacy provided to 70% to 90% of the population would reduce the number of new infections globally by 88% to 94% a year, nearly stopping the spread of AIDS.
- *Selective targeting:* The model demonstrates that targeting the vaccine to high-risk populations in countries with relatively modest epidemics still achieves 85% of the effect in terms of avoiding infections and saving lives, as compared to vaccinating the general adult population.
- *Incomplete achievement of universal access:* If the UN goals are not fully achieved, the magnitude of the AIDS epidemic would be greater than predicted in the baseline scenario, and the absolute impact of a vaccine would be larger.

THE MODEL: Effect of a vaccine on AIDS incidence and mortality

The model shows that a vaccine could substantially alter the course of the AIDS pandemic and reduce the number of new infections even if vaccine efficacy and population-coverage levels are relatively low and other programs for treatment and prevention have been scaled up. The model also shows that an AIDS vaccine could significantly reduce the number of deaths attributable to AIDS. The reduction in AIDS mortality is smaller than the predicted decrease in new infections because some deaths will be averted by expanded access to treatment.

No risk compensation, or behavioral disinhibition, is assumed in these scenarios. That is, we assume that the vaccination program does not cause people to adopt riskier behaviors because they think they or their partners are completely protected. Extreme risk compensation could theoretically mitigate or even eliminate the benefits of vaccination. Since these scenarios assume that other prevention efforts are scaled up to universal access before the introduction of a vaccine, extreme behavioral reversal would be unlikely. Clearly, it will be important to combine vaccination with other prevention activities—as well as education and information initiatives—to ensure that the full benefits of the vaccine are realized.



Vaccine scenarios	Efficacy	Percentage of population given vaccine	New infections averted 2015-30 (millions)	Percentage of new infections averted (millions)	Annual HIV infections in 2030 (millions)	AIDS deaths in 2030 (millions)	Cumulative AIDS deaths 2015-30 (millions)
Baseline	—	—	—	—	1.5	1.5	22
LOW	30%	20%	2.1	9%	1.3	1.4	22
MEDIUM	50%	30%	5.6	24%	1.0	1.3	21
HIGH	70%	40%	9.8	41%	0.6	1.1	20
VERY HIGH	90%	40%	12.0	50%	0.5	1.1	20

Vaccines would be cost-effective

Although the actual cost of future vaccines is unknown, the maximum price at which a vaccine would be considered cost-effective can be calculated using several different approaches. An example:

Vaccines vs. ART: An infection averted by a vaccine will mean that a person would not need antiretroviral treatment in the future. Thus the cost of a vaccine can be compared with the present value of future treatment costs. The current value of lifetime treatment for a person starting on ART today is about US$ 7,400, based on the assumptions in the table at right.

Survival rate, first year	86%
Survival rate, subsequent years	90%
Chance of moving to second-line treatment	80%
Annual cost of laboratory tests	US$ 190
Annual cost of service delivery	US$ 102
Annual cost of first-line ARV	US$ 200
Annual cost of second-line ARV, 2009	US$ 1,215
Annual cost of second-line ARV by 2015*	US$ 590

*Costs are discounted 3% a year

In the scenarios modeled here, the number of vaccinations required to avert one new infection ranges from 9 to 280. Therefore, a price as high as US$ 800 per vaccination in the most optimistic case would still be cost-effective when compared to the treatment costs avoided. In the least optimistic case, a vaccine would have to cost no more than US$ 25 per vaccination to be cost-saving.

Moving Forward

Despite progress fighting the pandemic, AIDS continues to pose social and economic challenges. This modeling shows that introducing even a medium-efficacy vaccine with limited coverage as part of a comprehensive package of treatment and prevention could significantly affect the number of new HIV infections throughout the world.

HIV prevention can increase productivity and family earnings, reducing the financial cost of AIDS and positively affecting health systems on a larger scale. Even if a vaccine is first introduced when other prevention and treatment activities have expanded, an AIDS vaccine would still make a significant impact. This underscores the importance of sustaining investments and policy efforts to accelerate AIDS vaccine research and development.

In addition to the humanitarian imperative, this analysis illustrates the potential economic benefits of AIDS vaccines. In an environment of universal access to treatment, each infection averted by a vaccine translates into thousands of dollars saved in averted ART costs, which is especially significant if resources are limited (Stover, et al, 2006).

This study used existing data to examine vaccine impact for selected countries with large numbers of HIV-infected people, but did not include in-depth country-level analyses. IAVI is working with national teams in Brazil, Uganda, Kenya and China to develop further analyses to better understand the potential impact of AIDS vaccines, and to develop appropriate policies to support AIDS vaccine R&D.

Findings from this research highlight the relevance of AIDS vaccines in fighting the pandemic, and can help to continue building support for vaccine development and make a case for global investment in AIDS vaccine R&D.

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Insights

IAVI's policy brief series outlines key public policy issues in the research, development and eventual distribution of AIDS vaccines.

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IAVI gratefully acknowledges the generous support provided by the following major donors

Alfred P. Sloan Foundation* ■ Basque Autonomous Government ■ Becton, Dickinson and Company (BD) ■ Bill & Melinda Gates Foundation ■ Bristol-Myers Squibb (BMS) ■ Broadway Cares/Equity Fights AIDS ■ Canadian International Development Agency ■ The City of New York, Economic Development Corporation ■ Continental Airlines ■ European Union ■ Foundation for the National Institutes of Health ■ Google Inc. ■ The Haas Trusts ■ Henry Schein, Inc. ■ Irish Aid ■ James B. Pendleton Charitable Trust ■ The John D. Evans Foundation ■ Ministry of Foreign Affairs and Cooperation, Spain ■ Ministry of Foreign Affairs of Denmark ■ Ministry of Foreign Affairs of The Netherlands ■ Ministry of Foreign Affairs of Sweden ■ Ministry of Science & Technology, Government of India ■ The New York Community Trust ■ Norwegian Royal Ministry of Foreign Affairs ■ Pfizer Inc ■ The Rockefeller Foundation* ■ The Starr Foundation* ■ Swedish International Development Cooperation Agency ■ Thermo Fisher Scientific Inc. ■ U.K. Department for International Development ■ Until There's a Cure Foundation* ■ The U.S. President's Emergency Plan for AIDS Relief through the U.S. Agency for International Development ■ The World Bank through its Development Grant Facility

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As of June 2009