Envisioning the Future of PEPFAR's Clinical Services through Artificial Intelligence

US Department of State Diplomacy Lab – AI Catalyst

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Executive Summary

- ***Data-driven AI Landscape*** – Growing capabilities of AI offer promising solutions to improve data-driven methods in healthcare and HIV specifically
- ***Bridging Capabilities*** – Technology has advanced capabilities and strong potential for efficiency, but it must be coupled with human understanding for accuracy and maintaining proper patient-centered care
- ***Finite Resources*** – With limited funding, resource constraints, and shifting policies, PEPFAR must prioritize cost-saving strategies– AI offers a powerful tool to improve efficiency and reduce spending
- ***Limitations to Consider*** – 1) Balance of tech to human access 2) Privacy and trust issues and 3) Differing needs of target populations

Problem Statement

This report examines how AI can advance PEPFAR's mission in combating HIV/AIDS. PEPFAR's growing interest in AI reflects the need to enhance epidemic control, optimize resource allocation, and address persistent challenges in HIV/AIDS intervention. With limited financial and medical resources, maximizing efficiency is crucial to expanding PEPFAR's reach and impact. AI has already demonstrated significant promise in other medical sectors– including drug discovery, diagnostics, and treatment optimization–and holds potential for its specific applications to the HIV/AIDS epidemic as well. By leveraging AI-driven data analysis, predictive modeling, generative AI solutions, and strategic resource management, PEPFAR can more effectively identify high-risk populations, streamline treatment processes, and improve access to health education.

Furthermore, recent news indicates potential reductions in resources dedicated to HIV/AIDS programs, making it ever more imperative to explore innovative solutions that sustain progress despite financial constraints. A strong understanding of AI's capabilities will be essential in bridging gaps, improving outcomes, and adapting to the evolving landscape of disease epidemiology and global health funding. As HIV/AIDS remains a major global challenge, integrating AI into PEPFAR's framework presents a critical opportunity to enhance efficiency, maximize impact, and ultimately save more lives.

Efficiency as a Policy Imperative

In light of diminished funding, we must optimize the resources already available to PEPFAR. This moment presents a strategic opportunity, not to fundamentally change PEPFAR, but to enhance it. By integrating AI and data science tools that are already being used in other healthcare domains, PEPFAR can become more efficient, more targeted, and more impactful. Our approach centers on cost savings, feasibility, and real-world precedents–ensuring that innovation supports, rather than disrupts, PEPFAR's mission.

Actionable Items Envisioning the Future of PEPFAR's Clinical Services through Artificial Intelligence

Based on the scoping review and the literature review, we have determined actionable items for both short- and long-term considerations.

Short-Term Improvement

AI offers powerful tools for immediate healthcare optimization and HIV management without the need for robust infrastructure. AI streamlines clinical decision-making through predictive modeling and automated workflows and can generate culturally-tailored outreach materials. By simplifying EHR navigation and leveraging existing data for risk prediction, AI reduces administrative burden and improves resource planning. Mobile health applications can also collect de-identified data for population insights while maintaining privacy. For patient engagement, AI enables customized adherence strategies, chatbot support for HIV self-testing, demand forecasting for test distribution, and result interpretation assistance. AI-powered mobile apps provide medication reminders and track adherence, while NLP can analyze clinical notes to identify early non-adherence signs. Virtual assistants further extend care reach to underserved communities through remote consultations.

Medium-Term Improvement

AI can also be applied to scalable healthcare strategies requiring moderate investment that optimize resource allocation and improve HIV care outcomes. Machine learning models identify high-risk individuals through integrated social and clinical data analysis, while targeted algorithms help redistribute healthcare personnel to high-need regions based on caseload insights. Community-based AI tools empower local health workers with tailored support solutions, and predictive analytics identify underserved populations missing from traditional outreach. AI personalized messaging to increase engagement among hesitant groups and flags patients at risk of dropping out of care for early intervention. Enhanced workforce planning and resource distribution optimize testing campaigns, while historical data analysis improves program effectiveness. Machine learning streamlines clinical scheduling and resource management, predictive modeling prevents medication shortages, and continuous NLP monitoring of patient data enables proactive care adjustments without burdening reporting systems.

Long-Term Improvement

With the capacity for greater infrastructure and policy investment, AI enables long-term transformative healthcare advancements. PEPFAR can implement AI frameworks to strategically identify expansion regions, ensuring optimal resource allocation where most needed. AI facilitates development of comprehensive, culturally-relevant community prevention plans tailored to local contexts. When embedded into national surveillance infrastructure, AI creates automated pipelines for real-time outbreak detection and public health response coordination. Machine learning-powered patient segmentation systems integrated with national testing programs enhance outreach precision and reduce missed diagnoses. Formalized AI infrastructure for workforce and resource management drives continuous improvements in cost efficiency and preparedness. Remote populations gain access through AI-based virtual consultations, multilingual chatbots, and triage tools that bridge geographic care gaps. Finally, confidential AI adherence support and discreet self-care technologies help normalize care for HIV-positive individuals, reducing stigma and improving community-wide health outcomes.

Strategic Recommendations

1. **Combining prevention strategies**
    a. **Combining HIV prevention strategies or applying strategies of other STDs/diseases to HIV prevention**: integrating solutions can serve to advance the effectiveness of prevention efforts by leveraging connections between different interventions, reaching wider populations, and addressing the interconnected nature of STIs–ultimately leading to a greater reduction in new HIV infections.
        i. **Prevention Methods:** combining access to treatment with HIV testing
        ii. **Healthcare Access:** combining HIV screening with that of other STDs or prevention programs for people who would not otherwise seek out HIV testing
        iii. **Behavioral Change:** combining education campaigns with interactive chatbots to encourage behavioral change
    b. **Integrating AI with Existing Public Health Services:** When responses are reviewed and tailored by health professionals, AI chatbots may be a valuable tool for organizations to enhance the efficiency and quality of service provision and to support the development of educational materials.
        i. **Healthcare Providers:** streamline reading charts or making medical recommendations combined with provider review
        ii. **Healthcare Services:** combine current services in hospitals or community-based organizations with AI to tailor suggestions
        iii. **Education**: supplement existing education campaigns with tailored messages utilizing AI
    c. **Challenges:** There may be initial friction in combining different healthcare solutions or implementing AI into current infrastructure. To address this, solutions for HIV prevention and other diseases should be first evaluated in consideration of which have the most synergy. In healthcare organizations, AI should be introduced slowly with the input of current providers to examine which areas would benefit most from AI advancements and which would require greater deliberation before application.
2. **Including communities in advocacy, service delivery, and policy-making**
    a. While integrating new technologies, it is necessary to ensure that services remain culturally appropriate and responsive to the needs of the specific populations it serves. Partnering with community organizations that have more direct access to vulnerable populations has improved linkage to care for HIV treatment and should be a priority with any AI application.
        i. **Advocacy:** People may be distrusting of data privacy or other technological concerns; providing proper education to community leaders can help address these concerns with patients.
        ii. **Service Delivery:** Working with trusted community partners can enhance trust and engagement with patients; it could also support overcoming language barriers. Providers can supplement technology with dialogue.

iii. **Policy-making:** Community organizations better understand the populations it serves and can thus provide meaningful insight into what AI interventions would be most effective or safe.

b. **Challenges:** Integrating community organizations could take time and require other administrative considerations like finances. There may also be differences in communities and populations that would require greater attention. Thus, it is necessary to consider this recommendation in alignment with resource allocation. However, community integration is a meaningful approach that, despite the time and effort required, is worth pursuing as it ensures sustainable, locally informed solutions that can lead to more effective and lasting outcomes.

3. **Surveying Participants for Awareness:**
   a. It could be a helpful metric to understand why patients stop using PrEP or what leads community members to believe that they are not at high risk despite being in a high risk community. Surveying participants can support a better understanding of how to create a sustainable programming by addressing the bottlenecks to proper usage of PrEP and seeking care.
   b. **Challenge:** Surveys may place people at risk of discomfort, which could impact their willingness to participate or provide honest responses. Designing accurate surveys to understand personal risk perception and PrEP adherence challenges can also be complex. Thus, surveys can be made anonymous and facilitated through community partners. Questions should be framed in a non-judgmental manner that captures diverse experiences. Incentives for participation could be offered, but it is important to ensure they do not introduce bias in ways that do not accurately represent the target population.
4. **Testing Implementation**
   a. To ensure that PEPFAR reaches the 90-90-90 goals for HIV containment, wider adoption of HIV testing must take effect among stigmatized or underserved communities immediately. Interventions that target these difficult-to-reach groups should be personalized and confidential to build trust and facilitate health-seeking practices. Artificial intelligence may aid such interventions by providing insight into high-priority groups, which include sex workers, men who have sex with men, and transgender individuals. Once these target groups are identified, and after information such as demographic characteristics and geographic location has been collected so that local public health leaders know how to reach them, accessible means of testing and recording results should be distributed. In particular, mobile health broadly affords high-risk populations means of testing due to the ubiquity of mobile devices and ease of information storage and distribution of test results to trusted individuals such as partners and providers.
   b. **Challenge:** Inherent inequalities among affected groups must be recognized. For example, testing uptake and recording of results may be more difficult to encourage among women, who may fear retribution from male partners. Furthermore, due to the ease of distributing test results on mobile devices, mobile health must be safeguarded with patient privacy guidelines to protect users' health information.
5. **Surveillance Implementation**

a. Thanks to electronic health records, information including HIV status is readily available to providers and public health leaders for vast segments of the population. However, stigmatized high-risk groups are difficult to reach. HIV surveillance strategies must take advantage of existing information and provide motives for high-risk individuals to share data. Existing EHR data can be analyzed with artificial intelligence to predict which patient characteristics correlate with high HIV risk or low adherence to care and medication uptake, and these data can then be applied to prioritize certain populations for targeted HIV health outreach. Furthermore, chatbots and e-pharmacies can act as services high-risk individuals can use to seek HIV counseling and purchase HIV medications and PrEP. Clients' information can then be collected to inform future interventions targeting high-risk populations.

b. Challenge: Since effective surveillance relies on users inputting sensitive data, surveillance measures must reliably collect accurate information without revealing users' identities. This can be accomplished in chatbot conversations, e-pharmacies, and other media wherein users interact with digital "providers" by collecting surveillance-relevant data without recording any personal identifying details. Public health leaders will have access to such data to make future AI-assisted predictions about reaching high-risk populations without individuals having to fear stigma or other social repercussions.

6. Reassessing Resources and Prioritization

a. As the future of funding for global HIV efforts becomes less certain, the optimal allocation of PEPFAR's finite resources is of the utmost importance. We recommend the use of AI to help scale the impact of PEPFAR while reducing the costs of operating in low-income countries. With better infrastructure in place, we anticipate countries being able to manage their own prevention and treatment programs with less assistance from the PEPFAR. Our consideration of the financial sustainability of PEPFAR programming is in alignment with the principles set forth by the Department of Government Efficiency.

b. AI can also help with reassessing resource allocation AND make processes more efficient/less costly

c. Challenges: One of the challenges posed by the program cuts implemented by the Department of Government Efficiency under President Trump is that they have the potential to undo decades of HIV/AIDS prevention and treatment work. Instead of weaning countries off of U.S. assistance, cutting funding may have irreparable damage. Therefore, we recommend appealing the recent funding decisions with a plan for helping countries transition to self-sufficient HIV/AIDS programs.

Scoping Review

Prevention

Treatment As Prevention

Treatment is a significant aspect of HIV prevention itself, and this specific approach is commonly deemed as TasP (Treatment as Prevention). Early prevention methods did not account for situations in which one sexual partner may not control the encounter or is not empowered to advocate for protective measures. In particular, this created a challenge considering gender-based violence: women or other at-risk populations were either unable to control their sexual activity or were at risk of facing stigma or violence if they did seek HIV prevention methods.[1] The lack of a discreet, user-driven prevention is thus a critical gap. Treatment as Prevention through ART was thought to be an opportunity to address this gap as those living with HIV would be able to reduce viral load and mitigate transmission, and using ART as PrEP could prevent HIV acquisition by people not infected but at high risk.[2]

Although a major breakthrough regarding HIV prevention, TasP has not been able to drive dramatic decreases in new infections because both approaches rely on adhering to daily pill-taking for full effectiveness.[3] Aside from scheduling, taking pills can also create barriers due to stigma, familial objections, and legal challenges; self-perception of being at low risk and stigma are likely the main factors of non-adherence.[4] A long-acting drug formulation or methods that do not require daily dosing may support better adherence and are in the process of being developed, but there are still limitations with cost and accessibility.

Prevention Strategies & Application of AI

Even given these various solutions available for HIV prevention, literature cites four main remaining challenges for widespread success: (1) reliance on biomedical prevention and behavior change without adequate consideration for factors that place certain people at higher risk; (2) absence of an effective solution, or combination of solutions, that applies to various circumstances of transmission; (3) lack of discreet, straightforward methods of prevention accessible to the person directly seeking care; (4) inconsistencies in accessibility and adherence to methods of prevention at high-risk encounters.[5]

Each of these contribute to ineffective programming in the platforms aimed at targeting prevention. HIV prevention is limited by lack of a solution that can be universally applied and is user-driven while addressing the unique circumstances of people's situations and levels of accessibility. Additionally, insufficient financial resources and subsequent lack of prioritized programming for prevention, regulatory and guideline restrictions, and weak health systems inhibiting access and availability also stand in the way

[1] The Evolution and Future of HIV Prevention Technology: An HIV Policy Primer
[2] The Evolution and Future of HIV Prevention Technology: An HIV Policy Primer
[3] The Evolution and Future of HIV Prevention Technology: An HIV Policy Primer
[4] The Evolution and Future of HIV Prevention Technology: An HIV Policy Primer
[5] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer

of widespread prevention success.[6] Stigma remains a barrier in accessing and using prevention options. However, there are avenues to address efforts to slow the spread of HIV, and AI holds potential in enhancing these efforts through efficiency and expanding care where human resources are scarce.

Optimizing Systems for Impact

Again, it is to be emphasized that a major challenge for success in widespread HIV prevention is in meeting the different needs and vulnerabilities placing certain groups at risk.[7] Because there is not yet a vaccine on the market or cure for the disease, solutions must focus on prevention. While pursuing the development of an overarching solution of behavior change alongside medical interventions, limited financing and access around the globe makes it clear that optimizing systems to address specific population needs will be paramount while doing so. Some of these challenges include insufficient funding, regulatory obstacles, inefficient health service delivery, and having the bandwidth to apply societal or cultural factors necessary for successful implementation of solutions.[8]

Finances

It is extremely critical to allocate resources efficiently both in terms of reach and effectiveness. Aside from direct healthcare costs, the high data dimensionality due to the abundance of risk factors for patient expenditure including demographics, diagnoses, comorbidities, and more create complex and unpredictable systems.[9] One way to handle the massive amounts of health data is to use new machine learning algorithms; with machine learning, AI applications in healthcare management can reduce the gap between available resources and public healthcare demand. With this gap narrowed, funding can be reallocated to other areas.

Regarding governance, AI can help investigate which social determinants of health cause more cost within specific patient populations and make resource allocation efficient with forecasting.[10] For example, ML frameworks have already been used to classify health projects and track financing, and AI can be used for public option mining to forecast the incidence of medical cases or predict the potential spread of disease. By providing insight on initial steps in institutional planning with greater foresight and accuracy, AI can reduce friction and spending in planning for health control strategies and intervention programs that effectively allocate medical resources.[11]

In the realm of revenue raising and expanding resources available for medical prevention, AI has implications in enabling organizations to alleviate catastrophic health expenditures and to analyze current efficacy of fundraising tactics.[12] With pooling, AI can help policymakers identify high-risk patients and

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[6] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer
[7] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer
[8] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer
[9] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation
[10] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation
[11] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation
[12] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation

the expense of implementing mitigation strategies; they guide shared decision-making regarding high-risk patient populations to align treatment decisions with their spending preferences and values.[13] Lastly, strategic purchasing and resource allocation strategies are key for prioritizing limited healthcare capacity, and AI can assist in developing information systems for administrators in financial management, resource allocation, and activity planning.[14] AI can facilitate a cost-benefit analysis which allows for maximum efficiency of human resources, and the results of such analysis can guide subsequent distribution of resources, enhance regional public health systems, and organize government coordination in allocating resources at various levels. Together, the medical and health service system can become more balanced and coordinated.

In light of new biomedical tools like CAB-LA and a 6-month prevention that are effective but pricey, AI can support the usage of these tools by evaluating where to allocate resources and improve cost-effectiveness so that these innovations can eventually serve as widespread solutions.

In the realm of e-Health and digital health, AI also holds promise in redesigning existing healthcare delivery models and redesigning the traditional relationship between patients and providers in a way that optimizes financial capabilities as well as the current scale of healthcare worker capacity. Mechanisms of healthcare delivery are to be discussed subsequently.

Prioritizing High-Risk Populations through Outreach

With limited resources to navigate the HIV epidemic, another way of optimizing current systems is to utilize what is currently available more efficiently. Targeting high-risk populations is a crucial strategy because the HIV epidemic is often heightened first by transmission of the virus among high-risk populations, and then spreads to the general population via bridging groups.[15]
Priority groups are at higher risk of contracting HIV due to their behaviors and local contexts; key population groups include injecting drug users (IDU), sex workers of all genders, men who have sex with men (MSM), and transgender people.[16] People are also vulnerable if their living situations are prone to shifting factors that place them at higher risk of contracting HIV; this includes young people, women, migrants, long-distance drivers, displaced populations, and men in uniform among others.[17] There is evidence that focusing on key populations to expand awareness, prevention, and behavior change interventions can slow, and potentially, curb the epidemic.

Essential to working with vulnerable populations is the need to create a friendly environment that is non-judgmental and non-stigmatizing to allow access of such groups to receiving service. There should also be a consideration for geographical, financial, and procedural accessibility.[18] Some specific strategies include peer involvement to break down barriers among a group and instill a sense of community, outreach to support individuals who do not seek services on their own for various reasons, low threshold

[13] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation
[14] The application of artificial intelligence in health financing: a scoping review | Cost Effectiveness and Resource Allocation
[15] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[16] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer
[17] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[18] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV

community-based facilities that minimize administrative and regulatory requirements that pose a barrier to people seeking help, and having self help and support groups where people can share similar experiences and empower individuals to share solutions with the overall group.[19] AI can be applied to some of these strategies to streamline processes and optimize usage of funding and human capital.

While outreach could still be conducted in part by human providers, large language models (LLM) such as ChatGPT can create outreach material customized to consider sociocultural, financial, and geographical differences. This saves time and energy for human providers, who can instead focus on proofing and distributing materials rather than curating them. In some cases, outreach could also be conducted using conversational AI. Voice-powered assistants, including Siri, are designed to help users with tasks such as finding information or managing appointments through a mix of technologies– such as machine learning, speech recognition, and natural language processing.[20] Following the conversational model, voice assistants can offer personalized suggestions and solutions over time, and integrating this technology to outreach efforts is an opportunity to consolidate resources while providing personalized care. This example has already developed in Nigeria, where chatbots are being deployed through accessible platforms like WhatsApp to reach users broadly and facilitate accessible discussions about HIV and AIDS.[21]

However, the usage of human outreach vs technology must be balanced. In some cases, people may desire to seek humanistic care, but conversational AI is also an opportunity to provide care to those who have concerns about patient privacy. Furthermore, vulnerable groups not seeking care can be identified using Machine Learning AI, as it can use data from other people in the area to target geographies or demographics. Although this is an opportunity to streamline resources by targeting groups in need, use of AI must be navigated with caution–specifically in consideration of privacy and security concerns.

Health Service Delivery

Beyond prevention in behavior change systems, AI can be applied directly to health service delivery and healthcare settings. Machine Learning (ML), in particular, holds strong potential to improve delivery of PrEP. With challenges related to a healthcare worker shortage, AI can provide ways to shift tasks by taking on more logistical tasks such as automating medication log updates and independently completing patient care documentation. By improving efficiency in a healthcare facility, AI can help scale the current workforce's impact and enhance health service delivery without involving additional providers.[22]

There are currently several HIV risk scores, primarily for MSM, and many applications of AI for HIV prevention are built on these scores by using ML to identify at-risk people who could benefit from HIV testing, PrEP, or other intervention strategies.[23] For example, AI can triage electronic health records (EHRs) and predict HIV risk using demographic characteristics, social history, diagnoses, lab tests and results, and prescriptions. There have already been several studies that have developed and validated HIV

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[19] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[20] Are Alexa And Siri Considered AI? | OpenGrowth.
[21] Using chatbots to create self-service channels for HIV prevention in Nigeria
[22] Expert Interview with Jhpiego Project Employee
[23] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic

risk prediction algorithms to identify high-risk patients from health data with ML.[24] These studies found that there was a level of disconnect between prediction of HIV risk and those currently prescribed PrEP, which suggests a possible lack of open conversations between patients and providers about HIV risk. Utilizing technology can help reduce disparities in prescribing PrEP across social or cultural factors that may arise from clients' lack of awareness and provider biases.[25] While an algorithm should not replace conversations between providers and patients, it can catalyze them and bridge gaps in accessibility across demographics.

It was also found that combining technological methods could improve predictive performance. In particular, Feller et al. found that natural language processing data could enhance machine learning algorithms to further optimize EHR-based tools.[26] Future development should focus on further customization of algorithms adapted to specific patient populations. In doing so, there may be greater effectiveness of implementing solutions without commensurate need for addition of resources.

A caveat to this solution is that it may not be as applicable to patients with minimal EHR data, and providers must still be adequately prepared to have nuanced conversations with clients.[27] However, AI may also be applied to these conversations using Large Language Models in a similar manner as discussed regarding outreach. Patients can utilize AI to navigate resources tailored to their situations independently, and providers can utilize AI to adequately prepare for conversations that meet patient needs. Regardless, integrating a better screening tool with AI for PrEP can help normalize conversations around the subject–eventually furthering the application of PrEP use and reducing disparities in its accessibility.[28] Once further developed, it will also be possible to apply technology in settings without widespread EHRs. For example, the Ministry of Health in Kenya developed an eight-item PrEP rapid assessment screening tool, and ML algorithms could be applied here to streamline decision-making.[29]

Education and Awareness

Education and awareness play a large role in prevention. Regardless of what prevention methods or medicine options are available, education about proper usage and how to minimize the risk of HIV transmission are key to stopping the spread of disease. As a cornerstone for prevention, public and patient education must be readily supported by clinicians, public health agencies, and community partners.[30] Healthcare providers and institutions must have adequate and accurate knowledge to address HIV and ensure that information and support are available to clients when and where needed. AI can be implemented as a way to both receive and disperse information.

Healthcare providers can use LLMs to parse through information to create infographics, get new information, or introduce interactive chatbots to patients to engage with and get information. Machine learning can also help providers identify where greater education and awareness efforts are needed.

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[24] Electronic health record tools to catalyse PrEP conversations - PMC
[25] Electronic health record tools to catalyse PrEP conversations - PMC
[26] Using Clinical Notes and Natural Language Processing for Automated HIV Risk Assessment - PMC
[27] Using Clinical Notes and Natural Language Processing for Automated HIV Risk Assessment - PMC
[28] Electronic health record tools to catalyse PrEP conversations - PMC
[29] Electronic health record tools to catalyse PrEP conversations - PMC
[30] HIV Prevention - StatPearls - NCBI Bookshelf

There have already been efforts to implement chatbots in pilot studies to distribute tailored, conversational content to users. For example, Brixey et al. implemented a chatbot that provided sexual health information on HIV/AIDS to users through Facebook Messenger using a response database compiled from professional medical and public health resources.[31] With technology, the wealth of resources can be consolidated, and algorithms can tailor information to each conversation. Alongside information dissemination, chatbots can be developed to support decision-making related to PrEP use or adherence.[32]

AI can also support individuals in protecting others from contracting HIV in serodiscordant relationships (relationships in which at least one partner has HIV and another does not).[33] Serodisclosure is a process that involves informing others of one's HIV status; levels of disclosure are generally high, but lower levels are documented in certain populations.[34] Serodisclosure helps raise awareness of HIV risk, encourages regular testing for individuals, facilitates informed sexual decision making, and destigmatizes overall conversations around HIV.[35] However, serodisclosure can be inhibited due to stigma or fear around disclosure, and openness often reflects available levels of resources and social support. Thus, providing access to support is critical. AI can bridge this gap through virtual reality (VR) and chat bots. For example, Muessig et al. created a VR program called "Tough Talks" for HIV-positive young men in MSM relationships built upon qualitative data, where participants can roleplay various disclosure scenarios with a virtual character to practice with.[36] In a follow-up report on the implementation of "Tough Talks", users reported high levels of satisfaction with 98% of activities receiving positive ratings in usability testing.[37] Participants found the AI-facilitated scenarios to be reflective of their lived experiences, but improvements could be made in creating an ideal virtual environment as some had difficulty having nuanced conversations.[38] "Tough Talks" is currently still being tested as a scalable intervention but serves as a strong example of how AI can support education and behavior change interventions catered to specific populations.

Monitoring, Surveillance, Reporting

Beyond prevention and treatment of the physiological pathway of disease, HIV prevention can be supported through proper monitoring, surveillance, and reporting of the disease as it is a disease transmitted through intimate human contact. If the chain of transmission can be monitored and controlled, preventing HIV can be achieved through limiting transmission and properly implementing preventative measures early on in the potential spread of disease. Already, data is being used to identify HIV outbreak hotspots and help organizations target resources accordingly, and Artificial intelligence is a promising avenue to enhance the scope of surveillance by improving efficiency and providing data in real-time. If

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[31] SHIHbot: A Facebook chatbot for Sexual Health Information on HIV/AIDS - ACL Anthology
[32] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[33] Partners With Mixed HIV Status
[34] Facilitating HIV Disclosure Across Diverse Settings: A Review | AJPH | Vol. 101 Issue 6
[35] HIV serodisclosure among men who have sex with men and transgender women on HIV pre-exposure prophylaxis
[36] "I DIDN'T TELL YOU SOONER BECAUSE I DIDN'T KNOW HOW TO HANDLE IT MYSELF." DEVELOPING A VIRTUAL REALITY PROGRAM TO SUPPORT HIV-STATUS DISCLOSURE DECISIONS - PMC
[37] Tough Talks Virtual Simulation HIV Disclosure Intervention for Young Men Who Have Sex With Men: Development and Usability Testing
[38] Tough Talks Virtual Simulation HIV Disclosure Intervention for Young Men Who Have Sex With Men: Development and Usability Testing

properly utilized, AI can help bridge solutions to improve access to quality services, respond to outbreaks quickly, and determine progress toward prevention goals across populations.

Clearly, technology brings optimism in being able to better support vulnerable populations, but risks of data privacy, security, and transparency must be managed in order to use monitoring as a tool to help high-risk populations rather than put them at risk.

Reaching Stigmatized Populations

Another key challenge of reaching stigmatized populations is their pervasiveness: often, those facing societal stigmas do not exhibit traditional health-seeking behaviors at medical facilities.[39] However, focusing on this group for treatment and prevention promises to deliver the highest-yield results for limiting the spread of HIV. Despite the challenges of seeing stigmatized patients in healthcare settings, the use of EHRs can greatly enhance care for marginalized populations. As EHRs are commonplace and comprehensive, machine learning algorithms can collect geographic, demographic, and medical data to predict characteristics of individuals who are least likely to seek HIV counseling or adhere to medication but are in most need of care.[40] In Kenya, machine learning is being used to predict individuals' HIV results and likelihood of dropping out of treatment given input risk assessment and patient characteristics, demonstrating the feasibility of using AI in low-resource HIV care settings.[41] However, low-resource settings present challenges to machine learning algorithms' demanding data requirement, as stigmatized individuals in these settings tend to avoid medical institutions and resort to seeing local healers instead.[42] EMRs must therefore be used to document cases more thoroughly while protecting patients' identities from the public sphere.

LLMs in the form of chatbots can be used to engage stigmatized individuals with personalized, anonymous HIV counseling. When Patients ask questions about testing and prevention, chatbots can give patients guidance on managing their condition and give directions on accessing higher points of care.[43] Without revealing patients' identities, chatbots can then record patient characteristics and geography, then relay these data to an algorithm to improve predictions for new HIV hotspots and characteristics of patients needing HIV care. This information can be used to create prevention and treatment interventions. Interventions that do not compromise patient privacy include the installation of e-pharmacies similar to MYDAWA, a private online pharmaceutical retailer in Kenya. Using such e-pharmacies, patients can input their health history and HIV test results, submit orders for PrEP and antiretroviral therapy, and have orders shipped to them unmarked to mask their identities from others, effectively making care more accessible even with the burden of social stigma.[44]

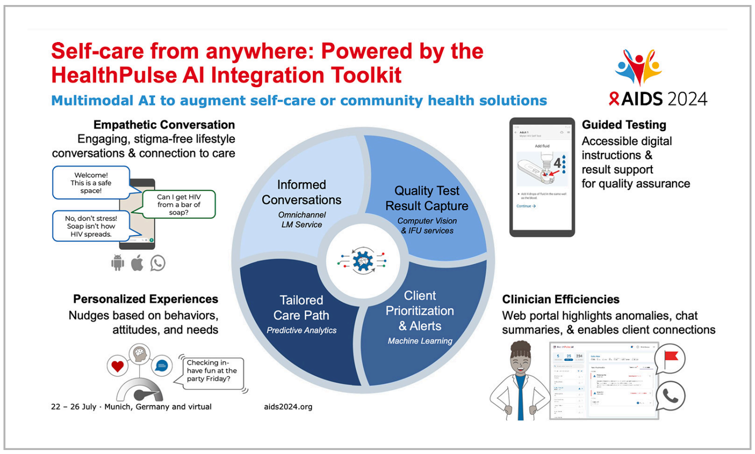
Testing

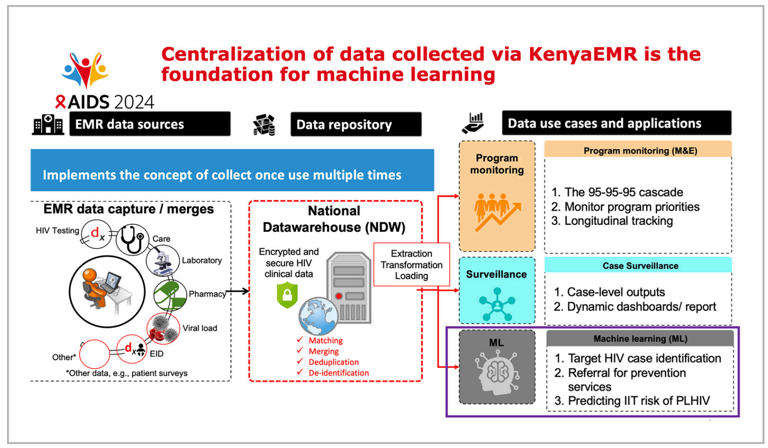
AI has the ability to make HIV testing more accessible and better identify at risk patients.

[39] The Correlates of Health Facility-related Stigma and Health-seeking Behaviors of People Living with HIV - PMC.
[40] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[41] Using Machine Learning in KenyaEMR - Kenya HMIS Documentation
[42] Using Machine Learning in KenyaEMR - Kenya HMIS Documentation
[43] "Your Choice": Using AI to Reduce Stigma and Improve Precision in HIV Risk Assessments
[44] Online HIV prophylaxis delivery: Protocol for the ePrEP Kenya pilot study - PMC.

Identification & Social Networks

Universal HIV screening and testing programs are prohibitively expensive, and current programs often fail to identify the most at-risk individuals.[45] A study of knowledge of HIV-positive status from 2000–2019 in 40 countries in sub-Saharan Africa found that although knowledge of HIV-positive status has increased substantially and steadily over the past decade, it remains lower among men and young people aged 15–24 years than other groups.[46] Social and virtual networks remain underutilized for distribution of HIVST kits and may benefit from improved messaging for specific populations about the benefits of HIVST.[47]





[48, 49]

Mobile App

Mobile platforms offer a convenient way to encourage health-seeking behaviors and facilitate communication between patients and providers, resulting in a paradigm shift to "mobile health." Mobile health interventions may facilitate testing and prevention for individuals at risk for HIV. One smartphone app provides users with instructions for HIV testing and enables users to scan test results, which are interpreted and saved by the app. Users can then choose to send test results to sexual partners and healthcare providers.[50]

The integration of mobile health with AI is facilitated by the ubiquity of mobile health devices, such as smartphones, in daily life. Notably, smartphones can integrate AI directly to predict outcomes for HIV patients. In a study that used smartphones to monitor reports of condomless anal sex by men who have sex with men (MSM), a significant risk factor for HIV, interventions designed to curb risky behavior were

45 Review of Application of Artificial Intelligence and Machine Learning for HIV Prevention Interventions to Eliminate HIV - PMC
46 Achieving the 95 95 95 targets for all: A pathway to ending AIDS - PMC
47 The future of HIV testing in eastern and southern Africa: Broader scope, targeted services | PLOS Medicine
48 Can AI Spark New Progress Against HIV?
49 HealthPulse AI Leverages MediaPipe to Increase Health Equity - Google Developers Blog
50 SMARTtest: A smartphone app to facilitate HIV and syphilis self- and partner-testing, interpretation of results, and linkage to care

implemented prior to when risky behavior was predicted to occur. MSM used smartphones to input reports of condomless anal sex or sexual desire, which trained a machine learning algorithm to predict the best times to administer such interventions. These interventions included reminders of healthy sexual behavior and notices of locations where users could access resources such as contraceptives.[51]

AI can also be integrated in mobile health in the form of chatbots that provide answers to users' questions about HIV testing and prevention. Such an application of AI is advantageous due to the ability of mobile health to contact hard-to-reach populations. In Malaysia, for instance, an AI chatbot was found to be helpful in avoiding stigma-inducing interactions and effective at encouraging HIV testing and pre-exposure prophylaxis (PrEP) uptake among MSM.[52] In general, chatbots served as a more accessible form of obtaining clinical knowledge due to their ability to provide answers immediately and offer patients a route for asking questions without revealing their disease status or identity.[53]

Care & Treatment

Data Management

AI not only has the advantage of storing data but also making conclusions based on it. Connecting the treatment plan with patients' input and feedback will help elevate the system. Natural Language Processing (NLP) models can analyze unstructured data from patient feedback, clinical notes, and community health worker reports to identify patterns and barriers to care. For example, if patients are not able to receive their treatments due to commuting distance, language processing models can take note of these patterns and summarize solutions like building clinics in some areas or implementing mobile clinic services.

Additionally, AI analytics can process large datasets to identify trends in appointment adherence, medication pickup patterns, and treatment interruptions, allowing healthcare providers to proactively address potential dropout risks. The tool can make decisions easily by analyzing multiple data sources simultaneously, such as geographic information systems (GIS) data, demographic information, and transportation networks to optimize service delivery points. Predictive analytics can also forecast patient volumes, identify high-risk areas for treatment discontinuation, and suggest targeted interventions. For instance, machine learning algorithms can analyze historical data to predict which patients might need additional support services, enabling healthcare providers to implement early interventions. Furthermore, AI-powered dashboards can provide real-time visualization of key performance indicators, helping program managers make data-driven decisions about resource allocation and service delivery optimization.

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[51] Using Smartphone Survey Data and Machine Learning to Identify Situational and Contextual Risk Factors for HIV Risk Behavior Among Men Who Have Sex with Men Who Are Not on PrEP
[52] Testing the Feasibility and Acceptability of Using an Artificial Intelligence Chatbot to Promote HIV Testing and Pre-Exposure Prophylaxis in Malaysia: Mixed Methods Study
[53] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study

Resource Optimization

Integrating AI tools into the HIV healthcare system can help with issues related to supply chain management, medication distribution as well as staff allocation and scheduling. For instance, machine learning algorithms can predict medication stock levels and potential stockouts by analyzing historical consumption patterns, seasonal variations, and demographic trends. AI-powered supply chain systems can also track temperature-sensitive medications during transport, ensuring proper storage conditions are maintained. Regarding staff allocation, AI algorithms can analyze patient flow patterns and peak visit times to recommend optimal staffing levels, reducing wait times and improving resource utilization. These tools can also help identify potential service delivery bottlenecks and suggest solutions for more efficient resource allocation. Furthermore, AI can assist in route optimization for mobile clinics and community health workers, ensuring better coverage of remote areas while minimizing transportation costs and time.

Retention in Care

Treatment adherence has always been an issue, especially in areas where commuting might be challenging or when there is a lack of patient monitoring. AI tools such as mobile applications can be customized to patients to track their medication intake and record reasons for nonadherence. In a study to reduce nonadherence in patients with Anticoagulation therapy, using AI on patients with smartphones to remind them to take the pills has led to 50% improvement in medication adherence.[54] Indeed, this tool will help patients to better track their treatment and help clinicians track their treatment plan.

Limitations

The use of AI in HIV testing, prevention, and treatment–though with significant potential–still faces situational, technical, and ethical challenges. Public health leaders must overcome these sets of challenges and develop safeguards against potential hazards before implementing AI tools in HIV management.

Though HIV patients share many characteristics, different regions where HIV is prevalent can differ drastically. While countries in the West are endowed with efficient infrastructure and technology that promotes health-seeking behaviors, LMICs face challenges such as shortages of healthcare providers, low availability of HIV drugs and diagnostics, and limited access to quality infrastructure required to connect patients with providers. Even within a single country, disparities in HIV data vary widely. For instance, some regions of a country may experience poor internet connectivity while others may lack convenient transportation systems.[55] Furthermore, areas where stigmatized individuals such as sex workers live may be more difficult for AI-guided interventions to penetrate. Dampened health-seeking behaviors result in a lack of available EHR data, and certain data, such as the HIV status of sex workers' partners, may be unknowable. AI implementation strategies must consider such heterogeneity by adjusting to local needs and environmental constraints and taking the unreliability of data for certain groups into account.

AI implementation in the clinic faces technological constraints owing to its "black box" prediction methodology. Due to this method's lack of transparency, decision-making in healthcare systems must first

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[54] Using Artificial Intelligence to Reduce the Risk of Nonadherence in Patients on Anticoagulation Therapy - PMC
[55] Expert Interview with Jhpiego Corporation employee

validate AI recommendations and can thus hinder the technology's smooth integration.[56] Furthermore, AI predictions can be flawed. Due to biased provider behaviors and historic disparities in HIV prevention and care, AI algorithms trained on existing data may exacerbate inequities in current interventions. For instance, the prevalence of HIV among Black men who have sex with men has been underestimated, and paltry data is available for small populations such as trans women. AI algorithm accuracy and confidence in AI performance may be improved by broad implementation in all areas of healthcare, which would provide more data for algorithms to use and enhance trust in healthcare settings. To overcome flaws in data reflecting historic biases against marginalized groups, AI algorithms can focus on risk factors that are independent of physical characteristics and provider behavior, such as geographical location and socioeconomic status.[57]

The prognosis for AI integration in HIV interventions is also affected by public perceptions of its practicality and ethical consequences. Chief among patient and provider concerns is the potential for AI to precipitate breaches in privacy. Sensitive user data is required to train AI for HIV interventions, and providers have expressed concern over protection of patient data in the face of "black box" training methods.[58] Among patient-facing perspectives, smartphone study subjects indicated discomfort over sexual partners having access to their test results,[59] and chatbot study subjects commented that they did not trust chatbot responses completely due to inaccuracies and absence of human input.[60] Privacy concerns could be addressed via integration with HIPAA-secure apps to communicate with providers while maintaining confidentiality, as well as usage of private data management servers to store HIV test results instead of saving results directly on the smartphone. Further iterations of AI-guided smartphone apps and chatbots need to focus on linking users to stigma-free care sites, such as LGBTQ-friendly healthcare centers, and improving on answering users' complex healthcare questions, which may involve improving chatbot answers or including human responses without exposing vulnerable information from the user.[61]

More accurate AI-guided responses and timing of interventions will improve user trust and adherence in following HIV care guidelines (see Appendix). Initial adoption of AI in administrative and quality control settings can enhance clinic efficiency. Then, acceptance among healthcare workers can be increased by allowing personnel such as case workers to decide how AI shapes patient user interfaces and experiences.[62] Ultimately, healthcare institutions can respond to AI skepticism and accuracy concerns by recruiting diverse stakeholders to assess AI performance, monitoring patient outcomes and treatment, and measuring algorithm performance among not just aggregate populations but also specific groups.[63]

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[56] Expert Interview with Jhpiego Corporation employee
[57] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[58] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[59] SMARTtest: A smartphone app to facilitate HIV and syphilis self- and partner-testing, interpretation of results, and linkage to care
[60] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study
[61] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study
[62] Expert Interview with Jhpiego Corporation employee
[63] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study

Discussion and the General Application of AI to HIV Solutions

Rather than replacing current interventions, AI has the greatest potential for success when combined with other strategies. It is key to have capable and understanding service providers, and AI can actually support this. Reaching out to people through technology to provide information can make the process more discreet and encourage greater behavior change through engagement with willingness to access resources without risk of exposing one's identity. Some services that are provided to vulnerable populations include awareness raising and behavior change communication, counseling and testing, supply of prevention material like condoms and sterile injection equipment, STI diagnosis and management, and referral for secondary and tertiary health care needs.[64] AI can tailor solutions more seamlessly to case-by-case situations, increasing effectiveness and accessibility of solutions without the need for significantly more resources, whether financially or in human capital. Especially given a shortage of healthcare providers, technology serves as a potential way to bridge the gap.

Contrary to concerns that expert knowledge and machine learning are incompatible, machine learning was more promising for identifying PrEP candidates because it was informed by human knowledge.[65] Algorithms should not be used in isolation; it should be supported by human review and classification of outcomes. Aside from improving accuracy and efficiency, AI can be tailored to align better with specific goals of programs. Human input, vision, and oversight remain essential in telling the machine the goals for objective function.[66] Similarly, for healthcare organizations and information distribution platforms, human input remains relevant. Already, sites like HIV.gov have been implementing AI alongside human review to expand outreach and make content more accessible.[67] They cite using generative AI to generate new text-based and visual content to create unique material and in doing so, have condensed the time to create summary videos of weekly blog posts to just around two hours (originally ~5). However, they also mention challenges regarding AI and human creativity. Thus, it is important to intentionally plan around and understand the implications of AI to maintain transparency.

When identifying target groups and tailoring services to them, AI can balance resource scarcity and potential risks to optimize HIV care delivery. This gives AI the potential to make services more available to stigmatized populations, but it is also imperative to recognize that targeting specific populations carries potential risk. Thus, it is important to engage community partners with the co-creation of tools and to prioritize data transparency when enacting AI as part of healthcare solutions.

Lastly, not every prevention or intervention is the same, and not every patient is the same. Critical to the solution is how we can make the best of available resources to target interventions for different populations. Truly being able to use AI on health outcomes in HIV depends on whether, when, and how patients and providers adopt suggested strategies.[68] More research can be done to assess patient and provider perspectives on AI applications in HIV prevention, and the results can inform how to further tailor solutions to expand the use of technology. For example, AI can be used to figure out why some individuals start then stop PrEP use and survey self-perception of risk with greater privacy. AI can

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[64] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[65] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[66] Artificial Intelligence and Machine Learning for HIV Prevention: Emerging Approaches to Ending the Epidemic
[67] HIV.gov's Use of Generative AI
[68] HIV.gov's Use of Generative AI

subsequently be applied as well to figure out how to address such reasons, and Generative AI may be employed to give patients the choice of a digital healthcare provider that keeps their identity fully disclosed.

Private Sector Opportunities

The current landscape of AI development and PEPFAR funding also offers space for the private sector to enter. With limited investment in HIV-related interventions and the rise of democratized technology such as smartphones in low-resource countries, companies like OpenAI and Google can scale developments of accessible large language models abroad and reach a large population of new users in pursuit of HIV education and care delivery endeavors. In addition, the private sector can help countries affected by HIV develop their EHR systems to better track HIV patients, monitor their outcomes, and predict where to reach at-risk patients. By working together with public health leadership, the private sector can benefit from a historic expansion opportunity to advance HIV care in resource-limited settings [Ref–interview with Dr. Reid].

Conclusion

Artificial intelligence (AI) can be integrated into multiple stages of HIV detection and treatment to enhance the efficiency and accessibility of the President's Emergency Plan for AIDS Relief (PEPFAR). AI can be integrated to optimize medical staff medicine and other resource allocation, expanding outreach to high-risk populations and advancing personalized treatments. However, there are several challenges to using AI including data privacy, bias in algorithms, equitable access, and affordable infrastructure that must be addressed to ensure equitable access. AI tools such as machine learning, and natural language processing can be used for education, adherence support as well as risk management and resources allocation. However, AI should not be viewed as a standalone solution but rather as a complementary tool within a broader healthcare strategy. AI holds immense potential to revolutionize HIV/AIDS prevention and treatment, but its success will depend on careful implementation, continuous evaluation, and a commitment to equity and inclusion.

Appendix: Background & Medical Review

History and Status of HIV/AIDS in Low-Income Countries

Acquired Immune Deficiency Syndrome (AIDS) was first recognized by the U.S. Centers for Disease Control and Prevention (CDC) in 1982. In that same year, the first AIDS case was reported in Africa, marking the beginning of what would become a global epidemic. In 1984, scientists identified the cause of AIDS as a retrovirus, later named Human Immunodeficiency Virus (HIV).[69] Throughout the late 1980s and 1990s, the virus spread rapidly, particularly in low-income countries, where healthcare systems were ill-equipped to handle the crisis. HIV/AIDS remains a major global health challenge, with over 39 million people currently living with the virus.[70] Low-income countries, particularly in sub-Saharan Africa, bear the highest burden, accounting for nearly 70% of all cases. Limited access to healthcare, stigma, and inadequate funding continue to hinder prevention and treatment efforts. While the development of antiretroviral therapy (ART) in the mid-1990s transformed HIV from a fatal disease into a manageable condition, millions in resource-poor settings still struggle to access life-saving medications. Social and economic factors such as poverty, gender inequality, and lack of education further contribute to high transmission rates. Although new infections have declined due to increased awareness and medical advancements, challenges remain in eradicating the epidemic in resource-limited settings.

What is PEPFAR?

The U.S. President's Emergency Plan for AIDS Relief (PEPFAR) represents an extensive commitment by the U.S. to combat HIV/AIDS with over $110 billion in federal investment since its inception. Led by the Bureau of Global Health Security and Diplomacy, PEPFAR has played a transformative role in saving 26 million lives, preventing millions of new infections, and advancing epidemic control in more than 50 countries. PEPFAR was established in 2003 under President Bush, with the goal of achieving HIV/AIDS epidemic control in over 50 countries around the world.

Managed through a whole-of-government approach, it operates under the oversight of the U.S. Department of State's Office of the U.S. Global AIDS Coordinator and Health Diplomacy, working alongside agencies such as the CDC, NIH, USAID, the Department of Defense, and others. Beyond its direct impact on HIV/AIDS, PEPFAR has significantly strengthened healthcare infrastructure, enabling partner countries to address both current and emerging health threats. Its success is a testament to strategic, transparent, and cost-effective global health investments. However, the fight is not over—HIV continues to evolve, requiring continuous adaptation and innovation to close gaps, protect vulnerable populations, and ensure long-term health security worldwide.[71]

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[69] Global HIV/AIDS Timeline | KFF
[70] Global Statistics | HIV.gov.
[71] The United States President's Emergency Plan for AIDS Relief

General Disease Transmission

HIV (human immunodeficiency virus) is a sexually transmitted disease (STD) that affects cells of the immune system and can lead to AIDS (acquired immunodeficiency syndrome) when HIV has *severely* weakened the immune system. Specifically, HIV infects and destroys white blood cells, called CD4 cells or helper T cells, in the immune system–causing white blood cell count to drop and limiting the immune system's ability to fight off infections.[72] HIV was first identified in 1983, and the first diagnostic test for the disease was created in 1985, enhancing the understanding of how the disease was transmitted.[73] Since then, at least 60 million people have been diagnosed with HIV-1, and it has caused over 25 million deaths worldwide with developing countries experiencing the greatest HIV/AIDS morbidity and mortality.[74] A notable distinction between HIV and AIDS is that AIDS is the final and most serious stage of an HIV infection, where low counts of white blood cells and severely damaged immune systems can be observed in affected patients.[75] HIV is the initial virus that weakens the immune system, and AIDS is the condition that may result if not given proper treatment; this generally progresses in about 10 years.[76] Only people diagnosed with HIV may be affected by AIDS (though not everyone with HIV progresses to AIDS if treated).

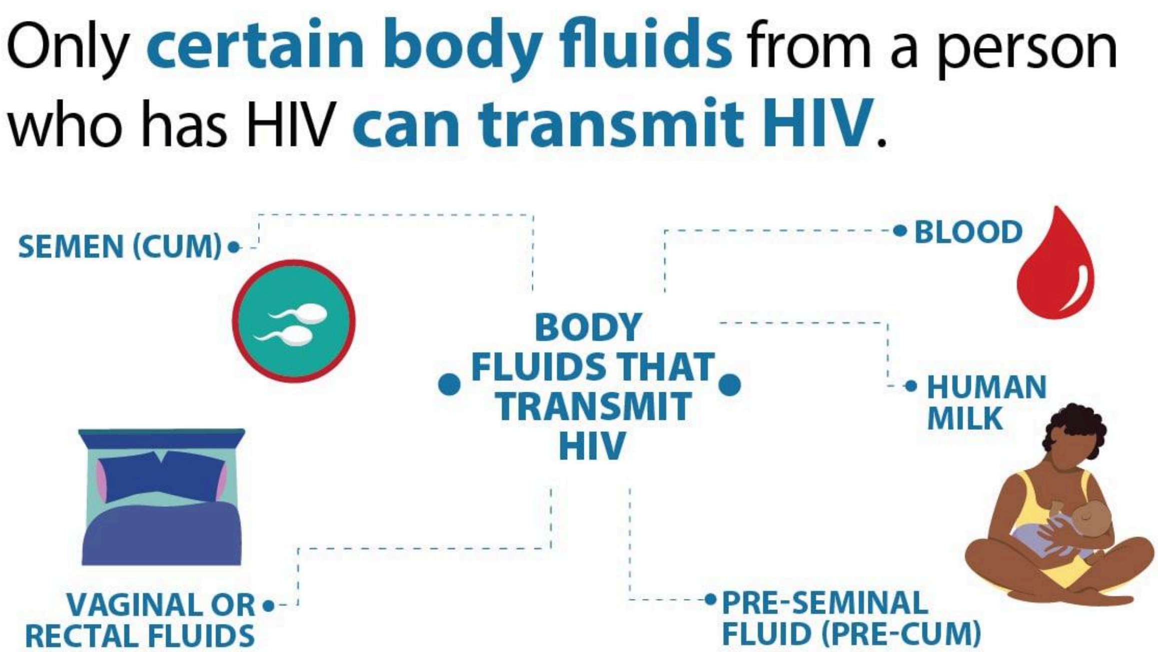

Figure 1. Methods of HIV transmission?

As an STD, HIV is transmitted through the blood, semen, vaginal fluids, breast milk, and rectal fluids of an infected person (see Figure 1); it can enter the body through the mouth, anus, penis, vagina, or broken skin (cut or wound).[77] It may also be transmitted to babies from a birthing parent with HIV during

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[72] HIV & AIDS: Causes, Symptoms, Treatment & Prevention
[73] THE EVOLUTION AND FUTURE OF HIV PREVENTION TECHNOLOGY An HIV Policy Primer
[74] Origins of HIV and the AIDS Pandemic
[75] HIV & AIDS: Causes, Symptoms, Treatment & Prevention
[76] HIV & AIDS: Causes, Symptoms, Treatment & Prevention
[77] HIV & AIDS: Causes, Symptoms, Treatment & Prevention

pregnancy, childbirth, or breastfeeding; this is referred to as perinatal transmission of HIV.[78] HIV is most commonly transmitted through having sex without a condom or sharing needles to inject drugs, it can affect anyone exposed to the virus. There are, however, certain populations that are disproportionately affected by HIV due to a multitude of factors. In the United States and worldwide, populations that are vulnerable to HIV include men who have sex with men (MSM), Black and Hispanic hispanic communities, trangender people, and people who inject drugs due to systemic barriers to quality healthcare and prevalence of high-risk behaviors.[79] Globally, the highest prevalence of HIV is recorded in young adults in sub-Saharan Africa.[80] It is key to work with vulnerable groups to prevent HIV as evidence has shown that expanding awareness, prevention, and behavior change interventions to those at heightened risk of HIV can slow the epidemic.[81] While doing so, programs designed to address these key populations must prioritize a supportive environment that is non-judgmental and non-stigmatizing and should ensure geographical, financial, and procedural accessibility.[82] Specific suggestions will be discussed in a later section.

HIV prevention tools are growing in availability, and HIV medicine taken as prescribed now allows people with HIV to live long and healthy lives without transmitting the disease to their HIV-negative partners through sex.[83] Prevention tools include using condoms correctly at every instance of sex, pre-exposure prophylaxis (PrEP) to prevent getting HIV for those who are negative but at risk, and treatment as prevention (TasP) for those living with HIV to maintain an undetectable viral load and prevent others from being infected.[84] With these efforts, the HIV epidemic can be slowed and limited. This scoping review will explore how to utilize and enhance these current solutions alongside the application of artificial intelligence (AI) for greater effectiveness against the HIV epidemic.

General Disease Prevention

As mentioned prior, there are a few major avenues for HIV prevention: safe practices, like condom usage; medicine, such as pre-exposure prophylaxis (PrEP); and treatment as prevention (TasP). Risk of transmission differs widely based on the type of exposure or behavior, so it is critical to understand the level of each to effectively implement prevention strategies. Similarly, some strategies are more effective than others, and combining prevention methods is generally seen to be more effective overall. However, regardless of the method, any option must be used correctly and consistently; the discussion that follows is based on CDC estimates of effectiveness of each strategy when used optimally.[85]

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[78] The Basics of HIV Prevention | NIH
[79] Who Is at Risk for HIV? | HIV.gov
[80] UNAIDS
[81] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[82] WHO EMRO | Vulnerable groups and key populations at increased risk of HIV
[83] Who Is at Risk for HIV? | HIV.gov
[84] Who Is at Risk for HIV? | HIV.gov
[85] https://www.cdc.gov/hivpartners/php/riskandprevention/?CDC_AAref_Val=https://www.cdc.gov/hiv/risk/estimates/preventionstrategies.html

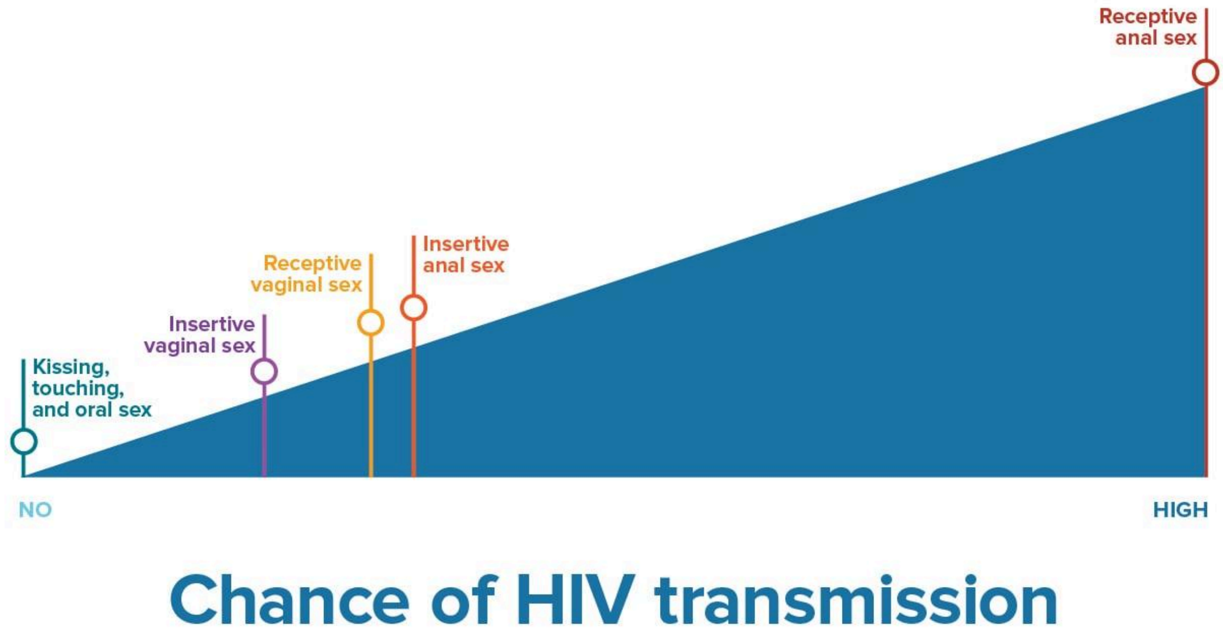

Figure 2. Chance of HIV transmission based on Sexual Activity

Regarding safe practices, there are certain behaviors that are at greater risk for HIV transmission (see Figure 2).

There are 3 main categories of HIV treatment with differing target users. (1) Antiretroviral Therapy (ART) for *HIV-positive individuals*: ART is a 3-medicine treatment for HIV-positive people that reduces the levels of HIV in a person's body.[86] ART helps the body stay strong and helps it fight off infections and other illnesses. Taking ART daily as prescribed to achieve and maintain viral suppression has an effectiveness estimate of 100% when used optimally. (2) ORAL Daily Pre-Exposure Prophylaxis (PrEP) for *HIV-negative individuals*: PrEP is a pill that includes 2 anti-HIV medicines taken daily to prevent HIV for HIV-negative people *before* expected exposure to HIV. PrEP reduces the risk of getting HIV from sex by about 99% and from injection drug use by at least 74%. (3) Post-Exposure Prophylaxis (PEP): PEP is taken within 72 hours after exposure to HIV (e.g. after rape) for 28 days to prevent HIV.[87] PeP is taken after you think you have been exposed to HIV. Medicine to treat HIV should be taken as soon as possible after diagnosis to prevent the chance of transmitting HIV to others, getting sick, or developing AIDS.[88] Getting and keeping an undetectable viral load is ideal for people with HIV to stay healthy as reducing the amount of virus in the body prevents transmission to others. This is also known as treatment as prevention.

[86] https://www.cdc.gov/hivpartners/php/riskandprevention/?CDC_AAref_Val=https://www.cdc.gov/hiv/risk/estimates/preventionstrategies.html

[87] What is the difference between PrEP, PEP, and ART? | MyPrEP.co.za

[88] HIV Treatment as Prevention | HIV Partners | CDC

General HIV Testing

Human immunodeficiency virus (HIV) can be detected through a nucleic acid test, combination antigen/antibody test, or antibody test. Nucleic acid tests (NATs) detect HIV antibodies as well as viral load. The NAT requires a blood draw and is processed in a lab. Combination antigen/antibody tests check for signs of the virus rather than the virus itself. Antigens activate in a person's immune system to fight HIV. If one has HIV, antigen p24 will be in their blood. One's immune system makes HIV antibodies to fight off the virus. However, antigens show up in the blood before antibodies.

NATs are more expensive, and are usually used when someone has symptoms. HIV screenings are usually conducted using an antibody test on oral fluid samples or a combination antigen/antibody test using blood. Most rapid and at-home tests are antibody tests that can detect infection 23-90 days after exposure.[89]

Positive results should be subsequently confirmed with the more expensive NAT test that will also ascertain the quantity of virus present in the blood (viral load). NATs are used for monitoring HIV treatment.[90]

Site of Service & Self-Testing

HIV self-testing (HIVST) has been shown to increase the uptake of HIV testing services and help achieve the UNAIDS 95-95-95 targets. HIVST is an important tool to reach those who otherwise would not seek testing at healthcare facilities or community-based testing sites. [91] In a study of HIVST in India, nearly all participants were willing to accept HIVST, found the test kits easy to use and interpret, and about two-thirds were willing to pay for HIVST. Self-testing was found to successfully reach a large proportion of first-time testers. HIVST has also been found to be a more effective way to reach people who need more frequent testing due to ongoing HIV risk.[92]

In Malawi, facility-based HIV self-testing increased HIV testing among outpatients and should be considered for scale-up in settings with a high unmet need for HIV testing.[93] This may make universal testing efforts more affordable.

HIVST can complement existing HIV testing strategies for PrEP services and enable differentiated service delivery approaches for oral PrEP and the dapivirine vaginal ring to reduce clinic visits, reducing the need to return to health facilities for testing. [94]

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[89] HIV Testing: Types, How Often, What To Expect & Results
[90] https://hivinfo.nih.gov/node/1863
[91] https://doi.org/10.1002/jia2.26348
[92] The future of HIV testing in eastern and southern Africa: Broader scope, targeted services | PLOS Medicine
[93] ClinicalKey
[94] WHO launched new implementation guidance for simplified and differentiated service delivery of pre-exposure prophylaxis (PrEP)

UNAIDS 95-95-95 Target

On World AIDS Day 2014, The Joint United Nations Programme on HIV/AIDS (UNAIDS) launched new global targets for HIV treatment aimed at ending the AIDS epidemic by 2030. To achieve this, countries are working toward reaching the interim “95-95-95” targets—95% of people living with HIV knowing their HIV status; 95% of people who know their HIV positive status will receive sustained antiretroviral therapy (ART); and 95% all people receiving ART will have viral suppression—by 2025.[95] These targets are successors to the earlier 90-90-90 targets for 2020, which were missed.

The 90-90-90 targets reflected a fundamental shift in the approach to HIV treatment, moving from a focus on the number of people accessing antiretroviral therapy (ART) towards case detection, and a cascade of services that seek to ensure that people within all demographics and groups and geographic settings, including children and adolescents living with HIV achieve viral suppression and its consequent individual and societal benefits.[96] These targets have been widely adopted and largely successful in putting additional focus on the scale up of ART.

	2025 target	**Numerator**	**Denominator**
The first 95 (indicator 1)	At least 95% of people living with HIV **know their HIV status**	Number of people living with HIV who know their HIV status	Number of people living with HIV
The second 95 (indicator 2)	At least 95% of people who know their HIV status are **on treatment**	Number of people living with HIV who are on treatment	Number of people living with HIV who know their HIV status
The third 95 (indicator 3)	At least 95% of people on treatment have a **suppressed viral load**	Number of people living with HIV who have a suppressed viral load	Number of people living with HIV who are on treatment

Note: the denominator of the second 95 is the numerator of the first 95 (green boxes), and the denominator of the third 95 is the numerator of the second 95 (blue boxes).

Long-Acting Injection (CAB-LA)

There is now a long-acting injectable cabotegravir (CAB-LA) available as PrEP. CAB-LA is an intramuscular injectable, long-acting form of PrEP first administered 4 weeks apart for the first 2 injections followed by an injection every 8 weeks.[97] Landmark studies found that CAB-LA had a 79% relative reduction in HIV risk compared with oral PrEP considering the barrier of daily adherence, but will remain offered alongside oral PrEP rather than as a replacement.[98] This solution was most recently found to be safe for use before and during pregnancy and thus serves as a promising solution to be observed in the coming years.[99] In particular, calculations suggest that CAB-LA has the potential to reduce HIV incidence by 27% over the next 20 years when compared with oral PrEP options in South

[95] https://www.kff.org/global-health-policy/fact-sheet/the-global-hiv-aids-epidemic
[96] Achieving the 95 95 95 targets for all: A pathway to ending AIDS - PMC
[97] WHO recommends long-acting cabotegravir for HIV prevention
[98] WHO recommends long-acting cabotegravir for HIV prevention
[99] Long-acting injectable cabotegravir for HIV prevention is safe in pregnancy | National Institutes of Health (NIH)

Africa.[100] It is, however, a much more expensive option in comparison to oral PrEP being marketed at $22,000 per year in the United States and £7100 per year in the United Kingdom as of 2023.[101] In comparison, generic oral PrEP is priced in the United States at $55 per year and £168 per year in the United Kingdom. If CAB-LA is to be a solution for at-risk populations in low- and middle-income countries, a cost between $60-119 per year would need to be achieved in order to be as cost-effective as oral options.[102] Clearly, efforts to improve cost-effectiveness must be implemented alongside usage of CAB-LA for it to serve as a widespread solution, and there must be thoughtful consideration on where resources should be allocated while waiting for cost-effectiveness to improve.

There are also other efforts to create new, longer-acting HIV prevention options such as implants and a twice-yearly subcutaneous lancapavir that has been proved to effectively prevent HIV infection. However, the same limitations of cost and accessibility arise regarding these options. Opportunities to utilize AI in an effort to address such limitations will be discussed in the next section.

Ethics & Data Security

The integration of mobile health and AI raise important ethics and privacy concerns. Sensitive user data is required to train AI for HIV interventions. Furthermore, smartphone study subjects indicated discomfort over sexual partners having access to their test results,[103] and chatbot study subjects commented that they did not trust chatbot responses completely due to inaccuracies and absence of human input.[104] Privacy concerns could be addressed via integration with HIPAA-secure apps to communicate with providers while maintaining confidentiality, as well as usage of private data management servers to store HIV test results instead of saving results directly on the smartphone. Further iterations of AI-guided smartphone apps and chatbots need to focus on linking users to stigma-free care sites, such as LGBTQ-friendly healthcare centers, and improving on answering users' complex healthcare questions, which may involve improving chatbot answers or including human responses without exposing vulnerable information from the user.[105] More accurate AI-guided responses and timing of interventions will improve user trust and adherence in following HIV care guidelines.

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[100] Thembisa
[101] Cabotegravir—Global Access to Long-Acting Pre-exposure Prophylaxis for HIV - PMC
[102] Cabotegravir—Global Access to Long-Acting Pre-exposure Prophylaxis for HIV - PMC
[103] SMARTtest: A smartphone app to facilitate HIV and syphilis self- and partner-testing, interpretation of results, and linkage to care
[104] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study
[105] Formative Evaluation of the Acceptance of HIV Prevention Artificial Intelligence Chatbots By Men Who Have Sex With Men in Malaysia: Focus Group Study