Social Development Studies, 2026, Volume 2, Issue 3
https://www.bbwpublisher.com/journal/SDS
Online ISSN: 3083-3868
Print ISSN: 3083-3876

The Influence of Antiretroviral Therapy (ART) on the Evolutionary Trajectory of HIV

Hanyu Shi

University of Minnesota, Minneapolis 55455, USA

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Abstract: AIDS is a huge challenge for global public health. Nowadays, the most effective treatment is antiretroviral therapy(ART), which can effectively suppress the viral load in the body and prolong the asymptomatic incubation period of infected people. With the wide clinical application of ART, drug pressure has changed the survival environment of HIV. This article takes whether ART changes the evolutionary trajectory of HIV as the core research question, and selects the United States, which has complete medical resources and a high ART coverage rate, and Yaounde, Cameroon, which has scarce resources and diverse subtypes of virus strains, as the comparative research areas. By integrating research methods from multiple disciplines such as genetics, clinical medicine, public health, and history, and combining existing literature research data, this paper analyzes the occurrence probability and transmission characteristics of drug-resistant mutations under different regulatory conditions. After a literature review, it was found that the degree of virus genetic variation in infected individuals who strictly follow medical advice to suppress the virus is extremely low. Patients with poor medication compliance and intermittent medication are more likely to develop drug-resistant strains. This article predicts that under the pressure of drugs, the evolution direction of HIV may gradually shift towards stronger drug resistance. Social factors such as regional economic level, drug accessibility, and public health policies have further exacerbated the evolutionary differentiation of HIV in different regions. Studying the evolution of HIV under ART intervention can have a favorable impact on global AIDS prevention and control.

Keywords: HIV; AIDS; Antiretroviral therapy; Virus evolution; Virus mutation

Online publication: June 30, 2026

1. Introduction

This article focuses on AIDS, a disease caused by the human immunodeficiency virus (HIV). HIV is a retrovirus primarily transmitted through sexual contact, blood, and mother-to-child transmission. It's a modern disease first identified in 1981, with the first therapeutic drugs not becoming available until 1987 [1]. After entering the human body, HIV will infect and destroy CD4+T cells, weakening the immune system. When the immune function of the human body declines, opportunistic infections and certain cancers will

occur in the body. Without treatment, the CD4 count continues to decline, ultimately severely impacting people's lifespan and quality of life. The treatment for HIV is suppressive, it cannot be cured. The most common therapy currently is antiretroviral therapy (ART). ART can suppress the viral load in the body to very low levels, prolonging the latent asymptomatic period. However, HIV has an extremely high mutation rate, and even when the virus is suppressed for extended periods, these cells may still proliferate slowly. Once treatment is discontinued or drug resistance develops, viral rebound may occur [2]. Ultimately, people may die from opportunistic infections caused by one or more factors [3]. HIV is not an ancient pathogen; its emergence and spread in the 20th century are closely related to social and ecological factors. Nowadays, antiretroviral therapy is being promoted on a large scale worldwide, and human intervention has become an indispensable external force for the evolution of HIV. The extensive use of ART has changed the treatment outcomes of HIV-infected individuals, and it has also altered the living environment for the virus. ART can keep the virus suppressed in the patient's body for a long time, and it significantly reduces the chance of continuous evolution of HIV. However, this does not mean that HIV has stopped changing. ART cannot eliminate the virus in the human body. Latent viruses persist in the infected person's body, and this is the basis for possible subsequent virus mutations. There are also huge differences in economic levels and medical resources in different countries and regions. The popularity and testing capabilities of ART are also different, which makes it impossible to unify the survival conditions of HIV in the whole world. Also, the impact of ART on the evolution of HIV is not just making the virus evolve faster or slower, but rather altering which viruses are more likely to survive and spread. So it is necessary to study what changes have occurred in the evolutionary trajectory of HIV in combination with different social and medical backgrounds. Understanding the evolution patterns of AIDS will have great significance for the healthy development of humanity.

2. Research question

The research question is: Does the widespread adoption of antiretroviral therapy alter the evolutionary trajectory of HIV? Through this question, I want to explore how HIV has evolved in the process of widespread adoption of ART. By comparing the clinical and project records of patients, laboratory results and other data, I want to determine whether drug-resistant mutations occur more frequently in the human body. I will investigate whether the transmissibility of HIV has changed or whether this change is more pronounced only in specific populations. I also want to clarify which risk scenarios are most likely to drive new infections. I will focus on two regions, the United States and Yaounde in sub-Saharan Africa. I chose to focus on the period after the introduction of ART in 1995 [4]. Because I wanted to observe the impact of ART on the virus, I chose the period after this therapy emerged. I chose these two regions because they offer two different comparison frameworks. The United States has a high ART coverage rate, professional virus surveillance, and a relatively high economic level, which enables more comprehensive surveillance and treatment. Sub-Saharan Africa has a very high infection rate in the world, limited resources, a low economic level in many regions, and insufficient monitoring. Compared with other African countries, the HIV infection rate in Cameroon is relatively low, but the prevalent HIV strains in the country are extremely diverse [5]. By comparing these two regions, we can observe the development trajectory of the HIV virus under different levels of monitoring and treatment. Overall, I hope that through this research, we can have a clearer understanding of exactly what changes have occurred in HIV since the popularization of ART. At the same time, by comparing the different medical resources and monitoring conditions between the United States and Yaounde, Cameroon, it can help me determine whether the changes in HIV are mainly related to ART itself or are also influenced by medical resources, patient compliance and the social environment. Through these

comparisons, we can understand exactly what HIV has changed, in which populations the changes are more obvious, and what significance these changes have for future treatment and prevention.

3. Proposed study

3.1. Multidisciplinary research and data analysis

The interdisciplinary strategy is necessary for this research because it is hard to make accurate conclusions from one aspect. I need to combine the evidence from different perspectives. I will mix different fields together, such as medicine, genetics, public health, and historical development. Then I can draw relatively objective conclusions. As the leader of the project and the geneticist, I need to clarify the main question, list the evolution of the virus, and provide various information on mutations. The clinical workers need to provide project samples, treatment notes, various virus models, and the differences in treatment among different patients. The public health workers need to provide information on the population receiving ART, the detection rate, and the rate of viral transmission. The historians need to give me enough background knowledge, including the historical trajectory and the geographical distribution of HIV. Finally, I also need to combine all these data, conduct analyses in different contexts, and present the evolution of the virus. Each researcher first creates their own data table for observation and analysis. I will integrate the evidence presented by each person and compare it through charts. Classify different types of evidence and analyze the changes of the virus during treatment by region and time period. When studying this disease, social and political factors must be taken into account. These issues include whether drugs and tests are generally accessible and whether the prices are affordable for people, as well as the economic situation of the local people, the reliability of the laboratory's capabilities, and whether the government has formulated comprehensive policies. I expect that ART has already altered the evolutionary environment of HIV so that HIV will change its evolutionary trajectory. This change does not mean that the virus stops evolving due to drug suppression, but rather it may alter the direction and pattern of its evolution towards drug resistance under environmental pressure. And this change is most likely to occur in those with poor adherence and drug resistance. Reeves et al., 2018[6] mentioned that one year after ART treatment, more than 99% of the infected cells belonged to the clonal population. Among individuals adhering to medication schedules and maintaining long-term viral suppression, few new genetic changes emerge. Rebounds always caused by treatment interruption or poor adherence originate from previously infected latent cells capable of replication, rather than new rounds of rapid replication during treatment. In other words, individuals achieving suppression exhibit minimal viral genetic changes. Drug-resistant mutations are more common among individuals who fail to achieve treatment targets or exhibit poor adherence, which may influence the future evolution of the virus in certain aspects. Moreover, if ART is taken intermittently or if drug-resistant mutations already exist in the population before the start of treatment, drug-resistant variants may emerge [7]. After ART intervention, the drug will inhibit the replication of most viruses. Only those virus variants with poor adherence carrying drug-resistant mutations can survive and continue to replicate. In the future, the evolutionary trajectory of HIV will always remain under the pressure of drugs, so the future evolutionary direction may be to acquire a stronger drug tolerance.

3.2. Research limitations

Data vary across regions and may contain omissions during collection, so making direct comparisons will be more difficult. Data organization may become inefficient due to excessive complexity. Sometimes there are unstable factors in the laboratory, and they may affect the accuracy of experiments. Resource shortages in some regions

may also lead to disruptions in drug treatment and testing for patients. Social factors can also influence people's willingness to seek medical care and undergo testing. I also think that the data from different regions will be difficult to make consistent. The United States and Yaounde differ in terms of medical systems, testing frequencies, treatment methods, and data recording. So some data will be hard to compare together. If the number of tests in a certain area is higher, it may seem that more drug resistance has been detected, but this does not mean that the virus is really changing faster; it could just be because the monitoring is more complete in a certain area. Another challenge is that it is difficult to measure patients' compliance accurately. Some patients may miss their medication, but medical records may not fully reflect this situation, which can affect the judgment of the relationship between treatment efficacy and drug resistance. The types of HIV in different regions are not exactly the same, which may cause the virus to show different changes. Therefore, I need to carefully distinguish between the differences in the virus itself and the impact brought by ART. In addition, privacy is also an important issue. As this research involves patients' treatment and testing information, all data must have names and personal identity information removed and the scope of use strictly limited. The research may also encounter the problem of insufficient sample size, especially in certain years or regions, where the available virus sequences and drug resistance data may be relatively scarce. This will make the results not comprehensive enough. To reduce these problems, I will try to compare data from the same time period and similar types, and clearly explain which parts of the data are more complete and which parts are lacking.

4. Significance

The significance of this research is that we can understand the evolution of HIV under the influence of ART. When I used to make conclusions about the origin and evolution of the virus, I only focused on the viruses themselves. However, the treatment may provide a new living condition for the viruses. It is significant for me to understand whether the use of medical treatment will affect the evolution of a disease. Thus, we can tell apart the mutations caused by the external environment and the actual virus mutations. A deeper understanding of this issue may affect the evolution of many diseases in general. Knowing whether the use of ART will alter the evolution path of HIV can help us allocate the funds we have better. We will know better about the "high-risk groups" and effectively reduce the expansion of new cases and drug resistance. This data can tell the government to put the most attention into the most valued areas. This research can also help us to better understand why there are different HIV treatment outcomes in different regions. Even if the same type of ART is used, there may still be significant differences in different regions due to different conditions. By comparing these differences, I hope to make it clearer that the changes in HIV are not only related to the virus itself, but also to medical conditions and the social environment. This research can remind us that in the future, controlling HIV cannot just rely on some new medicine. It is also necessary to ensure a stable supply of drugs, convenient testing, and that patients can adhere to treatment for a long time. Only in this way can we more effectively reduce drug resistance, lower the incidence of new infections, and improve the quality of life for people living with HIV. As our understanding of HIV deepens, we may have the opportunity to find a treatment that, to some extent, saves the lives of most people.

5. Conclusion

By comparing the data of the United States and Yaounde, Cameroon, and multiple existing research results,

it can be seen that the wide popularization of ART may have changed the original evolutionary law of the HIV virus. The drug pressure brought by treatment has become a key human factor affecting the direction of virus mutation. In regions with good medical conditions and patients' compliance with medication, drugs can significantly inhibit viral replication, and HIV mutations are restricted. In regions where medical resources are scarce, drug supervision is lacking, and patient compliance is poor, drugs cannot continuously suppress the virus, increasing the possibility of the emergence of drug-resistant variant strains and promoting the evolution of HIV towards greater drug resistance. Factors such as regional economic level, drug accessibility, and public health policies can also indirectly affect the clinical outcome of ART, further widening the differences in HIV outcomes among different regions around the world. This study suggests that in the future, global AIDS prevention and control cannot just rely on drug research and development. It is also necessary to pay attention to the supply of drugs at the grassroots level, medication management, health education for high-risk groups, and to enhance the medication compliance of infected individuals. These factors are key measures to curb the large-scale spread of HIV drug-resistant strains and control the adverse evolution of the virus. In the future, countries can appropriately adjust the allocation of prevention and control funds, prioritizing regions with weak healthcare infrastructure and high rates of drug resistance. This will not only reduce new infections but also provide an opportunity to curb the evolution of HIV into highly drug-resistant strains, thereby helping more people living with HIV survive for longer periods.

Disclosure statement

The author declares no conflict of interest.

References

[1] Understanding Evolution, 2008, Understanding HIV's Not-So-Ancient History. University of California Museum of Paleontology, visited on January 16, 2026, https://evolution.berkeley.edu/evo-news/hivs-not-so-ancient-history/

[2] Kearney MF, Spindler J, Shao W, et al., 2014, Lack of Detectable HIV-1 Molecular Evolution During Suppressive Antiretroviral Therapy. PLoS Pathogens, 10(3): e1004010.

[3] Nieves-Colón MA, 2025, Lesson 5.2 – The HIV/AIDS Pandemic: Part 1 – Origins and Spread of HIV. ANTH 4002, University of Minnesota, Minneapolis.

[4] Nieves-Colón MA, 2025, Lesson 5.3 – The HIV/AIDS Pandemic: Part 2 – HIV/AIDS in the USA and South Africa. ANTH 4002, University of Minnesota, Minneapolis.

[5] Ceccarelli L, Salpini R, Moudourou S, et al., 2012, Characterization of Drug Resistance Mutations in Naïve and ART-Treated Patients Infected With HIV-1 in Yaounde, Cameroon. Journal of Medical Virology, 84(5): 721–727.

[6] Reeves DB, Duke ER, Wagner TA, et al., 2018, A Majority of HIV Persistence During Antiretroviral Therapy Is Due to Infected Cell Proliferation. Nature Communications, 9(1): Article 4811.

[7] Van Zyl G, Bale MJ, Kearney MF, 2018, HIV Evolution and Diversity in ART-Treated Patients. Retrovirology, 15(1): Article 14.

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