

HIV INFECTION PREVENTION: EPIDEMIOLOGICAL CHARACTERISTICS, ROUTES OF TRANSMISSION, CLINICAL STAGES, AND PRINCIPLES OF TREATMENT

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АННОТАЦИЯ:

This scientific narrative review examines the global epidemiology and etiopathogenesis of human immunodeficiency virus (HIV) infection, its sexual, parenteral, and vertical transmission pathways, clinical manifestations, and the four clinical stages defined by the World Health Organization (WHO). Current recommendations concerning laboratory diagnosis, assessment of antiretroviral therapy (ART) effectiveness, pre-exposure and post-exposure prophylaxis, prevention of mother-to-child transmission, and infection prevention and control in healthcare settings are synthesized. According to WHO estimates for the end of 2025, approximately 41.0 million people worldwide were living with HIV, underscoring the need for continuous, integrated prevention and treatment services. The review identifies early diagnosis, uninterrupted ART, risk-adapted prevention, and stigma-free healthcare communication as mutually reinforcing priorities..

INTRODUCTION

Human immunodeficiency virus (HIV) infection remains a major concern in contemporary medicine and public health. The virus primarily affects CD4⁺ T lymphocytes, which have a central role in immune defense, and can progressively impair immune function over time if left untreated. Acquired immunodeficiency syndrome (AIDS) denotes an advanced clinical stage of HIV infection. Thus, the terms “HIV” and “AIDS” are not synonymous: the former refers to the virus and associated infection, while the latter describes its late clinical consequences [1, 3].

Advances in medical science and technology have made HIV infection a manageable chronic condition when it is diagnosed promptly and treated appropriately. Nevertheless, delayed diagnosis, barriers to healthcare access, unsafe invasive procedures, and misconceptions about the infection continue to facilitate its spread. Prevention therefore depends not only on individual behavior but also on the quality of healthcare systems, availability of laboratory services, legal safeguards, and public awareness [1, 4, 10].

This article aims to explain, from a scientific perspective, the interrelationship between the three principal modes of HIV transmission, its clinical stages, principles of treatment, and primary, secondary, and tertiary preventive measures. For physician-epidemiologists in particular, it is essential to integrate clinical and laboratory findings with epidemiological assessment.

AIM, MATERIALS, AND METHODS

The aim of this review is to synthesize available evidence regarding the mechanisms of HIV transmission, WHO clinical stages 1–4, diagnostic approaches, antiretroviral treatment, and scientifically supported prevention methods, and to identify practical priorities for epidemiological services.

Materials and methods. This narrative review considered WHO HIV fact sheets and clinical guidance issued during 2024–2026, UNAIDS strategic documents, evidence-based recommendations from the United States Centers for Disease Control and Prevention (CDC), and findings from the START and HPTN 052 studies assessing the preventive impact of antiretroviral therapy [1–12]. The evidence was summarized using thematic comparison and descriptive analysis. The article is a literature review; it presents no newly collected clinical observations, regional patient statistics, or independent experimental results.

1. EPIDEMIOLOGICAL SIGNIFICANCE OF HIV INFECTION

According to WHO estimates published in July 2026, approximately 41.0 million people worldwide were living with HIV at the end of 2025; an estimated 1.2 million new infections and 570,000 HIV-related deaths occurred during that year. These figures are global estimates and should not be interpreted as the sum of locally laboratory-confirmed cases. They demonstrate the need to sustain prevention programs and ensure equitable access to treatment [1, 2].

The “95–95–95” targets represent an internationally used framework for evaluating the HIV response: 95% of people living with HIV should know their status, 95% of those who know their status should receive ART, and 95% of those receiving ART should achieve viral suppression. Global estimates for 2025 were 88%, 89%, and 95%, respectively. The gaps in the first two indicators highlight the importance of expanding early diagnosis and uninterrupted linkage to care [2].

In the epidemiological chain of HIV infection, the source is a person living with HIV; the vehicle of transmission consists of specific virus-containing biological fluids; and a susceptible host is a person exposed under conditions permitting infection. Transmission risk

is influenced by viral load, the nature of biological contact, the integrity of skin or mucosal barriers, and access to preventive services. Therefore, exposure alone does not establish that infection has occurred; individual circumstances require assessment by a qualified healthcare professional [1, 7].

2. ETIOLOGY AND IMMUNOPATHOGENESIS

HIV belongs to the retrovirus group and exploits the host cell's machinery during intracellular replication of its genetic material. CD4+ T lymphocytes are among its principal cellular targets. Progressive disruption of immune function increases susceptibility to opportunistic infections and certain malignancies. However, the rate at which clinical manifestations develop differs among individuals. Relevant factors include timely diagnosis, adherence to treatment, comorbidities, and individual biological characteristics [1, 3].

In clinical practice, the CD4+ cell count is one measure of immune status, whereas viral load is a laboratory indicator of the extent of HIV replication. Although these variables are related, they serve different purposes: CD4 counts help assess immunological risk, while viral load measurements monitor the virological response to ART. Evaluating clinical symptoms without considering laboratory findings may lead to an incorrect interpretation of disease stage [3, 5].

During early HIV infection, some individuals experience transient, nonspecific symptoms, while others remain asymptomatic for extended periods. The absence of symptoms does not establish the absence of infection. From an epidemiological standpoint, HIV cannot be diagnosed on the basis of appearance or complaints alone; laboratory testing and individualized risk counseling are essential [1, 4].

3. PRINCIPAL ROUTES OF HIV TRANSMISSION

According to WHO, HIV can be transmitted through certain biological fluids, including blood, semen, vaginal secretions, and breast milk. Epidemiological analysis generally distinguishes three principal routes: sexual, parenteral, and vertical transmission. Although the measures needed to reduce risk differ by route, all depend on safe environments and timely access to appropriate healthcare [1].

3.1. Sexual transmission. HIV transmission may occur when virus-containing biological fluids come into contact with susceptible mucosal tissues. Unprotected sexual contact and certain concurrent sexually transmitted infections can influence risk. Evidence-based education, preventive measures, timely HIV and other sexually transmitted infection testing, and additional prophylaxis prescribed by a specialist when indicated are important components of prevention [1, 6].

3.2. Parenteral transmission. Direct exposure to infected blood, nonsterile invasive medical equipment, improper use of single-use devices, lapses in blood donor screening and transfusion safety, or accidental occupational exposure among healthcare personnel may create circumstances in which parenteral transmission can occur. Adherence to standard

precautions, proper instrument sterilization, and safe handling of sharps are essential organizational measures to reduce this risk in healthcare facilities [1, 7].

3.3. Vertical transmission. HIV may pass from mother to child during pregnancy, childbirth, or breastfeeding. However, testing during pregnancy, timely initiation of maternal ART, coordinated perinatal and postnatal follow-up, and appropriate infant prophylaxis can substantially reduce the risk. Decisions concerning maternal and infant care must be individualized in accordance with clinical guidelines and national or local protocols [1, 8].

HIV is not transmitted through handshakes, hugging, eating together, sharing dishes, coughing or sneezing, water, or ordinary everyday social contact. Isolating people living with HIV from community life or treating them discriminatorily has no epidemiological justification and may discourage them from seeking healthcare [1, 11].

4. CLINICAL PRESENTATION AND THE FOUR WHO STAGES

The clinical manifestations of HIV infection are diverse. Early symptoms, when present, may include fever, sore throat, enlarged lymph nodes, fatigue, and rash. These findings are nonspecific. Infection can subsequently remain asymptomatic for a prolonged period in some individuals. Without treatment, progressive immune dysfunction may lead to opportunistic infections, persistent symptoms, and severe complications [1, 3].

The WHO clinical classification for adults and adolescents comprises four stages. It helps organize HIV-associated clinical conditions, but it should not be taken to mean that every person necessarily progresses through the stages in the same rigid sequence. Staging is based on a physician's clinical assessment, considered alongside relevant laboratory findings [3].

Table 1. WHO clinical stages of HIV infection in adults and adolescents

Stage	Principal clinical characteristics	Epidemiological and clinical implications
Stage 1	Asymptomatic infection or persistent generalized lymphadenopathy.	Absence of clinical symptoms does not exclude HIV infection.
Stage 2	Moderate weight loss, recurrent upper respiratory tract infections, and selected skin or mucosal manifestations.	Mild-to-moderate symptomatic disease may be present.
Stage 3	Unexplained significant weight loss, prolonged fever or diarrhea, oral candidiasis, pulmonary tuberculosis, and other infections.	More extensive clinical assessment and evaluation for complications are needed.
Stage 4	Severe opportunistic infections (e.g., Pneumocystis pneumonia or cryptococcal meningitis) and certain malignancies.	Conditions associated with advanced immunodeficiency may occur.

Source: Synthesized from the WHO clinical staging classification [3].

5. LABORATORY DIAGNOSIS AND EPIDEMIOLOGICAL SURVEILLANCE

HIV infection is diagnosed using specific laboratory tests. Contemporary testing algorithms employ assays detecting antibodies and/or antigens and, in selected circumstances, tests that detect viral nucleic acids. An initial reactive result does not, by itself, constitute a final diagnosis; it must be confirmed in accordance with the applicable national diagnostic algorithm. If exposure may have occurred recently, the diagnostic window period must be considered, and a qualified professional should determine whether repeat testing is required [4].

The WHO “5 Cs” provide an important framework for the quality of HIV testing services: consent, confidentiality, counselling, correct results, and connection to appropriate care and prevention services. These principles emphasize that HIV testing is more than specimen collection; it must also support meaningful linkage to prevention, treatment, and ongoing follow-up [4].

For infants younger than 18 months born to mothers living with HIV, antibody tests alone may be insufficient for a definitive diagnosis; age-appropriate virological testing may be required. This consideration is particularly important for the early identification of vertical transmission and prompt linkage to treatment [1, 8].

The quality of epidemiological surveillance cannot be assessed solely by counting newly identified cases. Relevant indicators should be evaluated together, including access to HIV testing, delays in diagnosis, time from confirmed diagnosis to ART initiation, virological monitoring, services provided to pregnant women and infants, and the management of occupational exposures. Throughout these activities, patient identity and confidential medical information must be protected [2, 4].

6. CURRENT PRINCIPLES OF HIV TREATMENT

A widely available, standard treatment that completely eradicates HIV from the body does not yet exist. Nevertheless, antiretroviral therapy effectively suppresses viral replication, helps preserve immune function, and reduces HIV-related morbidity and mortality. International clinical guidance generally recommends initiating ART as soon as possible following diagnosis. The final treatment plan should be determined by a clinician based on the patient's circumstances and applicable clinical protocols [1, 5].

The benefits of early ART have also been demonstrated in major clinical investigations. The randomized START trial showed improved clinical outcomes when treatment was not deferred in people with early, largely asymptomatic HIV infection. The HPTN 052 study showed that early, effective treatment substantially reduces the likelihood of sexual transmission to a partner. These findings establish ART both as an individual therapeutic intervention and as a major preventive tool in public health [9, 10].

Treatment effectiveness is assessed through regular laboratory monitoring, principally by documenting a decline in viral load and sustained virological suppression. CD4+ cell measurements provide additional information on immune status and the risk of certain

complications. If the virological response is unsatisfactory, a specialist should reassess treatment adherence, drug interactions, possible resistance, and other clinical factors [5].

The scientific principle of “Undetectable = Untransmittable” (U=U) is a major achievement in HIV prevention: a person living with HIV whose viral load remains durably undetectable while receiving ART does not transmit HIV to sexual partners. This finding does not eliminate the need for consistent treatment and virological monitoring, nor does it replace protection from other sexually transmitted infections. The U=U conclusion should not automatically be extended to other transmission routes [1, 11].

Successful ART depends on more than the selection of medications. Trusting communication with the patient, clear explanation of medical instructions, monitoring for adverse effects, psychological and social support, and continuity of care are important determinants of outcomes. Avoiding discrimination and respecting the dignity and confidentiality of people living with HIV are directly relevant to effective clinical care [4, 12].

7. COMPREHENSIVE PREVENTION OF HIV INFECTION

HIV prevention may be conceptualized at three levels. Primary prevention aims to prevent acquisition and transmission of the virus; secondary prevention focuses on early detection and timely linkage to treatment; and tertiary prevention seeks to reduce disease complications and adverse social consequences. These levels are interconnected, and continuity across them is essential for effective epidemiological control [1, 4, 5].

7.1. Primary prevention in the general population. Scientifically accurate information about HIV transmission and everyday contacts that do not transmit the virus, voluntary testing for HIV and other sexually transmitted infections, medical counseling on suitable preventive measures, and individualized risk assessment are key elements of primary prevention. Education should rely on evidence and respectful communication rather than fear or blame [1, 4].

7.2. Pre-exposure prophylaxis (PrEP). Healthcare professionals may recommend PrEP to people who do not have HIV but face an elevated risk of acquisition in particular epidemiological circumstances. Current WHO guidance considers several forms of prophylaxis. Selection of a suitable option, relevant testing, and monitoring should be undertaken under specialist supervision in accordance with national guidelines. PrEP provides additional protection against HIV but does not in itself prevent other sexually transmitted infections [6].

7.3. Post-exposure prophylaxis (PEP). Medical evaluation should not be delayed after a potentially significant HIV exposure. According to WHO guidance published in 2024, PEP, when indicated, should be initiated as soon as possible, preferably within the first 24 hours and no later than 72 hours after exposure; the recommended course lasts 28 days. A qualified healthcare professional should determine whether PEP is indicated and specify the relevant testing and follow-up schedule, because not all exposures carry the same risk [7].

7.4. Infection prevention and control in healthcare facilities. Safe invasive procedures, correct use of sterile and single-use equipment, secure disposal of used sharps, screening of donated blood and other relevant materials, continuing staff education, and rapid-response pathways for occupational exposures help reduce parenteral transmission. Safety systems should prioritize timely identification and prevention of risk rather than assigning blame to individual staff members [1, 7].

7.5. Prevention of mother-to-child transmission. Voluntary, high-quality testing during pregnancy, prompt maternal ART when HIV is diagnosed, regular virological monitoring, and coordinated delivery and infant follow-up services are central to preventing vertical transmission. Infant testing and preventive measures should be selected according to age and applicable national or local clinical protocols. Decisions regarding breastfeeding should likewise be made with an appropriately qualified healthcare professional [1, 8].

7.6. Addressing stigma and discrimination. Restricting the rights of people living with HIV, publicly portraying them as a “source of danger,” or disclosing confidential medical information may discourage testing and contribute to interruptions in treatment. UNAIDS reports identify stigma as an important barrier to accessing healthcare. Confidentiality and non-discrimination must therefore be regarded as integral elements of epidemiological prevention [12].

8. PRIORITIES FOR APPLIED EPIDEMIOLOGY

Evaluation of prevention programs should extend beyond counting the number of activities conducted. Program performance may be assessed using indicators such as access to HIV testing, time between diagnosis and linkage to treatment, continuity of ART, coverage of viral-load monitoring, the quality of antenatal screening and follow-up, and response times following occupational exposures. Interpretation of such indicators requires attention to regional epidemiological characteristics and the reliability of the underlying data [2, 4].

Coordinated collaboration among clinicians, laboratory professionals, obstetrician-gynecologists, family physicians, and public health specialists is particularly important in the work of a physician-epidemiologist. Health information should be aggregated in ways that prevent identification of individual patients, while referral systems must comply with applicable confidentiality requirements. Public education materials should be medically accurate, accessible, and free from discriminatory language directed at any social group [4, 12].

In regions such as Samarkand, where healthcare services are used by people of different ages and social backgrounds, several organizational measures can be considered scientifically appropriate: simplifying referrals for voluntary testing through primary care; ensuring prompt specialist appointments for people newly diagnosed with HIV; strengthening coordination between maternity and infectious disease services; maintaining clear internal response pathways for occupational exposures; and correcting common misconceptions in public

education through reliable sources. These are proposed priorities, not outcomes of an evaluated regional program.

DISCUSSION

The scientific evidence reviewed indicates that no single intervention is sufficient to control HIV infection. Sexual, parenteral, and vertical transmission each require specific preventive measures; however, early diagnosis and ART provide a shared foundation for many of these approaches. For example, timely treatment protects the health of a person living with HIV and, when durable virological suppression is achieved, prevents sexual transmission. Reliable testing services also facilitate access to treatment and risk-appropriate preventive care [4, 5, 11].

It is also necessary to distinguish clinical staging from the assessment of epidemiological transmission risk. WHO clinical stages 1–4 are useful for describing a patient's clinical condition, but transmission risk cannot be calculated from stage alone. Viral load, type of exposure, and preventive measures already in place must be assessed separately. Accordingly, training for healthcare workers should present clinical and epidemiological criteria as complementary rather than interchangeable concepts [1, 3, 7].

The sources examined reflect international evidence and recommendations. Implementation in local practice must take account of national clinical protocols, healthcare coverage, and available resources. A central limitation of this narrative review is that it does not analyze newly collected primary epidemiological data from the Samarkand region; accordingly, no independent statistical conclusions are drawn regarding local trends in HIV transmission or the effectiveness of regional prevention measures.

CONCLUSION

First, prevention of HIV infection requires an integrated epidemiological approach that accounts for the distinct characteristics of sexual, parenteral, and vertical transmission. Second, knowledge of WHO clinical stages 1–4 is important for assessing disease severity, whereas laboratory testing remains essential for early diagnosis. Third, prompt initiation and uninterrupted continuation of ART not only reduce disease complications but also constitute an evidence-based means of preventing sexual transmission of HIV. Fourth, clinically supervised PrEP and PEP, infection prevention and control, coordinated maternal and child health services, and the principles of confidentiality and non-discrimination strengthen comprehensive prevention [1, 4–8, 11].

In summary, effective HIV prevention depends on the integration of clinical expertise, laboratory diagnosis, individualized counseling, and public health management. Practical interventions should aim to protect health, reduce new HIV infections, and ensure high-quality, respectful medical care for people living with HIV.

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