

Research Article

Implementation of Prevention of Mother-to-Child Transmission in the Global Eradication of HIV/AIDS: A Critical Analysis of Progress and Persistent Gaps

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Abstract

The global effort to eradicate Human Immunodeficiency Virus (HIV) and Acquired Immunodeficiency Syndrome (AIDS) has identified the prevention of vertical transmission as a critical strategic pillar. This narrative review and critical synthesis provide a comprehensive analysis of the implementation of Prevention of Mother-to-Child Transmission (PMTCT) programs within the broader HIV/AIDS eradication agenda. Drawing upon epidemiological data, policy frameworks, and regional case studies from 2000 to 2023, we assess the profound impact, persistent challenges, and evolving strategies of PMTCT. The analysis confirms that scaled-up PMTCT services have averted millions of pediatric HIV infections globally, with a documented 52% decline in new childhood infections between 2001 and 2012. However, progress is markedly heterogeneous, characterized by stalled antiretroviral therapy (ART) coverage rates among pregnant women since 2014 and persistent high transmission burdens in sub-Saharan Africa, which accounts for approximately 90% of global vertical transmissions. This paper argues that the future of PMTCT, and by extension, the feasibility of ending AIDS as a public health threat hinges on the systematic integration of services into strengthened primary healthcare systems, the dismantling of socio-structural barriers to care, and the adoption of person-centered, equity-focused implementation models. Conclusively, while PMTCT is a proven biomedical intervention, its ultimate success is a function of robust health systems and sustained political commitment. The findings underscore the urgent need for policy shifts that prioritize health system integration and address the social determinants of health to achieve equitable PMTCT coverage globally.

Keywords

HIV/AIDS, Infectious Disease Transmission, Vertical, Antiretroviral Therapy, Highly Active, Primary Health Care, Health Equity, Maternal-Child Health Services

1. Introduction

The HIV/AIDS pandemic, now in its fifth decade, represents one of the most significant global health challenges of modern times. Since the first clinical reports in 1981, the virus has

claimed over 40 million lives, with an estimated 39 million people living with HIV at the end of 2022 [1]. While extraordinary advancements in antiretroviral therapy (ART) have transformed HIV from a fatal diagnosis to a manageable chronic condition,

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the path to eradication remains complex and multifaceted. A pivotal focus within this journey is the interruption of HIV transmission from mothers to their children, a preventable route that continues to drive pediatric HIV incidence.

Mother-to-child transmission (MTCT), or vertical transmission, can occur during pregnancy, labor and delivery, or through breastfeeding. Without any intervention, the risk of transmission ranges from 15% to 45% [2]. The launch of the Global Plan towards the Elimination of New HIV Infections among Children by 2015 and Keeping Their Mothers Alive marked a paradigm shift, framing PMTCT not merely as a clinical intervention but as a cornerstone of the global HIV response [3]. This initiative catalyzed an unprecedented scale-up of services, contributing to a 58% reduction in new HIV infections among children from 2010 to 2022 [1].

Despite these gains, the trajectory is not one of unimpeded progress. An estimated 130,000 children acquired HIV in 2022, the majority through vertical transmission, indicating a persistent failure in service delivery and access [4]. The stagnation in global ART coverage for pregnant and breastfeeding women living with HIV, plateauing at around 82%, signals alarming implementation gaps [2]. These disparities are not randomly distributed but are concentrated in regions with fragile health systems, pervasive stigma, and gender inequality, most notably in sub-Saharan Africa. While several reviews have documented the clinical efficacy of PMTCT, this analysis distinctively focuses on the implementation challenges within health systems and the socio-structural environment, providing a synthesized, cross-regional perspective aimed at informing policy.

1.1. Aim

Therefore, this manuscript seeks to move beyond a descriptive account of PMTCT to provide a critical, evidence-based analysis of its implementation within the global eradication framework.

1.2. Objectives

Specifically, it objects are;

- (1) Trace the evolution of PMTCT from a vertical program to an integrated service model. (
- 2) Analyze the biomedical and programmatic pillars of effective PMTCT.
- (3) Evaluate regional disparities in implementation.
- (4) Identify the foremost health system and socio-structural barriers to universal coverage.
- (5) Propose a forward-looking agenda that links PMTCT success with broader health system strengthening and the pursuit of global health equity.

2. Literature Review: The Evolving Paradigm of PMTCT

The scholarly discourse on PMTCT has evolved in parallel

with scientific and programmatic advances. Early literature focused predominantly on the clinical efficacy of antiretroviral (ARV) prophylaxis, epitomized by the landmark PACTG 076 trial [5]. Subsequent research expanded to address operational challenges of delivering complex regimens in resource-limited settings [6]. The introduction of lifelong ART for all pregnant and breastfeeding women ("Option B+") shifted the literature towards health systems research, exploring retention in care, adherence, and the integration of PMTCT into maternal and child health (MCH) services [7].

A significant body of work highlights the critical role of the World Health Organization's (WHO) four-pronged framework in providing a comprehensive public health strategy, moving beyond a narrow focus on ARVs to encompass primary prevention and family planning [8]. Recent scholarship increasingly employs an equity lens, analyzing how gender inequality, stigma, and punitive laws create access barriers for marginalized women, undermining the potential of biomedical tools [9, 10]. This review synthesizes these strands of evidence to construct a holistic analysis of PMTCT implementation, identifying where the gap between technical potential and real-world impact remains widest.

3. Methods: Analytical Approach

This paper is a critical narrative review and synthesis of secondary data. It does not involve primary data collection but rather analyzes and integrates findings from existing literature and reports to construct a comprehensive, evidence-based argument. The analysis was conducted through the following steps:

1. Data Sources: The review draws on key global and regional reports from authoritative bodies including the Joint United Nations Program on HIV/AIDS (UNAIDS), the World Health Organization (WHO), the United Nations Children's Fund (UNICEF), and the Pan American Health Organization (PAHO). Peer-reviewed literature was identified via searches in PubMed and Google Scholar using keywords such as "PMTCT," "vertical transmission," "Option B+," and "elimination of mother-to-child transmission."
2. Time Frame: The period from 2000 to 2023 was selected to capture the era of rapid PMTCT scale-up following the launch of major global initiatives, including the Millennium Development Goals and the 2011 Global Plan.
3. Case Study Selection: Regional and country case studies (e.g., Botswana, South Africa, Nigeria, Thailand, Brazil) were selected purposively to illustrate a spectrum of PMTCT implementation contexts. The selection criteria were:
 - (a) representation of different epidemiological burdens (high vs. low).
 - (b) demonstration of success or critical challenges.
 - (c) availability of robust, documented evidence on program outcomes and barriers. For instance, Botswana was selected as a "success" case from a high-burden region due to its his-

toric WHO certification for elimination, while Nigeria was selected to represent a high-burden setting where implementation gaps remain severe.

4. Synthesis: Information was synthesized thematically to trace program evolution, outline core interventions, compare regional outcomes, identify cross-cutting barriers, and derive policy-oriented recommendations.

4. The Evolution and Pillars of PMTCT: From Siloed Intervention to Integrated Care

4.1. Historical Context and Programmatic Evolution

The history of PMTCT is a testament to rapid scientific innovation and adaptive programming. The landmark Pediatric AIDS Clinical Trials Group (PACTG) Protocol 076 in 1994 first demonstrated that zidovudine (AZT) administered to the mother during pregnancy and delivery, and to the newborn, could reduce transmission by approximately two-thirds [5]. This single-drug regimen, though logistically complex and costly, established the proof of concept. The subsequent evolution has been toward simpler, more efficacious, and more tolerable multi-drug ART regimens. The current WHO recommendation of lifelong ART for all pregnant and breastfeeding women living with HIV (the "Option B+" strategy) represents the culmination of this evolution, prioritizing maternal health and maximizing prevention benefits [11].

Programmatically, PMTCT has shifted from standalone, vertically managed initiatives toward integration within routine maternal, newborn, and child health (MNCH) services. This shift recognizes that siloed programs are unsustainable and that maternal health outcomes are interdependent. Effective integration improves accessibility, reduces stigma associated with visiting dedicated HIV clinics, and leverages existing MNCH platforms for broader impact.

4.2. The Four-Pronged Strategic Framework

WHO's comprehensive PMTCT framework, built upon four prongs, provides the foundational blueprint for national programs [8]:

- 1) Prong 1: Primary prevention of HIV among women of childbearing age.
- 2) Prong 2: Prevention of unintended pregnancies among women living with HIV.
- 3) Prong 3: Prevention of HIV transmission from a woman living with HIV to her infant.
- 4) Prong 4: Provision of treatment, care, and support for women living with HIV, their children, and families.

This framework underscores that PMTCT is not a single-point intervention but a continuum of care that begins before

conception and extends through the postpartum period and beyond.

5. Biomedical and Programmatic Cornerstones of Effective PMTCT

5.1. Antenatal HIV Testing and Counselling (HTC)

The gateway to PMTCT is universal, routine, and opt-out HIV Testing and Counselling (HTC) within antenatal care (ANC). Provider-initiated testing and counselling (PITC) norms have significantly increased testing rates. Innovations like rapid diagnostic tests (RDTs) providing same-day results and dual HIV/syphilis point-of-care tests have enhanced efficiency. However, the first ANC visit often occurs late in pregnancy, shortening the time for effective ART initiation before delivery. Community-based testing and partner/community-assisted testing models are emerging strategies to reach women earlier and outside clinical settings.

5.2. Antiretroviral Therapy: The Engine of Prevention

ART is the central component of Prong 3. Viral suppression (typically defined as a viral load <1000 copies/mL) in the mother virtually eliminates the risk of transmission. The universal "Treat All" or "Option B+" policy has simplified service delivery. Ensuring drug adherence is critical; factors affecting adherence include drug side effects, pill burden, fear of disclosure, and lack of psychosocial support. Differentiated Service Delivery (DSD) models, such as community ART groups and multi-month scripting, are improving retention and adherence.

5.3. Intrapartum Care and Safe Delivery Practices

Elective Caesarean section was historically recommended for women with high viral loads near delivery, but with effective ART and viral suppression, vaginal delivery is safe and recommended. Key intrapartum practices include avoiding unnecessary invasive procedures and minimizing the time between rupture of membranes and delivery. Intravenous zidovudine may be administered during labor if the mother's viral load is unknown or >1000 copies/mL.

5.4. Postnatal Strategies: Infant Prophylaxis and Infant Feeding

All HIV-exposed infants should receive postnatal antiretroviral prophylaxis, typically with daily nevirapine or zidovudine syrup for 4-6 weeks. The choice of prophylaxis regimen

depends on the mother's treatment status and adherence. Infant feeding represents a complex risk-benefit calculation. WHO recommends that mothers living with HIV should breastfeed for at least 12 months while they and the infant are on ART, as the protective benefits of breastfeeding against other causes of infant mortality outweigh the minimal transmission risk when the mother is virally suppressed [2].

5.5. Early Infant Diagnosis (EID) and Linkage to Care

Infants exposed to HIV require virological testing (DNA or RNA PCR) at specified intervals typically at birth, 6 weeks, and at the end of breastfeeding, as maternal antibodies persist for up to 18 months, rendering antibody tests unreliable.

Point-of-care EID technologies that provide results in hours rather than weeks are revolutionizing this space, enabling same-day initiation of ART for infected infants, which is critical for survival.

6. Regional Implementation Analysis: Successes and Persistent Challenges

Following the Pan American Health Organization (PAHO)'s initiative, the WHO released global guidance on certification for the Elimination of Mother-to-Child Transmission (EMTCT) of HIV and syphilis, establishing a pathway with bronze, silver, and gold tiers to encourage gradual progress [12]. Table 1 provides a comparative summary of key indicators and contexts across regions.

Table 1. Comparative Overview of PMTCT Implementation Across Selected Regions (circa 2022-2023).

| Region/ Country Case | Epidemiological Context | Key PMTCT Indicators (Estimates) | Primary Success Factors | Major Persistent Barriers |
|---------------------------|--|---|--|---|
| Sub-Saharan Africa | High burden (~90% of global paediatric HIV) | ART coverage (pregnant women): ~82% [1]. MTCT rate: Highly variable (from <2% to >30%) [1, 13]. | Political commitment, "Treat All" policy, task-shifting (e.g., South Africa). High ANC attendance & data use (e.g., Botswana). | Health system fragility, commodity stock-outs, stigma, gender inequality, funding gaps. |
| Botswana (Success Case) | High burden country | ART coverage: >95% [1]. MTCT rate: ≤5% (achieved elimination certification) [1]. | Near-universal ANC, high ART access, data-driven programming | (Model for other high-burden settings) |
| Nigeria (Challenge Case) | Highest burden of vertical transmission globally [13]. | ART coverage: Suboptimal [13]. MTCT rate: High [13]. | - | Weak health infrastructure, low service coverage, supply chain failures, knowledge gaps among providers [13]. |
| Asia & Pacific (Thailand) | Low-to-moderate burden | ART coverage: ~98% [1]. MTCT rate: <2% (elimination achieved) [1]. | Strong public health system, early policy adoption, UHC integration, 100% Condom Program | Equity in reaching all marginalized groups |
| EM/MENA Region | Concentrated, rising epidemic | ART coverage: Data limited. MTCT rate: Data limited [1] | Effective regimens for those identified | Stigma, low ANC testing, criminalization of key populations, weak data systems [1] |
| Latin America (Brazil) | Moderate burden, declining MTCT | ART coverage: High in certified municipalities [14]. MTCT rate: Declining, subnational elimination achieved [14, 15]. | Pioneering subnational certification, policy innovation | Data fragmentation, equity challenges for marginalized groups [14, 15]. |

Note: ANC = Antenatal Care; ART = Antiretroviral Therapy; EMTCT = Elimination of Mother-to-Child Transmission; EM/MENA = Eastern Mediterranean, Middle East and North Africa; MTCT = Mother-to-Child Transmission; UHC = Universal Health Coverage. Data synthesized from referenced sources [1, 13-15].

6.1. Sub-Saharan Africa: The Epicenter of Burden and Innovation

Sub-Saharan Africa remains the global epicenter, accounting for nearly 90% of pediatric HIV infections [1]. Botswana made history in 2021 as the first high-burden African country to be certified by WHO for achieving EMTCT, built on near-universal ANC attendance and high ART coverage [1]. South Africa has implemented a robust, decentralized PMTCT model, driving MTCT rates below 2% in many districts, though challenges like high patient volumes and loss to follow-up persist. In stark contrast, West and Central Africa lag significantly, with Nigeria bearing the highest burden of vertical transmission globally due to poor PMTCT program coverage, weak health infrastructure, and stock-outs of essential commodities [13].

6.2. Asia and the Pacific: Divergent Trajectories

Thailand is a global PMTCT success story, reducing its MTCT rate to below 2% through strong political leadership and integration into universal health coverage [1]. China has scaled up its program through the "Four Frees and One Care" policy but faces challenges in reaching marginalized populations like internal migrant women, highlighting issues of equity within broad coverage statistics.

6.3. Eastern Mediterranean, Middle East and North Africa (EM/MENA): A Concentrated Epidemic

The EM/MENA region presents a paradoxical picture with a low but rising HIV incidence concentrated among key populations [1]. PMTCT implementation is hampered by low ANC testing rates due to stigma, weak surveillance systems, and legal barriers that criminalize key populations, driving affected women away from health services.

6.4. Latin America and the Caribbean: Progress with Persistent Gaps

MTCT in Latin America has declined globally, yet persistent cases indicate failures in prevention [15]. Brazil pioneered subnational EMTCT certification, with municipalities like Curitiba and São Paulo achieving validation [14]. A key barrier has been the lack of a single national data source for monitoring prenatal testing coverage, necessitating alternative methods like systematic analysis of medical records [14]. Countries like El Salvador and Panama have MTCT rates between 2-5%, while others like Guatemala and Mexico, despite progress, still have rates above 5% [15].

7. Cross-Cutting Barriers to Universal PMTCT Coverage

7.1. Health System Constraints

Critical shortages and high workloads of nurses and midwives, frequent stock-outs of test kits and drugs, and fragmented, paper-based data systems hinder patient tracking and accurate measurement of outcomes like final MTCT rate.

7.2. Socio-Structural and Gender-Related Barriers

HIV-related stigma and discrimination, gender inequality, intimate partner violence, and poverty with its associated opportunity costs create profound barriers to service access, adherence, and retention for women.

7.3. Policy and Funding Gaps

Heavy reliance on external funding (e.g., from PEPFAR and the Global Fund) raises sustainability concerns, coupled with inadequate domestic investment in health. Furthermore, public health evidence indicates that restrictive policies criminalizing HIV transmission, sex work, or drug use create environments of fear, deterring individuals from seeking testing and treatment services, thereby undermining PMTCT goals [16, 17].

8. Recommendations: Toward an Integrated and Equitable Future

8.1. Deepen Integration Within Primary Health Care (PHC)

PMTCT must be fully embedded as a standard component of PHC and universal health coverage (UHC) packages through co-location of services, task-shifting, and strengthening linkages to chronic HIV care, family planning, and mental health services.

8.2. Invest in and Strengthen Community-Led Systems

Investment should focus on community-based testing, adherence support through peer mentors and mother-support groups, and stigma reduction programs led by networks of people living with HIV.

8.3. Leverage Technology and Data for Action

Implement interoperable electronic medical records and mHealth platforms, accelerate the rollout of point-of-care viral load and EID testing, and use data analytics for real-time management and targeting of interventions.

8.4. Address the Social Determinants of Health

A multisectoral approach is required to promote gender equality and scale up social protection (e.g., cash transfers). Aligning national laws with international public health guidance by reviewing and reforming punitive legal frameworks that marginalize key populations is essential to creating an enabling environment for effective PMTCT service delivery [16, 17].

9. Limitations of the Study

This analysis is based on a review of published literature, reports, and case studies, which may be subject to publication bias and varying data quality across regions, particularly in settings with weak health information systems. The evolving nature of the pandemic and programmatic responses means that some data points may be superseded by more recent developments not yet captured in the literature.

10. Conclusion

The implementation of PMTCT stands as one of the great public health achievements of the 21st century. Yet, the stagnation in global coverage is a stark warning that technical solutions, when delivered through weak and inequitable systems, have inherent limits. The future of PMTCT lies in a fundamental reorientation from a vertical HIV program to an indispensable component of resilient, equitable, and person-centered primary health care systems. This requires sustained political will, smarter financing, genuine community engagement, and an unwavering commitment to human rights. The path to ending AIDS is inextricably linked to the path toward health for all.

Abbreviations

| | |
|-------|---|
| AIDS | Acquired Immunodeficiency Syndrome |
| ANC | Antenatal Care |
| ART | Antiretroviral Therapy |
| ARV | Antiretroviral |
| EMTCT | Elimination of Mother to Child Transmission |
| HTC | HIV Testing and Counselling |
| MCH | Maternal and Child Health |
| MNCH | Maternal, Newborn and Child Health |
| MTCT | Mother to Child Transmission |
| PAHO | Pan American Health Organization |

| | |
|-------|--|
| PHC | Primary Health Care |
| PMTCT | Prevention of Mother to Child Transmission |
| UHC | Universal Health Coverage |
| WHO | World Health Organization |

Author Contributions

Mukhtar Aisha Zakari is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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