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ORIGINAL ARTICLE

Immunological and virological response in HIV-1 infected patients receiving active antiretroviral therapy at a tertiary care center in Northern India

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ABSTRACT

Background and Objectives: Human Immunodeficiency Virus (HIV) remains a major global health challenge, with limited Indian data on factors influencing treatment outcomes. This study assessed immunological and virological responses and survival determinants among treatment-naïve HIV-1–positive adults.

Materials and Methods: A retrospective observational study was conducted at a tertiary care centre from May 2022 to April 2023. Adults (≥18 years) who initiated first-line ART (TDF + 3TC + DTG) between January 2019 and December 2020 with 24-month follow-up were included. Baseline demographics, CD4 count, viral load, and adherence were analysed using descriptive statistics and logistic regression.

Results: Of 452 screened patients, 355 were eligible. Mortality at 6, 12, and 24 months was 22%, 26.8%, and 29.9%, respectively, with overall survival of 70.1%. Baseline CD4 count, viral load, adherence, and ART initiation timing significantly influenced outcomes ($p < 0.05$). Patients with baseline between 200 to 350 had almost 7 times the odds of survival compared to those with <200 cells/µL. Early ART initiation (≤7 days) improved survival (3-fold) and viral suppression (2.4-fold), while adherence >95% was the strongest predictor of success. Older age and high viral load predicted poorer outcomes.

Conclusion: Early ART initiation, strict adherence, and favourable baseline markers significantly improved survival and suppression, supporting the "test-and-treat" approach and the UNAIDS 95-95-95 targets.

Keywords: HIV 1; CD4; HAART; Immunological response; Polymerase chain reaction; Viral load

INTRODUCTION

The Human Immunodeficiency Virus (HIV), a Lentivirus of the family *Retroviridae*, causes chronic infection that progresses to Acquired Immune Deficiency Syndrome (AIDS) if untreated (1). Globally, over 75 million individuals have been infected, and 38.4 million are currently living with HIV, underscoring its status as one of the leading causes of morbidity and mortality (2). India, with an estimated

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5.13 million people living with HIV, bears the second-highest burden worldwide, highlighting the regional public health challenge (2). Beyond medical consequences, HIV continues to exert profound social and economic effects in low- and middle-income countries.

The introduction of antiretroviral drugs (ARVs) transformed HIV infection from a fatal illness into a chronic, manageable condition. Combination antiretroviral therapy (ART) effectively suppresses viral replication, reduces plasma ribonucleic acid (RNA) to undetectable levels, and facilitates immune reconstitution, reflected in increasing CD4 T-lymphocyte counts (3, 4). Sustained viral suppression not only reduces disease progression and opportunistic infections but also extends life expectancy and improves quality of life. Consequently, ART has shifted the perception of HIV from a "death sentence" to a chronic, manageable disease (5).

Monitoring patients on ART remains critical to ensure treatment efficacy, identify adherence barriers, and detect drug-related toxicities. While clinical and immunological parameters provide useful information, viral load testing remains the World Health Organization (WHO)-recommended gold standard for assessing therapeutic response and detecting treatment failure (6-8). Viral load offers earlier and more precise insights into ART effectiveness than immunological or clinical markers.

Although global evidence identifies immune recovery, viral suppression, and treatment failure as key ART outcomes, data from the Indian population remain limited, particularly regarding the sociodemographic and clinical determinants of immunological and virological responses (7-9). This knowledge gap is especially relevant given India's large and diverse HIV epidemic, which differs in epidemiology and healthcare access compared with African and Western cohorts. To address these regional disparities, this study analysed follow-up data from treatment-naïve Indian patients initiating ART. Specifically, it examines the association between baseline characteristics and subsequent immunological and virological outcomes and assesses the impact of early ART initiation on long-term prognosis.

Early initiation of antiretroviral therapy (ART), along with favourable baseline immunological (higher CD4+ T-cell counts) and virological (lower viral load) parameters, is significantly associated with enhanced immune reconstitution and sustained virological suppression. Together, these factors contribute to improved overall outcomes among treatment-naïve HIV-1–infected individuals in the Indian population.

MATERIALS AND METHODS

A retrospective observational study was conducted at the Department of Microbiology, SN Medical College, Agra, from May 2022 to April 2023. The study included treatment-naïve HIV-1–positive patients aged ≥18 years, diagnosed at the ICTC and initiated on ART between January 2019 and December 2020, with complete 24-month follow-up data. Patients aged <18 years, pregnant or lactating women, individuals co-infected with hepatitis B/C or tuberculosis, and those lost to follow-up were excluded.

The data were compiled in Microsoft Excel and analyzed using SPSS 21.0 software. Categorical variables were summarized using frequencies and percentages, while continuous variables were expressed as mean and standard deviation. Firth's penalized logistic regression model was employed to identify determinants associated with the dichotomous outcome variable.

Procedure:

- Patients were tested and diagnosed with HIV in accordance with the National Guidelines for HIV Care and Treatment 2021 issued by the National AIDS Control Organization (NACO), Ministry of Health and Family Welfare, Government of India. Confirmatory testing was performed at the nearest Integrated Counselling and Testing Centre (ICTC) using three different rapid diagnostic tests (RDTs) based on distinct antigens/principles, as per national protocol (6).

1) COMBAIDS - RS Advantage-ST HIV 1+2 Dot Immunoassay kit.

2) STANDARD Q HIV 1/2 Ab Immunochromatography Kit.

3) TREDRO HIV 1/2 Ab Immuno Concentration Technology kit.

- Following diagnosis at the ICTC, patients were referred to the ART centre, where upon enrolment they underwent a comprehensive evaluation comprising a full clinical assessment (including medical history and physical examination) and laboratory workup (6).
- Following the current recommendations to

'TREAT ALL' regardless of CD4 count or WHO Clinical Stage, all patients were provided same-day/rapid ART initiation if they were sufficiently prepared, well informed, and had no clinical contraindications (6, 7).

- Patients were started on first-line ART. The preferred regimen was Tenofovir Disoproxil Fumarate (TDF, 300 milligrams) + Lamivudine (3TC, 300 milligrams) + Dolutegravir (DTG, 50 milligrams) (TLD) as a Fixed-Dose Combination, administered once daily.
- CD4 T lymphocyte counts (cells/µL) were determined using a BD FACSCount™ system (Becton, Dickinson, USA) based on flow cytometry. Plasma HIV-1 RNA viral load (copies/mL) was quantified by Real-time Polymerase Chain Reaction (PCR) using a TaqMan™-based assay.
- The following data were collected at the Department of Microbiology and ART Centre:

Baseline socio-demographic and clinical profile (pre-ART).

Dates of HIV confirmation and ART initiation.

Follow-up laboratory data, including CD4 T lymphocyte count and plasma viral load, measured at 6-month intervals for 24 months post-ART initiation.

Patient adherence to ART over the 24-month study period.

Definitions of outcome assessed. Immunological response to ART was defined as a CD4 count recovery of ≥50 cells/µL at 6 months. This was evaluated by measuring CD4 T-lymphocyte count recovery and immunological failure. Baseline CD4 counts (before ART initiation) were compared with follow-up counts at 6, 12, and 24 months.

Virological response to ART was Defined as viral suppression to <1000 copies/mL at 6 months, which was then maintained. This was evaluated by measuring viral load suppression and virological failure. Plasma RNA viral load was tested at 6, 12, and 24 months after ART initiation.

Operational definition of terms used:

- CD4 T Lymphocyte count recovery: An increase of at least 50 cells/µL after 6 months of ART (6).
- Immunological failure: CD4 count at 250 cells/µL following clinical failure, or a persistent CD4 cell count below 100 cells/µL (6, 8).
- Viral suppression: A plasma viral load that is undetectable or <1000 copies/mL after 6 months of ART initiation and is maintained at this level throughout treatment (6).
- Virological failure: A plasma viral load >1000 copies/mL at or after 6 months of ART in a patient with >95% treatment adherence (6, 8).

The four outcome variables were assessed in relation to the following parameters: socio-demographics (age, gender, educational status, income level), clinical information (WHO clinical stage, duration of ART, ART drug regimen, opportunistic infections), and laboratory data (baseline and follow-up CD4 count and viral load (10).

RESULTS

A total of 452 ART-naïve adults (>18 years) infected with HIV-1 were registered and started ART between January 2019 and December 2020. Of these, 18 patients were lost to follow-up, 6 discontinued treatments, 42 opted out, and 31 were transferred to other facilities. Consequently, data from the remaining 355 patients who met the inclusion criteria were analyzed for this study. The baseline demographic, behavioral, and clinical characteristics of the study cohort are summarized in Table 1.

As shown in Table 1, the mean baseline CD4 count for the 355 patients was 321.35 cells/µL (SD = 204.8). Patients were assessed at 6, 12, and 24 months. Following ART, the mean CD4 count increased, and the standard deviation decreased, indicating reduced variability.

Fig. 1 represents the number of deaths during the course of study period. There were 78 (22%) deaths at 6 months of treatments, only 17 (26.8%) deaths were recorded at 12th month assessment and 11 (29.9%) patients died at 24th month of assessment, making the total deaths of 106 in the study period. It implies that

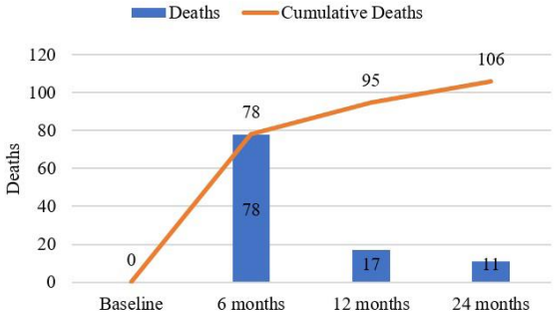

Fig. 1. Deaths of patients with timeline

Table 1. Summary of demographic, behavioral and clinical characteristics

Factor	Categories	Frequency (%)
Age	18-24	33 (9.3%)
	25-34	106 (29.9%)
	35-49	153 (43.1%)
	>=50	63 (17.7%)
Sex	Male	230 (64.8%)
	Female	125 (35.2%)
CD4 Baseline	<200	132 (37.2%)
	200-349	97 (27.3%)
	350-499	60 (16.9%)
	>=500	66 (18.6%)
ART Time Initiation	after 7 days	95 (26.8%)
	within 7 days	260 (73.2%)
Transmission Category	Unsafe Sex	256 (72.1%)
	Possible unsafe injection or blood transfusion	40 (11.3%)
	Unknown	59 (16.6%)
Adherence	<95	152 (42.8%)
	>=95	203 (57.2%)
Viral Load	Low	220 (62%)
	Medium	33 (9.3%)
	High	24 (6.8%)
	Total	277 (78%)
	Missing	78 (22%)
Suppressed	No	134 (37.7%)
	Yes	221 (62.3%)
Recovered	No	207 (58.3%)
	Yes	148 (41.7%)
Survival	No	106 (29.9%)
	Yes	249 (70.1%)
Mortality with Timeline	Deaths at 6 months	78 (22%)
	Deaths at 12 months	17 (4.8%)
	Deaths at 24 months	11 (3.1%)
	Survived	249 (70.1%)
	Total	355 (100%)
CD4 Count	Baseline	321.35 ± 204.8
(Mean ± S.D.)	6 months	383.35 ± 204.67
	12 months	409.23 ± 181.47
	24 months	455.98 ± 198.19

if a patient survives for 6 months and keep receiving the treatment, the mortality decreases.

Furthermore, logistic regression was performed to assess the impact of various baseline characteristics on patient survival, viral suppression, and immunological recovery (all coded as binary Yes/No outcomes). The factor "Adherence" was observed to have a zero cell frequency, which causes instability in standard logistic regression. Therefore, the more stable Firth's logistic regression method was applied. Additionally, 78 cases with missing viral load values were excluded from the regression analysis. The results are presented in Tables 2-4 for survival, suppression, and recovery, respectively.

According to Table 2, the odds of survival for patients aged over 50 are significantly different (p =

Table 2. Odds ratio and 95% confidence interval for survival among HIV patients

Factor	Category	%Death (Total)	OR (95% CI)	p value
	(Intercept)		0.46 (0.02, 7.45)	0.5853
Age	18-24	24.24% (33)	Ref	
	25-34	23.58% (106)	1.67 (0.14, 19.81)	0.6754
	35-49	30.07% (153)	1.61 (0.12, 17.27)	0.6995
	>=50	42.86% (63)	0.08 (0, 0.79)	0.0296**
Sex	Male	33.91% (230)	Ref	
	Female	22.4% (125)	0.88 (0.27, 2.86)	0.8266
CD4 Baseline	<200	65.15% (132)	Ref	
	200-349	11.34% (97)	6.67 (1.74, 32.39)	0.0048***
	350-499	10% (60)	5.13 (0.92, 41.08)	0.0631*
	>=500	4.55% (66)	3.15 (0.64, 20.84)	0.1631
ART Time Initiation	Late	40% (95)	Ref	
	Early	26.15% (260)	2.96 (0.9, 11.1)	0.0738*
Transmission	Unsafe Sex	27.13% (258)	Ref	
	Probable unsafe injection or Blood Transfusion	25% (40)	0.74 (0.11, 5.91)	0.7648
	Unknown	45.61% (57)	3.58 (0.67, 29.93)	0.1431
Viral Load	Low	3.64% (220)	Ref	
	Medium	30.3% (33)	0.56 (0.15, 2.03)	0.3758
	High	41.67% (24)	0.33 (0.06, 1.7)	0.1836
Adherence	<95	0% (203)	Ref	
	>=95	69.74% (152)	250.66 (21.74, 38757.56)	0.0000***

***significant at 1% level of significance, **significant at 5% level of significance, * significant at 10% level of significance

0.0296) from those of the 18-24 age group at the 5% significance level. The odds ratio is 0.08, indicating that the odds of survival for a patient over 50 are less than one-tenth of those for a patient aged 18-24, when other factors are held constant. A patient's sex does not significantly impact the odds of survival, as the associated p-value (0.8266) is greater than 0.05.

The odds of survival for patients with a baseline CD4 count between 200 and 349 were 6.67 times higher than for those with a count below 200 ($p < 0.05$). For patients with a baseline CD4 count between 350 and 499, the odds of survival were 5.13 times higher than the reference group (<200); however, this result was not statistically significant at the 5% level ($p > 0.05$). Finally, the odds of survival for patients with a baseline CD4 count over 500 did not differ significantly from those with a count below 200 ($p = 0.1631$).

The odds of survival are 2.96 times higher for patients who start treatment early (within 7 days) than for those who start treatment late (after 7 days). The results were not statistically significant at the 5% level. Specifically, the odds of survival did not differ significantly by transmission type, as the associated p-values were greater than 0.05. Furthermore, when other factors were held constant, the odds of survival were not significantly different across the various viral load categories. In contrast, adherence to treatment had a strong and significant impact on patient survival. Patients with more than 95% treatment adherence had 250 times higher odds of survival.

However, the odds ratios and 95% confidence intervals in Table 3 reveal a significant negative relationship between age and viral suppression. Specifically, when other factors were held constant, the odds of achieving suppression decreased as age increased. The odds ratios were 0.11 for ages 25-34, 0.06 for ages 35-49, and 0.03 for age ≥50. This indicates that compared to the reference group (18-24 years), the odds of suppression were substantially lower in older age groups. The odds of viral suppression were not significantly affected by sex, baseline CD4 count, transmission category, or timing of ART initiation. This means that

Table 3. Odds ratio and 95% confidence interval for suppression among HIV patients

Factor	Category	% Suppressed (Total)	OR (95% CI)	p value
	(Intercept)	72.73% (33)	21.6 (1.91, 293.67)	0.013**
Age	18-24	64.15% (106)	Ref	
	25-34	62.09% (153)	0.11 (0.01, 0.78)	0.027**
	35-49	53.97% (63)	0.06 (0.01, 0.5)	0.009***
	>=50	59.13% (230)	0.03 (0, 0.32)	0.002***
Sex	Male	68% (125)	Ref	
	Female	30.3% (132)	0.72 (0.26, 2)	0.531
CD4 Baseline	<200	79.38% (97)	Ref	
	200-349	81.67% (60)	2.07 (0.61, 7.34)	0.241
	350-499	83.33% (66)	1.12 (0.25, 5.17)	0.877
	>=500	50.53% (95)	0.73 (0.16, 3.15)	0.677
ART Time Initiation	Late	66.54% (260)	Ref	
	Early	64.84% (256)	2.35 (0.83, 6.89)	0.107
Transmission	Unsafe Sex	70% (40)	Ref	
	Probable unsafe injection of Blood Transfusion	45.76% (59)	0.88 (0.19, 4.59)	0.870
	Unknown	94.55% (220)	0.76 (0.19, 3.34)	0.709
Viral Load	Low	27.27% (33)	Ref	
	Medium	16.67% (24)	0.05 (0.01, 0.15)	0.000***
	High	18.42% (152)	0.01 (0, 0.05)	0.000***
Adherence	<95	95.07% (203)	Ref	
	>=95	72.73% (33)	13.92 (4.98, 44.31)	0.000***

***significant at 1% level of significance, **significant at 5% level of significance, * significant at 10% level of significance

across the categories of these factors, the odds of suppression did not differ significantly from their respective reference groups. In contrast, baseline viral load was a significant predictor. The odds of suppression were substantially lower for patients with medium and high viral loads compared to those with a low viral load. The odds ratios for both medium and high viral load categories were statistically significant at the 1% level ($p < 0.01$). Adherence to treatment was also significant at the 1% level. Patients with adherence greater than 95% were almost 14 times more likely to achieve viral suppression than those with adherence below 95%.

According to Table 4, age, sex, and transmission category had no significant impact on immunological recovery at the 5% significance level, as the p-values for these factors were greater than 0.05. For baseline CD4 count, the odds ratios for recovery were 1.2 (200-349 cells/μL), 1.1 (350-499 cells/μL), and 0.6 (≥500 cells/μL), with p-values of 0.471, 0.194, and <0.001, respectively. The odds ratio for the ≥500 cells/μL category was significant at the 1% level ($p < 0.01$). This indicates that patients with a baseline CD4 count of ≥500 cells/μL had 40% lower odds of recovery compared to the reference group (<200 cells/μL).

The timing of ART initiation had an odds ratio of 1.79, indicating that the odds of recovery were nearly twice as high for patients who started treatment early compared to those who started late. The associated p-value was 0.067, which is not statistically significant at the conventional 5% level. However, it does suggest a marginally significant trend at the 10% level ($p < 0.10$).

Baseline viral load also had a significant effect on recovery. The odds ratios for recovery were 0.35 for a medium viral load and 0.15 for a high viral load ($p = 0.028$ and $p < 0.001$, respectively), indicating that the odds of recovery decrease as viral load increases. Adherence was also a significant predictor of recovery ($p < 0.01$). The odds ratio was 3.52, meaning that patients with >95% adherence had 3.52 times higher odds of recovery than those with lower adherence.

Table 4. Odds ratios and 95% confidence intervals for recovery in HIV patients.

Factor	Category	% Recovered (Total)	OR (95% CI)	p value
	(Intercept)		0.52 (0.14, 1.91)	0.321
Age	18-24	39.39% (33)	Ref	
	25-34	45.28% (106)	1.15 (0.43, 3.1)	0.778
	35-49	43.14% (153)	1.06 (0.4, 2.79)	0.904
	>=50	33.33% (63)	0.57 (0.19, 1.68)	0.306
Sex	Male	40% (230)	Ref	
	Female	44.8% (125)	1.08 (0.62, 1.89)	0.793
CD4 Baseline	<200	25.76% (132)	Ref	
	200-349	63.92% (97)	1.32 (0.61, 2.84)	0.471
	350-499	53.33% (60)	0.57 (0.24, 1.32)	0.14
	>=500	30.3% (66)	0.18 (0.07, 0.42)	0.000***
ART Time Initiation	Late	29.47% (95)	Ref	
	Early	46.15% (260)	1.79 (0.96, 3.36)	0.067*
Transmission	Unsafe Sex	40.63% (256)	Ref	
	Probable unsafe injection or Blood Transfusion	55% (40)	1.57 (0.67, 3.8)	0.299
	Unknown	37.29% (59)	1.89 (0.83, 4.46)	0.131
Viral Load	Low	61.82% (220)	Ref	
	Medium	24.24% (33)	0.35 (0.13, 0.89)	0.028**
	High	16.67% (24)	0.15 (0.04, 0.44)	0.000***
Adherence	<95	13.82% (152)	Ref	
	>=95	62.56% (203)	3.52 (1.71, 7.37)	0.001***

***significant at 1% level of significance, **significant at 5% level of significance, * significant at 10% level of significance

DISCUSSION

This study investigated the factors influencing virological suppression among HIV patients after 24 months of antiretroviral therapy (ART), providing insights into the clinical and behavioural predictors of treatment success. The overall virological suppression rate observed was 62.3%, which is comparable to findings from other low- and middle-income countries. However, several baseline variables significantly influenced treatment outcomes (11, 12).

In this study, the cumulative mortality rates at 6, 12, and 24 months were 22.0%, 26.8%, and 29.9%, respectively. The overall survival rate at 24 months of ART was 70.1%. The one-year mortality rate in our study (26.8%) was higher than the rate reported in a multi-site Latin America and Caribbean study (8.3%) (12) and in a study from Mongolia (3.6%). One possible explanation for the elevated mortality could be low treatment adherence, as shown in Table 1, where only 57.2% of patients had >95% adherence.

In our study, 73.6% of the total deaths recorded over 24 months occurred within the first six months. This proportion is higher than the rates reported in other studies: 55.5%, 37.9% and 28.7% (11,12,13). Furthermore, this study revealed that baseline CD4 count, treatment adherence, and the timing of ART initiation were significantly associated with treatment outcome (survival).

Patients aged ≥50 years had lower odds of survival (OR = 0.08; p = 0.029) and suppression (OR = 0.03; p = 0.002) compared to the 18-24years group. This trend aligns with studies like Zhangh. G and Stanton AM et al. showing that older age groups, particularly >50 years, exhibit delayed immune recovery and higher early mortality following ART initiation (14, 15). This underscores the need for age-specific HIV management, especially with rising prevalence among older adults in developing countries. Female patients had slightly higher recovery, though non-significant, odds (OR = 1.08; p = 0.793) of favourable outcomes compared to males. This result is consistent with recent findings (e.g., UNAIDS 2024; Nguyen et al., 2023; Mageda K. et al., 2023) indi-

cating that while females often have better ART adherence and earlier testing, survival benefits equalize once both sexes are on consistent ART regimens (16-18). Our study showed that the older age group (35-49 years) had a higher mortality rate compared to the younger group, a finding that is consistent with other studies (19). This may be because physiological efficiency declines with age, resulting in a less effective immune system, a higher risk of comorbidities, and a diminished response to ART compared to younger patients (20).

An inverse relationship was also observed between baseline CD4 counts and mortality rates. Several studies support that initiating ART at a higher CD4 cell count reduces morbidity and prevents high mortality rates among individuals with advanced HIV. The study conducted in China showed that patients with a baseline CD4 count <350 cells/mm³ had higher mortality than those with a count ≥350 cells/mm³ (13). In keeping with the findings of prior studies, the study demonstrated that the CD4 cell count was an independent predictor of the course of AIDS. In this study rapid ART initiation was strongly associated with improved viral suppression and reduced mortality. These findings align with both real-world evidence and formal meta-analyses. A 2025 systematic review reported that rapid ART reduced mortality (adjusted risk ratio 0.80; 95% CI 0.65-0.98) and was cost-effective compared to delayed ART, with no increase in adverse events or viral failure (21). Similarly, a comprehensive analysis in resource-rich settings reaffirmed the benefits of reducing delay to ART initiation to preserve immune function (22).

Some real-world studies, particularly from sub-Saharan Africa, have reported higher six-month loss-to-follow-up (LTFU) rates among rapid ART initiators (21). This highlights the importance of incorporating patient readiness assessment, structured counselling, and engagement strategies alongside rapid start protocols.

To fully benefit from ART, treatment adherence is crucial. Nonadherence leads to treatment failure by increasing the risk of viral mutation, which can result in drug-resistant virus and, ultimately, death. The risk of death was significantly higher for patients who did not strictly adhere to their ART regimen than for those who did. Numerous global studies have reported similarly high mortality rates associated with suboptimal adherence (<95%), which aligns with our findings (23, 24).

The present data did not reveal any significant association between the mode of transmission (unsafe sex, injection/blood transfusion, or unknown) and mortality. A 2023 study by Li et al. evaluating 4,000 patients in Asia reported no statistically significant difference in time to viral suppression or all-cause mortality between individuals infected via heterosexual transmission versus injection drug use (25). Similarly, a 2024 multicentre analysis across six African countries showed that although certain transmission groups (e.g., people who inject drugs) faced structural barriers to care, their suppression rates and survival did not differ significantly once adherence and ART access were controlled (26).

Factors significantly associated with viral suppression included literacy, female sex, second-line ART, and the initiation of Enhanced Adherence Counselling (EAC) within one month of treatment failure (27). In a 2023 Kenyan study, second-line ART patients with optimal adherence achieved approximately 90% virological suppression. Complementary results from Nigeria and other LMICs showed up to 79% suppression after structured EAC, further underscoring its efficacy (28).

In the present analysis, medium and high viral loads were associated with significantly lower odds of virological suppression compared to the low viral load group ($p < 0.001$). A large-scale 2023 cohort study conducted in sub-Saharan Africa found that individuals with initial high viral loads (>100,000 copies/mL) were significantly less likely to achieve viral suppression at 6 and 12 months post-ART initiation (OR = 0.12; 95% CI: 0.05-0.31) (29). Similarly, a 2024 WHO regional report emphasized that patients with lower baseline viral load had higher chances of achieving and sustaining viral suppression, particularly in resource-limited settings.

From a mortality perspective, elevated viral load has consistently been shown to be a strong predictor of increased risk. For example, a 2024 longitudinal study in East Africa reported that individuals with persistent viral load above 10,000 copies/mL had a 2.8-fold increased risk of HIV-related mortality within 24 months (30).

These outcomes bolster the framework recommended by the 2022 JAMA HIV treatment guidelines, which advocate immediate ART initiation and highlight addressing social determinants such as housing, stigma, and peer support to ensure success (31). Integrating rapid ART initiation with robust

EAC and psychosocial interventions offers a synergistic strategy for sustained viral suppression and mortality reduction.

While our comparisons provide descriptive insights, further analytical interpretation is possible when contextualized with recent Indian data and UNAIDS benchmarks. For instance, according to UNAIDS (2024), India reported a 72% viral suppression rate among people on ART, which is higher than the 62.3% observed in our cohort (16). Moreover, recent multicentre studies from India documented lower one-year mortality rates (10-15%) compared to our findings, which they attributed to earlier ART initiation, improved adherence counselling, and enhanced programmatic support (32, 33). These contrasts suggest that system-level improvements, patient readiness, and structured adherence interventions play a critical role in determining ART outcomes beyond baseline clinical characteristics.

CONCLUSION

This study emphasizes the vital role of early ART initiation, strict adherence, and baseline immunovirological markers in improving HIV treatment outcomes. The observed continuous CD4+ recovery over 24 months suggests that immunological restoration is achievable in routine clinical settings. Although these findings support the 'test and treat' approach, their limited generalizability warrants cautious interpretation. The virological suppression rate, while encouraging, remains below UNAIDS 95-95-95 objectives, highlighting the need for more timely treatment, better adherence support, and closer monitoring to enhance outcomes and close current care gaps.

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