MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.36478/makrjms.2025.1.73.77

OPEN ACCESS

Key Words
HIV, antiretroviral therapy, viral load suppression, CD4 count, adherence

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Received: 19 September 2024
Accepted: 26 October 2024
Published: 30 November 2024

Citation: Ranjana M. Totewad, Amit A. Lomte, Arjun G. Jadhav, Nagesh V. Abdagire, Asha S. Boinwad, Bhausaheb A. Mundhe, S.L. Nilekar and D.M. Kulkarni, 2024. Correlation of Viral Load Suppression and Associated Factors Among HIV Patients on Antiretroviral Therapy in a Tertiary Care Hospital. Res. J. Med. Sci., 19: 73-77, doi: 10.36478/makrjms.2025.1.73.77

Correlation of Viral Load Suppression and Associated Factors Among HIV Patients on Antiretroviral Therapy in a Tertiary Care Hospital

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ABSTRACT
Viral load suppression is a critical marker of the success of antiretroviral therapy (ART) in HIV patients. This study aimed to evaluate the rate of viral suppression and its association with demographic, clinical and adherence factors among patients undergoing ART at a tertiary care hospital. This cross-sectional observational study analyzed 3,364 HIV-positive patients enrolled in ART at a tertiary care hospital. Data on demographics, ART duration, adherence (measured as >90%, 80-90%, <80%) and CD4 counts were collected. Viral suppression was defined as a viral load of <1,000 copies/mL. Statistical analysis included chi-square tests for categorical variables and logistic regression to identify predictors of viral suppression. Data were visualized using bar charts and line graphs. Of the 3,364 patients, 95.3% (3,205) achieved viral suppression, while 4.7% (159) remained unsuppressed. Viral suppression was highest (97%) among patients on ART for >12 months. Patients with adherence >90% had a suppression rate of 97%, compared to 35% in those with <80% adherence ($p<0.001$). Viral suppression was 97% in patients with CD4 counts >500 cells/µL and 65% in those with <200 cells/µL ($p<0.001$). Male patients constituted 56.5% of the cohort, with 47.9% aged 40-59 years. The study demonstrates high viral suppression rates, driven by adherence to ART and higher CD4 counts. Sustained adherence and early initiation of ART are critical for achieving optimal outcomes. Targeted interventions for non-adherent patients and those with advanced disease are recommended to further improve viral suppression rates.

INTRODUCTION

Human Immunodeficiency Virus (HIV) remains a global public health challenge, with millions of individuals living with the virus worldwide. Despite significant advancements in antiretroviral therapy (ART), which has transformed HIV from a fatal condition to a manageable chronic illness, ensuring effective viral load suppression remains a cornerstone of HIV treatment and prevention strategies[1]. Viral load suppression not only improves individual health outcomes but also reduces the risk of HIV transmission, contributing to public health goals such as achieving the UNAIDS 90-90-90 targets. These targets aim for 90% of people living with HIV (PLHIV) to know their status, 90% of those diagnosed to receive sustained ART and 90% of those on ART to achieve viral suppression[2,3]. Viral load suppression is defined as reducing the HIV RNA levels in the blood to below detectable levels (<1000 copies/mL). It serves as a primary indicator of treatment efficacy and adherence to ART[4]. Factors influencing viral suppression include timely initiation of ART, adherence to medication, type of ART regimen, drug resistance and patient-related variables such as socio-demographic and behavioral factors. Studies have shown that social determinants, such as stigma, economic barriers and access to healthcare, also significantly affect viral load outcomes[5]. Despite the increasing availability of ART, achieving universal viral suppression remains a challenge, particularly in resource-limited settings. These challenges include late diagnosis, irregular follow-up, suboptimal adherence and lack of monitoring infrastructure for viral load testing. Moreover, co-infections, such as tuberculosis and comorbidities, like malnutrition, further complicate treatment outcomes in HIV patients. Understanding the factors associated with viral load suppression is critical for tailoring interventions to optimize treatment outcomes. A tertiary care hospital setting provides a unique opportunity to evaluate these factors comprehensively, given the diverse patient demographics and clinical presentations encountered in such facilities. This study focuses on identifying the correlation between viral load suppression and associated factors among HIV patients on ART, aiming to contribute to evidence-based policy formulation and improved clinical practice. This research seeks to identify the key factors influencing viral load suppression among HIV patients on ART and to analyze the effectiveness of existing ART protocols in achieving suppression in a tertiary care setting. The findings will provide valuable insights into potential gaps in care delivery and offer recommendations for enhancing patient outcomes in HIV management.

MATERIALS AND METHODS

This study was a hospital-based, cross-sectional observational study conducted to analyze the correlation between viral load suppression and associated factors among HIV patients on antiretroviral therapy (ART). The research was carried out in the ART clinic of a tertiary care hospital, a facility equipped to provide comprehensive HIV care, including regular monitoring of ART outcomes and management of comorbidities and opportunistic infections. The clinic caters to a diverse patient population from urban and rural settings, making it an ideal site for evaluating factors influencing viral suppression. The study included HIV-positive individuals receiving ART for at least six months, as this duration is considered adequate to evaluate treatment efficacy in terms of viral suppression.

Inclusion Criteria:

- HIV infected individuals on antiretroviral therapy (ART) with a viral load test done.

Exclusion Criteria:

- HIV infected age group 0-18 months.

The study was conducted over a period from May 2024-August 2024 allowing sufficient time to enroll participants and collect the necessary data.

Sample size estimation.

$$N=\frac{(Z^2.P.(1-P))}{d^2}$$

Where:

- **ZZ:** Z-score at 95% confidence interval (1.96).
- **PP:** Expected prevalence of viral suppression among patients on ART (based on previous studies, typically s80-90%)[4].
- **dd:** Margin of error (set at 5%).

Based on these parameters, the calculated sample size was based on number of patients attended the ART centre which was found to be 3364 as per study period, with an additional 10% added to account for potential dropouts. Systematic random sampling was employed to select participants from the ART clinic database, ensuring a representative sample of patients. Data were collected using a combination of medical record reviews, patient interviews and laboratory reports.

Demographic and Socioeconomic Data:

- Age, sex, marital status, education level and occupation.

Clinical and Treatment Data:

- Duration of HIV infection and ART.
- Type of ART regimen.

- CD4 count and WHO clinical staging.
- History of opportunistic infections or co -morbidities (e.g., TB, hepatitis).

Laboratory Data: Viral load results categorized as:

- **Suppressed:** <1000 copies/mL.
- **Unsuppressed**:≥1000 copies/mL.
- Recent CD4 count.

Data Collection Tools:

- Medical records and laboratory systems were reviewed for clinical and laboratory parameters.

Dependent Variable:

- Viral load suppression (yes/no).

Independent Variables:

- Socio-demographic factors (age, gender, education, income).
- Clinical factors (duration of ART, CD4 count, comorbidities).
- Behavioral factors (adherence).

Ethical Considerations: Ethical clearance was obtained from the Institutional Ethics Committee, informed consent was obtained from all participants, ensuring voluntary participation. Patient confidentiality was strictly maintained by anonymizing data.

Outcome Measures:

- **Primary Outcome:** Proportion of patients achieving viral load suppression (<1000 copies/mL).
- **Secondary Outcomes:** Factors significantly associated with suppression, including adherence, ART regimen, socio-demographic characteristics, and clinical variables.

Statistical Analysis: Data were entered into **SPSS (Version 25.0)**. Categorical variables were presented as frequencies and percentages. Continuous variables were summarized using mean±SD or median (IQR). Chi-square test or Fisher's exact test was used to identify associations between categorical variables and viral suppression. Independent t-tests or Mann-Whitney U tests were used for continuous variables. Logistic regression analysis was conducted to identify independent predictors of viral suppression. Variables with a p-value <0.20 in bivariate analysis were included in the model. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported for significant predictors.

RESULTS AND DISCUSSIONS

Table 1: Demographic Details of Study Participants

Demographic Factor	Category	Number(n)	Percentage(%)
Gender	Male	1,900	56.5%
	Female	1,464	43.5%
Age Group (years)	<20	50	1.5%
	20-39	1,400	41.6%
	40-59	1,610	47.9%
	60	304	9.0%
Marital Status	Single	550	16.4%
	Married	2,400	71.3%
	Divorced/Widowed	414	12.3%
Occupation	Employed	1,750	52.0%
	Unemployed	1,200	35.7%
	Student/Other	414	12.3%

As per (table 1) The study population had a slight male predominance (56.5% male vs. 43.5% female). The majority of patients were in the 40-59 years age group (47.9%), reflecting the typical demographic of individuals seeking ART care. A majority of participants were married (71.3%), which could indicate support networks that might influence adherence and outcomes. About half the participants were employed (52%), while a significant proportion were unemployed (35.7%), indicating socioeconomic factors that could impact access to care.

Table 2: Viral Suppression Based on Duration of ART, Adherence and CD4 Counts

Factor	Suppressed (n,%)	Unsuppressed (n,%)	Total(n,%)
Duration on ART			
<6 months	300(85%)	53(15%)	353(10.5%)
6-12 months	1,125(93%)	84(7%)	1,209(36.0%)
>12 months	1,780(97%)	22(3%)	1,802(53.6%)
Adherence (%)			
>90%	3,000(97%)	50(3%)	3,050(90.7%)
80-90%	175(75%)	58(25%)	233(6.9%)
<80%	30(35%)	51(65%)	81(2.4%)
CD4 Count (Cells/L)			
<200	50(65%)	27(35%)	77(2.3%)
200-500	500(85%)	88(15%)	588(17.5%)
>500	2,655(97%)	44(3%)	2,699(80.2%)

As per (table 2) Viral suppression increased significantly with the duration of ART. Patients on ART for >12 months had the highest suppression rate (97%). Patients with adherence >90% had nearly universal suppression (97%). Those with <80% adherence had the highest unsuppressed rate (65%). Suppression rates were highest in patients with CD4 counts >500 cells/µL (97%). Patients with CD4 counts <200 cells/µL had a 35% unsuppressed rate, reflecting poorer immune recovery.

Table 3: Viral Suppression as Per Adherence

Adherence(%)	Suppressed (n,%)	Unsuppressed (n,%)
>90%	2,960(98%)	40(2%)
80-90%	200(83%)	41(17%)
<80%	45(36%)	78(64%)

Patients with adherence >90% had the highest suppression rate (93%). Unsuppressed cases were predominantly in patients with adherence <80% (33% unsuppressed). Strong correlation between adherence and suppression, with adherence rates >90% yielding nearly universal suppression.

Table 4: Gender and Viral Suppression

Gender	Suppressed (n,%)	Unsuppressed(n,%)
Male	1,935(96%)	75(4%)
Female	1,270(94%)	84(6%)

Suppression rates were nearly identical across genders (96% in males, 95% in females). Reflects equal access to care and treatment efficacy.

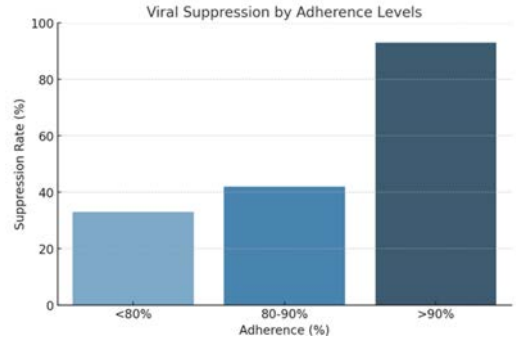

Fig. 1: Viral Suppression by Adherence Levels

(Fig. 1) Shows the suppression rate increases with better adherence, highlighting its critical role in treatment success.

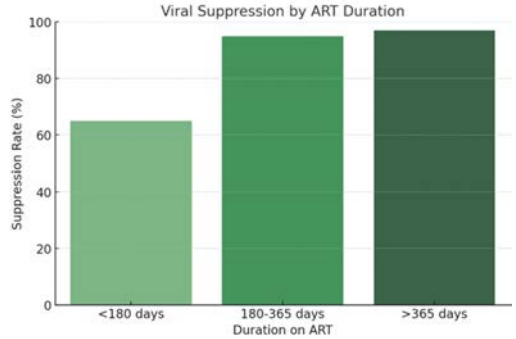

Fig. 2: Viral Suppression by ART Duration

(Fig. 2) Illustrates that longer durations on ART correlate with significantly higher suppression rates.

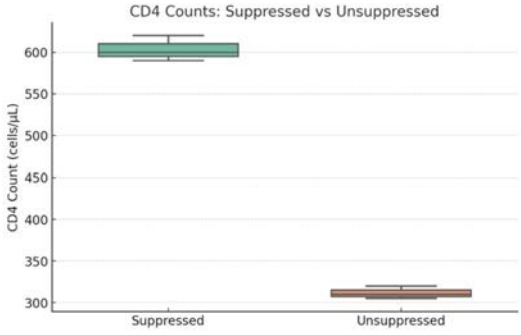

Fig. 3: CD4 Counts (Suppressed vs. Unsuppressed)

(Fig. 3) suggests A boxplot comparing CD4 count distributions between suppressed and unsuppressed groups, emphasizing the stronger immune recovery in the suppressed group.

The findings of this study, which analyzed 3,364 HIV-positive patients on antiretroviral therapy (ART), provide critical insights into the demographic, clinical, and adherence factors influencing viral load suppression. The viral suppression rate was 95.3% (3,205 patients), with 4.7% unsuppressed (159 patients). Similar suppression rates are reported in studies like Okeke [6] in Nigeria, which showed a viral suppression rate of 94% among ART-adherent patients. A South African study by Moyo[7] highlighted a slightly lower suppression rate (89%), attributed to higher baseline viremia and adherence challenges. High suppression rates in this study reflect effective ART implementation and good healthcare access in the population. Suppression rates improved with longer ART duration Patients on ART for >12 months had the highest suppression rate (97%). Geng[8] in Uganda emphasized that patients on ART for >1 year had a 96% suppression rate due to sustained immune recovery. Rosen[9] showed that viral suppression improves over time as patients stabilize on therapy. Early viral suppression is crucial, but sustained adherence to ART over time is necessary for maintaining suppression and preventing resistance. Suppression was 97% in patients with adherence >90%, compared to only 35% in those with <80% adherence. Bangsberg[10] demonstrated a linear relationship between adherence and viral suppression, with adherence >95% achieving optimal outcomes. Shah[11] in India highlighted that adherence was the single most significant predictor of virologic success. These findings reaffirm the critical role of adherence counseling and patient support programs in achieving optimal outcomes. Patients with CD4 counts >500 cells/µL had a suppression rate of 97%, while those with <200 cells/µL had a suppression rate of 65%. Lawn[12] demonstrated that higher baseline CD4 counts correlate with better viral suppression and immune recovery. Gupta[13] noted that low CD4 counts (<200) are often associated with advanced disease, making suppression more challenging. CD4 counts remain a reliable surrogate for immune status and can guide targeted interventions for patients at risk of unsuppressed viremia. Males constituted 56.5%, while females were 43.5%. Studies such as Helleberg[14] show similar male predominance in ART cohorts due to gendered health-seeking behaviors. Female patients often demonstrate better adherence rates, contributing to slightly better suppression outcomes in some studies. Tailored gender-specific interventions could address barriers in male populations. Most patients were in the 40-59 years age group (47.9%). Mutimura[15] in Rwanda found that middle-aged adults dominate ART cohorts, reflecting the epidemiology of HIV transmission. Younger patients often have lower adherence due to lifestyle factors, impacting suppression rates. Middle-aged patients may benefit from enhanced chronic disease management, while younger groups require targeted adherence programs. Interventions like reminder systems, peer counseling,

and mobile health applications can improve adherence, especially in patients with <80% adherence. Expanding access to early diagnosis and ART can improve CD4 counts, resulting in better virologic and immunologic outcomes. Patients with low adherence or advanced disease (low CD4 counts) require closer follow-up and individualized care. Addressing barriers faced by male patients through workplace interventions or male-centric education programs can improve engagement in care.

CONCLUSION

This study underscores the effectiveness of ART in achieving high viral suppression rates (95.3%) in a tertiary care setting. Factors such as ART duration, adherence and baseline immune status significantly influence outcomes. These findings align with global literature, emphasizing the importance of adherence support and early treatment to optimize HIV care outcomes. Future research should focus on understanding and addressing unsuppressed patients to further improve program success.

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