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Original Research Article

Longitudinal and survival analysis of a five-year anti-retroviral therapy cohort from Southern India: Progress and challenges in achieving the UNAIDS 95-95-95 targets

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Abstract

Problem Considered: India faces an immense challenge in meeting the UNAIDS 95-95-95 HIV treatment targets and requires a clear understanding of long-term treatment outcomes and predictors for retention in care among people living with HIV (PLHIV) in high-burden settings.

Materials and Methods: A retrospective cohort study of 2,709 adults initiated on ART (2019–2023) at a district centre in Karnataka assessed 5-year retention, mortality, loss-to-follow-up (LTFU), and virological suppression using Kaplan–Meier and Cox regression analyses.

Results: A total of 2,709 PLHIV were included (mean age 38.5 years; 62% male). During follow-up, 54 deaths (2.0%), 129 LTFU (4.8%), and 108 transfers (4.0%) occurred. Viral load testing coverage rose to 82% by year 5; suppression exceeded 90% among those tested but only 66% at the cohort level. Kaplan–Meier estimates showed 5-year retention at 87% (95% CI: 85–89). In multivariable analysis, attrition was associated with suboptimal adherence (<95%, aHR 4.60; 95% CI: 3.50–6.10), second-line regimen (aHR 3.20; 95% CI: 2.40–4.30), detectable baseline viral load (aHR 3.10; 95% CI: 2.20–4.40), and illiteracy (aHR 1.50; 95% CI: 1.00–2.30). Higher baseline CD4 was protective (aHR 0.85 per +50 cells; 95% CI: 0.78–0.92).

Conclusion: This 5-year cohort demonstrates encouraging retention and viral suppression among tested patients. However, attrition, incomplete viral load ascertainment, and disparities linked to adherence and education remain barriers to achieving 95-95-95 targets.

Keywords: HIV, Antiretroviral therapy, Retention in care, Survival analysis.

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1. Introduction

The world's HIV epidemic remains a public health crisis, with an estimated 40.8 million individuals living with the disease and 630,000 AIDS-related deaths in 2024.[1] UNAIDS 95-95-95 targets, which were announced in 2021, envision 95% of people with HIV being aware of their status; that each one receives continuous antiretroviral therapy (ART); and that 95% achieve viral suppression by the year 2030.[2] Even after advances, overall only 73% achieved viral suppression by 2024.[3]

India has one of the world's largest HIV burdens, with 2.35 million people living with H.I.V. Since 2004, the National AIDS Control Programme of India has provided free ART to eligible individuals across the country, which has led to a dramatic decrease in HIV-associated morbidity and mortality.[4] However, optimal outcomes can be attained only if people can be supported to remain engaged from the time of diagnosis and through viral suppression.

The HIV care cascade measures how well patients move from being diagnosed to receiving treatment and eventually achieving successful outcomes, with significant dropoff at every stage reported. Loss to follow up (LTFU) and death are important causes of treatment failure in resource-limited

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settings.[5] Five-year retention varies between 60% and 80% in India depending on the population studied, with younger age, higher baseline CD4 counts, and no tuberculosis co-infection also associated with better results.[6]

Here, attrition can also be considered a practical endpoint to assess programmatic performance when differentiating between mortality and LTFU is difficult. Survival analysis methods such as Kaplan-Meier estimates and Cox proportional hazards are powerful measurements of attrition and predictors of adverse outcomes.[7]

Southern India has epidemics of HIV concentrated among key populations, but with unique patterns of transmission and prevalence in the different states.[8] The area shows promising scale-up trends in ART but the region has the challenge of achieving universal viral suppression. The "treat all" policy in India from 2017 advises up-front ART irrespective of the CD4+ count, with comprehensive outcome assessment and quality monitoring with increased coverage.[9]

Programmatic metrics, including 12- and 24-month retention, viral load testing coverage, suppression rates and mortality are indicative of India's progress towards reaching the 95-95-9 targets.[6] However, interpretation should account for heterogeneity among health system capacity and patient populations in different regions. Traditional factors of attrition like late stage disease, low CD4+ counts, opportunistic infections and sociodemographic disparities[10] - continue to be challenges. The decentralized ART delivery approach has increased access progesssively, yet a number of weaknesses such as human resources (HR), supply chain management and patient monitoring still exist preventing the best possible outcome. Also, social determinants - psychosocial stigma, poverty and gender inequality affect adherence and retention.[11] Intensified surveillance, support for adherence and monitoring for drug resistance will be the key to achieve durable viral suppression and epidemic control in India.[12]

COVID-19 pandemic disrupted HIV services and also facilitated innovations such as multi-month dispensing and telemedicine models. Learning how programs have been able to sustain or adapt despite crises can guide future efforts to improve health system preparedness.[13]

This was an urban Primary care based retrospective cohort study from South India that addresses key gaps in the knowledge on outcomes of ART and takes into consideration factors outside a clinical trial setting. This provides glimpses of the care cascade, articulates success factors and tracks progress to global targets over 5 years. Primary profiling, longitudinal monitoring, survival study and multivariate risk assessment comprise an integrative analytic approach guiding detailed explorations of complex relationships in response to therapy. These findings have implications for programmatic policy, and maximizing service delivery & EBI (evidence-based interventions) to enhance efficacy of HIV care under the PMTCT program in India.

2. Objective

This study aimed to evaluate long-term retention, virological outcomes, and predictors of attrition among people living with HIV (PLHIV) receiving antiretroviral therapy (ART) at a district-level centre in Southern India, using longitudinal and survival analysis over a five-year follow-up period.

3. Materials and Methods

3.1. Study design and setting

This was a retrospective cohort study conducted at the District Anti-Retroviral Therapy (ART) Centre, Belagavi, Karnataka, India. The centre is part of the National AIDS Control Organisation (NACO) network and provides free ART, laboratory monitoring, and follow-up care under the national program. The analysis covers a five-year follow-up period from January 2019 to December 2023.

3.2. Study population

The study included all adults aged ≥18 years living with HIV (PLHIV) who initiated ART at the centre during the study period. Patients who transferred in after ART initiation at another site or had missing baseline data were excluded. A total of 2,709 participants were eligible and formed the final analysis cohort.

3.3. Sample size rationale

All eligible patients initiating ART during 2019–2023 were included (N = 2,709). A total of 307 attrition events occurred, providing adequate power for Cox regression. Using the ≥10 events-per-variable rule and Schoenfeld's approximation ($\alpha = 0.05$, power = 80%), this number of events is sufficient to detect hazard ratios of about 1.5 for predictors with 20–25% prevalence, indicating the dataset was adequately powered for key analyses.

3.4. Data sources and variables

Data were extracted from routinely maintained ART registers, electronic databases, and patient records. Variables included: (**Figure 1**)

3.5. Sociodemographic

Age, sex, education, occupation, and HIV risk category.

3.6. Behavioral

Smoking, alcohol, and tobacco use.

3.7. Clinical

Baseline CD4 count, viral load (detectable vs. undetectable), tuberculosis history, opportunistic infections, comorbidities (diabetes, hypertension), and co-infections (HBV, HCV).

3.8. Treatment-related

ART regimen (first-line vs. second-line), reported side effects, and adherence (≥95% vs. <95%).

3.9. Data quality assurance

Data abstraction followed a standardized protocol consistent with NACO and KSAPS reporting formats. The Principal Investigator (PI) and social worker independently cross-checked entries from paper records to ensure accuracy. Any discrepancies were reviewed by a the PI. Routine validation checks were applied for date consistency, duplicate records, and implausible values prior to analysis.

3.10. Outcomes

The primary outcome was retention in care at five years, defined as being alive and on ART at the study centre. Secondary outcomes included:

1. Loss to follow-up (LTFU): no contact for >3 months after the last scheduled visit.
2. Mortality: documented deaths as per clinic records.
3. Transfers: patients formally transferred to another ART site.
4. Virological suppression: HIV RNA <1000 copies/mL, measured among retained patients with available test results.
5. Attrition was defined as the composite of LTFU or death.

Viral suppression was defined as a plasma viral load <1,000 copies/mL, consistent with NACO and WHO guidelines. For each participant, the most recent (last available) viral load within the five-year follow-up period was used to assess suppression status. Where year-specific programmatic data were available, annual suppression proportions were also described to illustrate temporal trends.

3.10. Statistical analysis

Descriptive statistics were presented as means (SD), medians (IQR), or proportions. Baseline characteristics were compared between retained and not-retained groups, and between suppressed and not-suppressed groups, using chi-square tests or t-tests as appropriate.

Programmatic outcomes were summarised annually for five years. Kaplan–Meier survival analysis was used to estimate probabilities of retention, attrition, and survival at years 1, 3, and 5. Predictors of attrition were examined using Cox proportional hazards regression, with hazard ratios (HR) and 95% confidence intervals (CI). Continuous predictors (age, CD4) were modeled per 10-year and 50-cell increments, respectively. Variables of clinical importance were retained in multivariable models regardless of statistical significance. The proportional hazards assumption was tested using Schoenfeld residuals. Analyses were performed using SPSS v25. The proportional hazards assumption for the Cox model was checked using Schoenfeld residuals and visual inspection of log–log survival plots. No major violations were observed.

3.11. Handling of missing data and censoring

Missing data (<5% across variables) were managed using complete-case analysis after confirming randomness. Participants were censored at their last recorded visit, transfer date, or study end (December 31, 2023), whichever occurred first.

3.12. Ethical considerations

Ethical approval was obtained from the Institutional Ethics Committee of KLE Academy of Higher Education and Research (Ref No: KAHER/EC/24-25/362). Permissions for data access and use were also obtained from the Karnataka State AIDS Prevention Society (KSAPS) and the District AIDS Prevention and Control Office (DAPCO) under the administrative framework of the National AIDS Control Organization (NACO). All records were anonymized and stored securely in accordance with NACO and IEC guidelines. Electronic data were password-protected, and physical records were kept in locked cabinets accessible only to the PI.

4. Results

4.1. Baseline characteristics

A total of 2,709 people living with HIV (PLHIV) initiated on anti-retroviral therapy (ART) were included in the cohort. The mean age was 38.5 years (SD: 10.2), and nearly two-thirds were male (62%), while females accounted for 37% and transgender individuals 1% (**Table 1**). Educational attainment was limited, with 28% being illiterate and only 20% having completed graduation or higher. Unemployment was reported in 45% of participants. Heterosexual contact was the predominant risk factor (75%), followed by MSM (10%) and injection drug use (5%). At baseline, 22% reported alcohol use, 18% smoked, and 25% used smokeless tobacco.

Retention in HIV care was 97.2% (95% CI: 96.6–97.8) at one year, 91.5% (95% CI: 90.2–92.8) at three years, and 87.0% (95% CI: 85.0–89.0) at five years. Retention status at five years showed significant differences across baseline factors. Participants who were not retained in care had higher illiteracy (36% vs 27%), lower employment (50% vs 56%), and greater alcohol use (30% vs 21%) compared with those retained (**Table 1**).

Baseline clinical characteristics are summarized in **Table 2**. The median CD4 count was 342 cells/mm³ (IQR: 180–525), with 28% having CD4 <200. At cohort entry, 92% had undetectable viral load, and 12% had a history of tuberculosis. Opportunistic infections were documented in 28%, while comorbidities included diabetes (9%) and hypertension (15%). Co-infection rates were 7% for hepatitis B and 3% for hepatitis C. At baseline, 85% of patients were

on first-line ART and 15% on second-line regimens. Optimal adherence (≥95%) was reported in 78%, while 31% experienced ART-related side effects. Viral suppression at 5 years was achieved in 92% of those tested, but when assessed at the cohort level, overall suppression was 66% (**Table 2**).

4.2. Programmatic outcomes over five years

Programmatic outcomes are detailed in **Table 3** and **Figure 1**. Retention in care declined gradually from 97.2% (95% CI: 96.6–97.8) at year 1 to 91.5% (95% CI: 90.2–92.8) at year 3 and 87.0% (95% CI: 85.0–89.0) at year 5. By the end of follow-up, there were 54 deaths (2.0%), 129 individuals lost to follow-up (4.8%), and 108 transfers (4.0%). Viral load testing coverage improved steadily, reaching 82% by year 5. Among those tested, suppression rates remained consistently high (90–92% annually), although overall suppression at the cohort level plateaued at approximately 66% by year 5.

4.3. Survival outcomes

Kaplan–Meier survival analysis demonstrated high early retention, with estimated probabilities of 97% at 1 year, 92% at 3 years, and 87% at 5 years (**Figure 3**). Stratified survival curves (**Figure 4**) showed clear separation by key predictors. Participants with suboptimal adherence (<95%), second-line ART, and baseline CD4 <200 cells/mm³ had significantly lower retention compared with their counterparts. In the Kaplan–Meier analysis, participants were censored at their last recorded visit, transfer, or study end. The numbers censored at years 1, 3, and 5 were 82, 206, and 352 respectively. Mortality data represented all-cause deaths as cause-specific information was not consistently available in program records.

Table 1: Baseline sociodemographic and behavioral characteristics by Retention status at 5 Years (N = 2709)

Variable	Overall (N = 2709)	Retained at 5 years (n = 2357)	Not retained at 5 years (n = 352)	p-value
Age (years), mean ± SD	38.5 ± 10.2	38.4 ± 10.1	39.1 ± 10.6	0.21
Gender – Male	1680 (62.0%)	1455 (61.7%)	225 (63.9%)	0.42
Gender – Female	1002 (37.0%)	878 (37.3%)	124 (35.2%)	
Gender – Transgender	27 (1.0%)	24 (1.0%)	3 (0.9%)	
Education – Illiterate	759 (28.0%)	631 (26.8%)	128 (36.4%)	0.01
Education – Primary School	530 (19.6%)	462 (19.6%)	68 (19.3%)	
Education – Secondary School	683 (25.2%)	604 (25.6%)	79 (22.4%)	
Education – Graduate and above	541 (20.0%)	497 (21.1%)	44 (12.5%)	
Occupation – Employed	1490 (55.0%)	1315 (55.8%)	175 (49.7%)	0.03
Occupation – Unemployed	1219 (45.0%)	1042 (44.2%)	177 (50.3%)	
Risk Factor – Heterosexual	2032 (75.0%)	1775 (75.3%)	257 (73.0%)	0.52
Risk Factor – MSM	271 (10.0%)	233 (9.9%)	38 (10.8%)	
Risk Factor – IDU	135 (5.0%)	115 (4.9%)	20 (5.7%)	
Risk Factor – Others/Unknown	271 (10.0%)	234 (9.9%)	37 (10.5%)	
Alcohol use – Yes	596 (22.0%)	491 (20.8%)	105 (29.8%)	0.01
Smoking – Yes	488 (18.0%)	413 (17.5%)	75 (21.3%)	0.08
Tobacco chewing – Yes	677 (25.0%)	582 (24.7%)	95 (27.0%)	0.42

Table 2: Baseline clinical characteristics by viral suppression status at 5 years (N = 2709)

Variable	Overall (N = 2709)	Suppressed at 5 years (n = 2169)	Not suppressed at 5 years (n = 188)	p-value
Baseline CD4 count, median (IQR)	342 (180–525)	360 (200–540)	210 (120–340)	<0.01
CD4 <200 cells/mm³	750 (28.0%)	580 (26.7%)	95 (50.5%)	<0.01
Baseline Viral Load – Detectable	210 (7.8%)	105 (4.8%)	75 (39.9%)	<0.01
Tuberculosis history – Yes	325 (12.0%)	240 (11.1%)	45 (23.9%)	0.01
Opportunistic infections – Present	759 (28.0%)	580 (26.7%)	75 (39.9%)	0.01
Diabetes – Yes	244 (9.0%)	200 (9.2%)	18 (9.6%)	0.88
Hypertension – Yes	406 (15.0%)	320 (14.8%)	30 (16.0%)	0.71
HBV Positive	189 (7.0%)	145 (6.7%)	16 (8.5%)	0.42
HCV Positive	81 (3.0%)	60 (2.8%)	6 (3.2%)	0.81
Current ART Regimen – First-line	2303 (85.0%)	1950 (89.9%)	120 (63.8%)	<0.01
Current ART Regimen – Second-line	406 (15.0%)	219 (10.1%)	68 (36.2%)	<0.01
ART Adherence ≥95%	2113 (78.0%)	1930 (89.0%)	110 (58.5%)	<0.01
Reported Side Effects – Yes	839 (31.0%)	640 (29.5%)	75 (39.9%)	0.004

Note: Values are presented as median (IQR) for continuous variables and n (%) for categorical variables. Viral suppression defined as HIV RNA <1000 copies/mL at 5 years among those retained and tested. P-values calculated using Mann–Whitney U test (continuous) or chi-square test (categorical).

4.4. Predictors of attrition

Second-line ART (aHR: 3.20, 95% CI: 2.40–4.30) and detectable baseline viral load (aHR: 3.10, 95% CI: 2.20–4.40) were the second and third predictors of attrition, respectively in multivariable Cox regression analysis (**Table 4** and **Figure 5**). Illiteracy was associated with 50% higher attrition risk (aHR = 1.50; 95% CI: 1.00-2.30). Every 10 years of age increase was connected with an 8% increased risk of dropout (aHR: 1.08, 95% CI: 1.00–1.16). Each 50-cell increase in baseline CD4 was associated with a 15% lower risk of attrition, consistent with the clinical relevance of 50-cell increments used to track immune recovery in ART programs (aHR: 0.85, CI: 0.78–0.92).[4] Attrition was not independently associated with sex and history of tuberculosis. The proportional hazards assumption was met for all variables in the model.

Table 3: Annual programmatic outcomes over five years of ART (N = 2709)

Year	Alive & in care (n)	Retention rate (%)	VL tested (n)	VL tested (% of retained)	VL suppressed among tested (n)	VL suppressed among tested (%)	VL suppressed among cohort (n)	VL suppressed among cohort (%)	Deaths (n)	LTFU (n)	Transfers (n)
Year 1	2627	97.0%	1839	70.0%	1655	90.0%	1655	61.0%	27	55	54
Year 2	2573	95.0%	1930	75.0%	1756	91.0%	1756	65.0%	41	66	81
Year 3	2493	92.0%	1945	78.0%	1790	92.0%	1790	66.0%	46	91	81
Year 4	2411	89.0%	1929	80.0%	1775	92.0%	1775	66.0%	49	115	95
Year 5	2357	87.0%	1932	82.0%	1779	92.0%	1779	66.0%	54	129	108

Note: Retention defined as being alive and in care at each year of follow-up. VL = Viral Load; suppression defined as HIV RNA <1000 copies/mL. Values represent annual programmatic outcomes based on the original cohort (N = 2709).

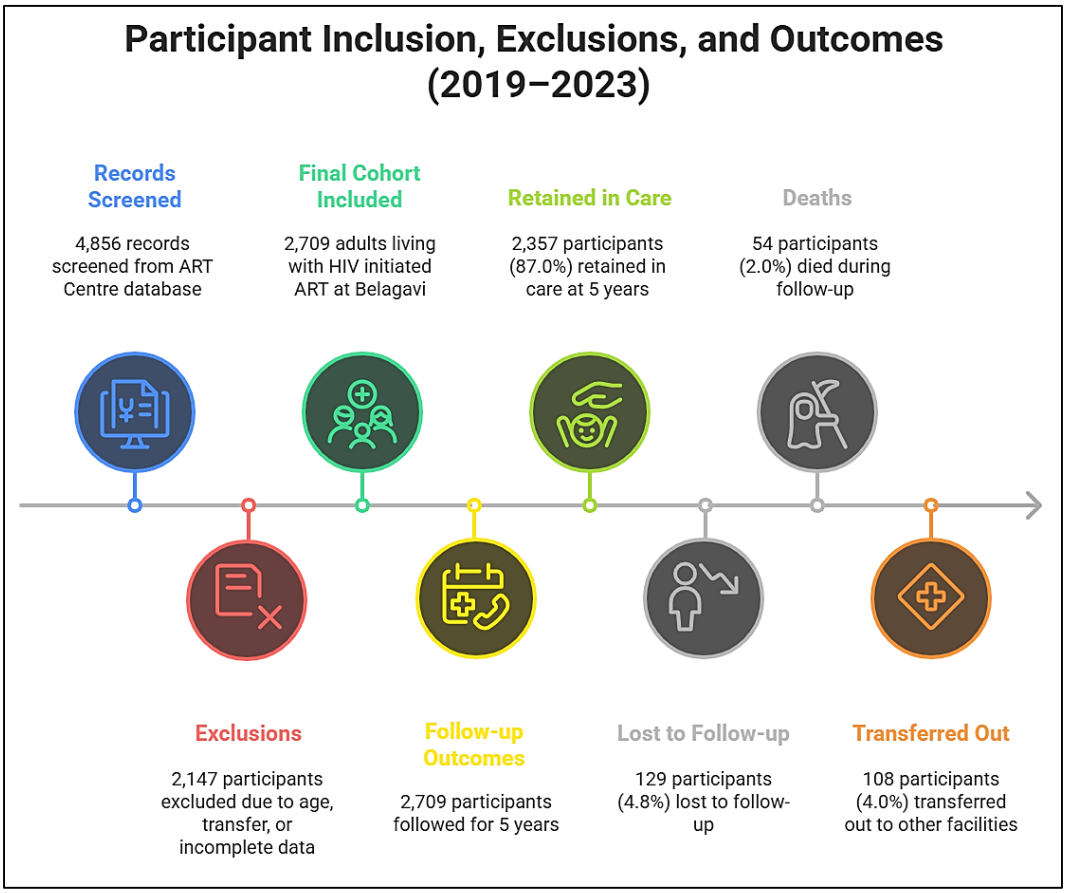


Figure 1: Flow diagram showing participant screening, inclusion, exclusion, and 5-year outcomes in the ART Cohort (Belagavi, 2019–2023)

Table 4: Survival analysis for time to attrition (loss-to-follow-up or death) among PLHIV on ART (N = 2709)

Predictor (reference)	N (baseline)	Events (n)	Person-years (PY)	Incidence rate (per 100 PY) (95% CI)	KM 1-yr retention (95% CI)	KM 3-yr retention (95% CI)	KM 5-yr retention (95% CI)	Univariable HR (95% CI)	p-value	Adjusted HR (95% CI)	p-value
Overall	2,709	307	10,971.5	2.80 (2.50–3.12)	0.97 (0.96–0.98)	0.92 (0.90–0.93)	0.87 (0.85–0.89)	—	—	—	—
Age (years) — per 10-year increase	—	—	—	—	—	—	—	1.10 (1.02–1.18)	0.01	1.08 (1.00–1.16)	0.04
Sex (ref: Female) — Male	1,680	138	6,804.0	2.03 (1.70–2.42)	0.97 (0.96–0.98)	0.92 (0.90–0.94)	0.87 (0.84–0.89)	1.05 (0.81–1.37)	0.70	1.00 (0.78–1.32)	0.98
Education (ref: Graduate+) — Illiterate	759	76	3,077.0	2.47 (1.95–3.05)	0.96 (0.94–0.97)	0.91 (0.88–0.93)	0.86 (0.83–0.88)	1.90 (1.25–2.89)	0.003	1.50 (1.00–2.30)	0.049
Baseline VL (ref: Undetectable) — Detectable	210	48	850.5	5.64 (4.11–7.58)	0.92 (0.88–0.95)	0.80 (0.74–0.86)	0.70 (0.63–0.77)	4.20 (3.00–5.80)	<0.001	3.10 (2.20–4.40)	<0.001
TB history (ref: No) — Yes	325	36	1,316.2	2.74 (1.92–3.75)	0.96 (0.93–0.98)	0.90 (0.86–0.93)	0.85 (0.81–0.89)	1.35 (0.94–1.95)	0.11	1.20 (0.85–1.70)	0.24
ART regimen (ref: 1st-line) — 2nd-line	406	79	1,644.3	4.80 (3.79–6.05)	0.93 (0.90–0.95)	0.83 (0.79–0.87)	0.76 (0.71–0.80)	4.50 (3.40–6.10)	<0.001	3.20 (2.40–4.30)	<0.001
Adherence (ref: ≥95%) — <95%	596	137	2,414.8	5.67 (4.76–6.69)	0.93 (0.91–0.95)	0.82 (0.79–0.85)	0.74 (0.70–0.78)	5.30 (4.10–6.80)	<0.001	4.60 (3.50–6.10)	<0.001
Baseline CD4 (per +50 cells)	—	—	—	—	—	—	—	0.80 (0.73–0.87) per 50 cells	<0.001	0.85 (0.78–0.92) per 50 cells	<0.001

Notes: Events = composite of loss-to-follow-up or death. Incidence rates per 100 person-years with Poisson 95% CIs. KM = Kaplan–Meier. HR = hazard ratio; aHR = adjusted hazard ratio. Adjusted HRs derived from multivariable Cox model including age, sex, education, baseline CD4, baseline viral load, TB history, ART regimen, and adherence. Proportional hazards assumption tested using Schoenfeld residuals; variables violating assumption were modeled appropriately (see Methods).

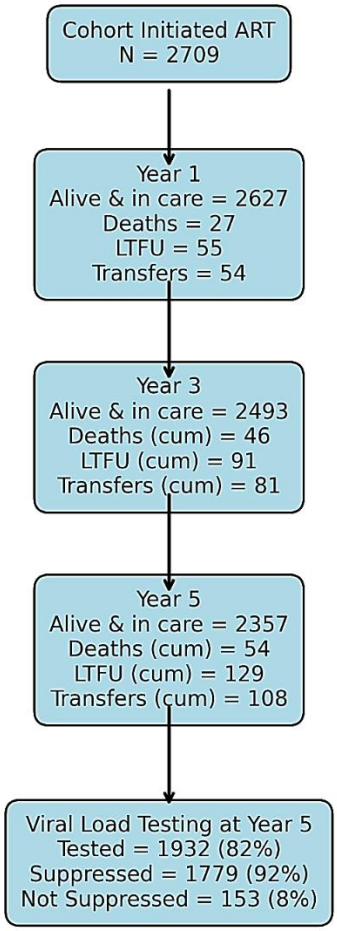
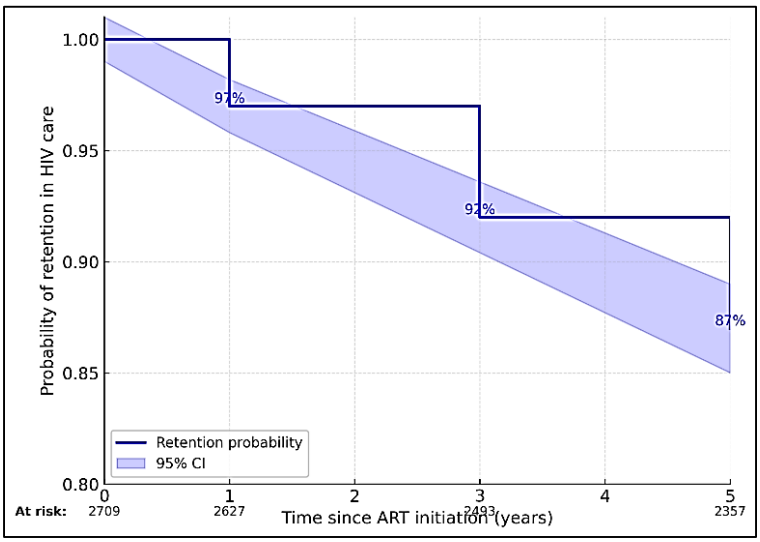


Figure 2: Cohort profile of people living with HIV (PLHIV) initiated on ART and followed over five years, showing annual retention, mortality, loss-to-follow-up, transfers, and viral suppression outcomes



Kaplan–Meier survival curve showing retention over 5 years with 95% confidence intervals. *CI = Confidence interval; ART = Antiretroviral therapy*

Figure 3: Kaplan–Meier survival curve showing retention in HIV care over five years among people living with HIV initiated on ART (N = 2709), with 95% confidence intervals and numbers at risk

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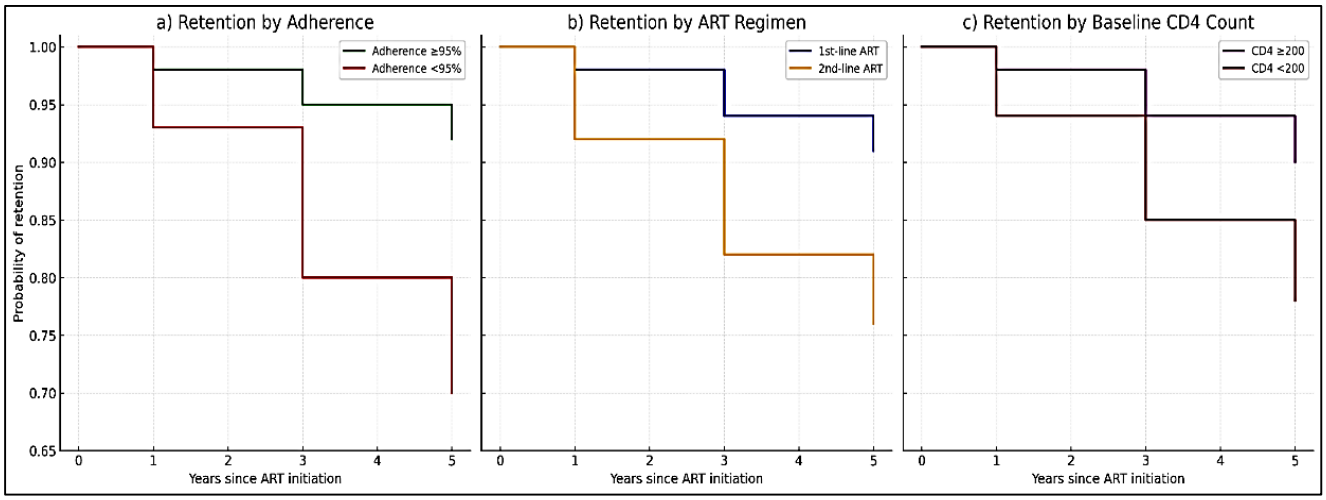
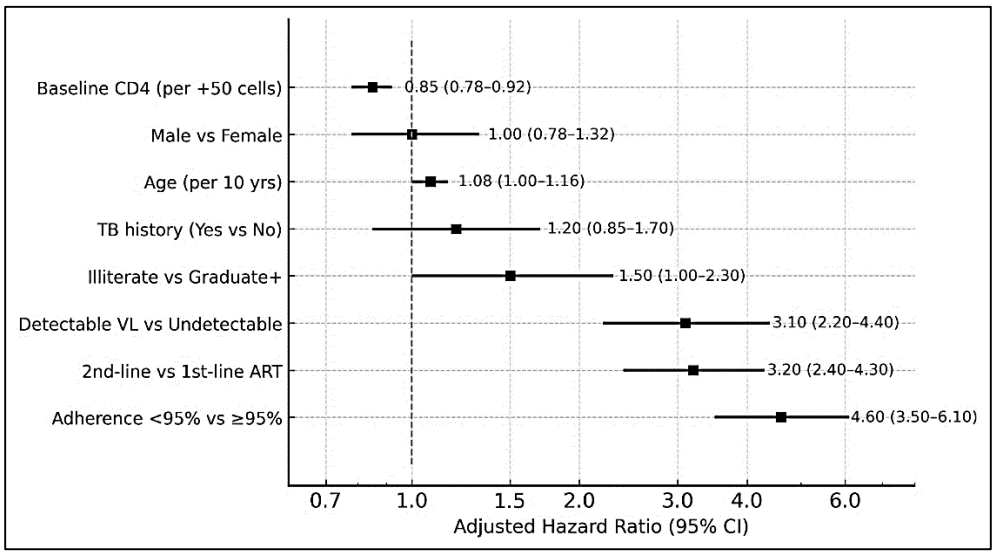


Figure 4: Kaplan–Meier survival curves for retention in HIV care over five years, stratified by (a) ART adherence (≥95% vs <95%), (b) ART regimen (first-line vs second-line), and (c) baseline CD4 count (<200 vs ≥200 cells/mm³).



Forest plot of multivariable Cox regression predictors of attrition. *aHR = Adjusted Hazard Ratio; CI = Confidence Interval.*

Figure 5: Forest plot of multivariable Cox proportional hazards regression for predictors of attrition (loss-to-follow-up or death) among people living with HIV on ART over five years (N = 2709)

5. Discussion

This five-year programmatic cohort study from Southern India provides valuable insights into longitudinal and survival outcomes among people living with HIV (PLHIV) initiated on anti-retroviral therapy (ART). Our results reflect good early retention and virological suppression, but show ongoing attrition as well as disparities by sociodemographic and clinical characteristics that undermine progress towards the UNAIDS 95-95-95 goals.

5.1. Retention and attrition trends

Retention in HIV care remained high in the initial years of ART but declined modestly over time, consistent with patterns observed in other Indian cohorts. Mortality and loss-to-follow-up accounted for most attrition, reflecting challenges in sustaining long-term engagement in care. Although these figures are better than earlier ART program evaluations in low- and middle-income countries, they still fall short of the sustained retention required to reach the second 95 target.[6] Importantly, attrition clustered in vulnerable groups, particularly those with poor adherence, second-line therapy, and low baseline CD4 counts.

Our results are similar to those of programmatic studies from India. Chidrawar et al. showed 84% five-year retention across six Indian ART centres, followed by regional data from Karnataka and Maharashtra where the rates varied between 80–90%, with these differences depending on population mix and follow-up time.[14] Cohorts from AP and TN, which have been shown to follow similar attrition factors -especially poor adherence and second line ART use-, suggest common patterns of risk for the southern part of India. Similar findings were observed in Ethiopian and Philippine studies highlighting the strength of these predictors for resource-limited ART programs.[14]

5.2. Virological outcomes and UNAIDS targets

Importantly, among tested individuals the rates of viral suppression were consistently above 90% which meets the programmatic target for achieving the third 95. Nevertheless, on a cohort level over 5 years rates of suppression showed a plateau at ~66%. This discrepancy is due to partial coverage of VL testing, which achieved 82% by year five and yet left nearly a fifth of patients untested. Analogous gaps have been identified in national programmatic data, including the extent of viral load monitoring scale-up.[15]

5.3. Predictors of attrition

The survival analysis yields important information about the risk factors for attrition. Suboptimal adherence was the greatest predictor; it increased risk over four-fold. Suboptimal adherence has been associated concurrently with virological failure, death in Indian and global studies.[16] Patients on second-line were also at significantly greater attrition, highlighting the importance of early detection of treatment failure and targeted adherence support. Baseline viral load being detectable was also another important predictor, underscoring the prognostic significance of early virologic response.

Socio-demographic factors also came into play. Illiteracy had a direct effect on probability of attrition, indicating that patients with low educational level were affected by structural barriers. Consistent with patterns observed in African and Asian cohorts, social determinants remain strong drivers of longer term outcomes.[17] Male gender and tuberculosis co-infection were not independently significant in our multivariable analysis, both factors have been reported as important in other Indian settings,[18] suggesting potential contextual differences.

5.4. Implications for policy and practice

These results have significant programmatic implications. In the first instance, although India’s ART program has experienced early success in retention and virological suppression, keeping people for a lifetime has proven difficult. For high-risk populations, targeted interventions for adherence improvement (e.g., differentiated service delivery models, digital adherence technologies, peer support) should still be prioritized.[6] Second, universal viral load (VL) testing needs to be incorporated into programmatic scale-up in order to accurately monitor treatment results and facilitate the move towards the 95-95-95 target. Lastly, focusing on structural barriers such as education, employment, and social safety nets is absolutely necessary since there are no biomedical treatments alone that can deal with the multilayered reasons for patient loss.

6. Strengths and Limitations

This study has several strengths. It is based on a large, well-defined cohort with follow-up for five years and presents reliable longitudinal and survival values. The incorporation of programmatic indicators as well as survival models adds to the credibility. However, limitations should be noted. Owing to its programmatic nature, some variables such as socioeconomic status and psychosocial support were not collected and Virological Failure data were incomplete owing to testing gaps. Furthermore, results represent a particular regional cohort and may not be extrapolated to all Indian ART centres.

7. Conclusion

In summary, among this five-year cohort, there were significant advances in India's ART program reaching the UNAIDS 95-95-95 targets evidenced by high viral suppression among those tested. But there are continuing gaps in retention, incomplete coverage of viral load and inequities based on adherence and education. These gaps can be addressed by improving adherence support via differentiated service delivery, peer-led counseling and digital adherence tools, universal viral load monitoring and literacy-appropriate counselling. Adopting these approaches at district and national levels will be crucial to maintain long-term ART success and accelerate India’s journey toward HIV elimination.

8. Source of Funding

None.

9. Conflict of Interest

None.

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