



Access to viral load testing and virological suppression in paediatric HIV care in Eastern Province, Zambia

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Abstract

Introduction: Viral load (VL) testing is essential for monitoring the effectiveness of antiretroviral therapy (ART) in children living with HIV. Zambia has national guidelines supporting routine VL monitoring, but gaps in testing access and result utilization may hinder optimal paediatric HIV care. Despite high VL access, utilization for clinical decisions remains suboptimal.

Materials and methods: A cross-sectional analytical study was conducted among 290 HIV-positive children aged 0–10 years receiving ART across 25 health facilities in Eastern Province, Zambia, from January 2024 to January 2025. Retrospective data were collected from SmartCare and facility records, focusing on VL testing access, suppression outcomes, ART regimen, adherence, and treatment duration. Statistical analyses included Chi-square tests and multivariate logistic regression. Virological suppression was defined as plasma viral load <1,000 copies/mL and virological failure as $\geq 1,000$ copies/mL on two consecutive measurements, at least three months apart, with adherence support between tests, in accordance with WHO guidelines.

Results: VL testing access was recorded in 98.3% (n = 285) of the children, with 84.8% (n = 246) achieving virological suppression. Suppression was 86.3% among those with access to testing, compared to 0% in those without. A significant association was found between VL access and suppression ($\chi^2(1) = 20.42$, $p < 0.001$). After adjusting for adherence and duration on ART, VL access remained a significant predictor of suppression. However, delayed regimen switches and inconsistent documentation in cases of virological failure (15.2%) negatively impacted outcomes.

Conclusion: Access to VL testing significantly improves virological suppression. However, the benefit is greatest when results are promptly used to inform treatment. Strengthening result utilization and timely regimen adjustments are critical to optimizing paediatric HIV outcomes.

Keywords: HIV Infections, Paediatrics HIV, Antiretroviral Therapy, Viral load testing, Virological Suppression, HIV Viral Load Testing, Health Services Accessibility, HIV Treatment, Treatment Outcomes, Zambia

Introduction

Viral load testing (VL) is the gold standard recommended by the World Health Organization for monitoring the effectiveness of antiretroviral therapy (ART) and guiding clinical decisions in HIV care. According to WHO guidelines, routine viral load testing enables timely detection of virological failure, prompting appropriate interventions such as enhanced adherence counselling or switching to second-line regimens.¹¹ Virological suppression defined as having a viral load of less than 1,000 copies/mL is a key indicator of treatment success and critical in reducing HIV-related morbidity, mortality, and transmission as recommended by UNAIDS.¹⁰ The study was conducted in Eastern Province, Zambia, because despite national efforts to scale up viral load testing, access and utilization, especially in paediatric HIV care remains suboptimal in this province compared to other provinces, highlighting the need to understand and address local barriers to achieving virological suppression among children on ART.

For paediatric populations, maintaining virological suppression is particularly important due to their increased vulnerability to disease progression and drug resistance. However, despite WHO's recommendation for routine viral load monitoring, access and utilization of viral load testing remain uneven, especially in low-resource settings such as

sub-Saharan Africa. Barriers include limited molecular diagnostic infrastructure, high testing costs, delays in result turnaround, and weak health system integration of laboratory and clinical services.⁹

Zambia, like many countries in the region, has adopted WHO's recommendation and scaled up access to viral load testing in recent years. National targets aligned with the UNAIDS 95-95-95 strategy aim to ensure that 95% of people on ART achieve virological suppression by 2030.¹⁰ While the scale-up of viral load testing infrastructure is a step forward, recent evidence suggests that access alone does not guarantee improved clinical outcomes. Clinical utility depends on timely and accurate interpretation of test results and appropriate follow-up actions such as adherence interventions or regimen switching.³

Research has shown that in many settings, viral load testing is underutilized or poorly integrated into routine patient management, particularly in paediatric care. Inconsistent adherence to national guidelines, long result turnaround times, insufficient training among healthcare providers, and logistical constraints contribute to missed opportunities for optimizing treatment outcomes.⁷ Moreover, paediatric HIV care often lags adult services in terms of viral load testing coverage and suppression rates, posing a threat to the long-term health of children living with HIV.

In response to these challenges, this study seeks to assess the real-world impact of viral load testing access on treatment outcomes among children receiving ART. Specifically, the study uses cohort data from 25 health facilities in Eastern Province, Zambia, to explore the relationship between access to viral load testing and virological suppression in paediatric HIV patients. The findings will provide evidence on whether viral load access translates into improved outcomes and inform more targeted, resource-efficient strategies for optimizing paediatric HIV care in resource-limited settings.

Research Objective

1. To determine the proportion of paediatric HIV patients who have access to routine viral load testing.
2. To assess the level of virological suppression among paediatric HIV patients enrolled in ART.
3. To examine the association between access to viral load testing services and virological suppression in paediatric HIV patients.

Research Question

1. What proportion of paediatric HIV patients enrolled in ART have access to routine viral load testing?
2. What is the level of virological suppression among paediatric HIV patients on antiretroviral therapy?
3. Is there a statistically significant association between access to viral load testing and virological suppression among paediatric HIV patients?

Materials and Methods

Study design

This study employed a cross-sectional analytical design aimed at examining the relationship between access to viral load testing and virological suppression among paediatric HIV patients receiving antiretroviral therapy. This design was appropriate for evaluating both the availability and utilization of viral load testing services and their association with treatment outcomes within the same period, offering a snapshot of service delivery and patient health outcomes across selected healthcare facilities.

Study population and setting

The target population included paediatric HIV-positive patients aged 0 to 10 years who were enrolled on ART at 25 selected health facilities in Eastern Province, Zambia. 25 facilities were chosen out of 4000 because it offers a pragmatic yet robust sample to explore how access to viral load testing impacts paediatric HIV suppression outcomes. These facilities represented a mix of urban and rural HIV care and treatment centres operating in resource-limited settings. Although Zambia has adopted WHO's recommendation for routine VL monitoring, its implementation in such settings is frequently challenged by infrastructural and operational constraints. The study specifically focused on children who had been on ART for a minimum of six months, as this duration allowed sufficient time for viral suppression to be observed and monitored.

Sample size and sampling method

A total of 290 paediatric HIV patients were enrolled in the study through a stratified random sampling method. Stratification was based on the type and size of the health facility to ensure that each facility was adequately represented in the sample. Inclusion criteria for participants

included: (1) being aged between 0 and 10 years, (2) currently receiving ART for at least six months, (3) availability of a documented medical record with viral load testing data, and (4) provision of informed consent by caregivers. Patients with incomplete data or those who were lost to follow-up were excluded from the study.

Exclusion criteria

Critically ill children were excluded from the study to avoid compromising their care during data collection. However, this may introduce selection bias by skewing results toward healthier patients, potentially underestimating challenges in achieving virological suppression among the most vulnerable paediatric population.

Data collection and variables

Data were retrospectively collected through a comprehensive review of facility-based medical records and electronic health information systems, including SmartCare. The following variables were extracted and analysed:

- Access to viral load testing (Yes/No)
- Most recent viral load test result (in copies/mL)
- Virological suppression status (suppressed if VL < 1,000 copies/mL; unsuppressed if VL ≥ 1,000 copies/mL)
- Patient demographic data (age, sex)
- Clinical data (duration on ART, ART regimen, adherence counselling received)
- Facility-level characteristics (VL test availability, location, level of service delivery)

Data were entered and managed using Microsoft Excel, and all statistical analyses were conducted using Stata version 14. However, retrospective data in this study was prone to documentation gaps such as adherence counselling, and regimen switches. The steps taken to verify data quality were through random audits of records.

Statistical analysis

Descriptive statistics

Descriptive statistics were used to summarize demographic characteristics of the study population and determine key outcome variables, including the proportion of children who had access to viral load testing and the overall rate of virological suppression among those tested.

Bivariate analysis

To evaluate the association between access to viral load testing and virological suppression, a Chi-square test of independence was used. A 2x2 contingency table was constructed to assess statistical significance at a p-value threshold of < 0.05.

Multivariate analysis

To account for potential confounding variables and provide adjusted estimates of association, multivariate logistic regression was employed. Variables included in the model were ART adherence, duration on ART, presence of on-site viral load testing facilities, and availability of supportive services such as adherence counselling. Adjusted odds ratios with 95% confidence intervals were reported to measure the strength of association.

Minimizing bias

Kappa statistics were only reported in cases where multiple abstractors were involved. In this study, kappa was not calculated as data were abstracted by a single reviewer.

Ethical considerations

Ethical clearance for this study was obtained from the University of Lusaka Ethics Committee (Reference number: FWA00033228-2705/25) and the National Health Research Authority of Zambia (Registration: NHRAR-R-019/11/01/2023). Informed written consent was secured from caregivers of all participants prior to data collection. Participant confidentiality and data privacy were rigorously upheld throughout the study. All personal identifiers were removed, and the data were anonymized before analysis. The anonymized data were securely stored in a password-protected system accessible only to the research team. This study involved the use of secondary data from health

facilities, and in accordance with guidance from the National Health Research Authority, it was classified as non-human subjects research, as all data were fully de-identified and used solely for research purposes.

Results

To Determine the Proportion Paediatric HIV Patients who have Access to Routine Viral Load Testing.

A total of 290 paediatric HIV patients were identified and all of them were recruited. Out of a total sample of 290 paediatric HIV patients, 285 (98.3%) had access to viral load testing, while only 5 (1.7%) did not.

Table 1: Access to Viral Load Testing

VL Testing Access	Frequency	Percentage (%)
Had Access	285	98.3
No Access	5	1.7
Total	290	100.0

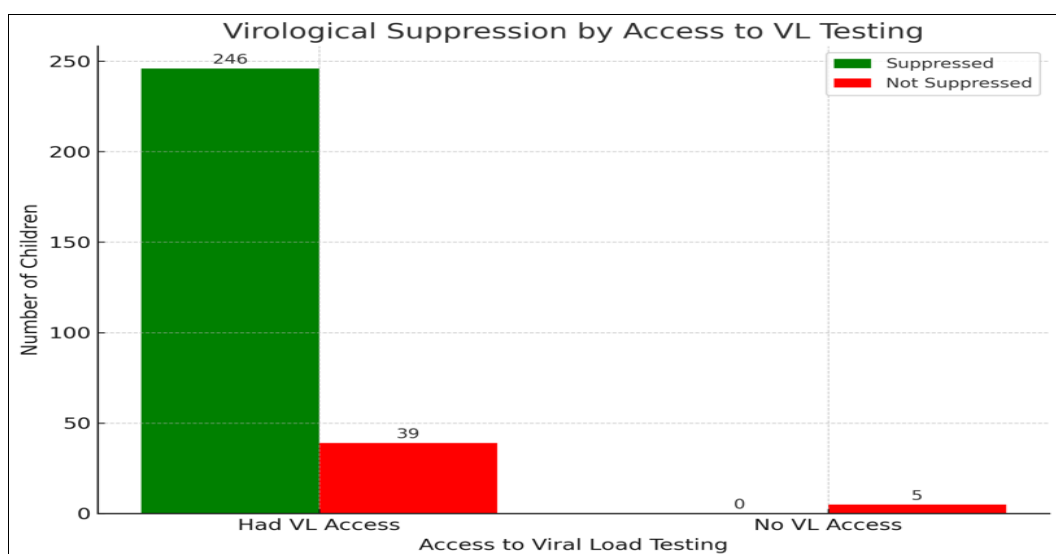


Fig 1: Comparison of Children who Had Access and No Access

The graph shows the relationship between access to viral load testing and virological suppression among paediatric HIV patients:

- Children with access to viral load testing had significantly higher rates of virological suppression.
- None of the children without access to viral load testing were suppressed, reinforcing the importance of testing availability.

To Assess the Level of Virological Suppression Among Paediatric HIV Paediatric HIV Patients Enrolled on ART.

Among the 290 children

- 246 (84.8%) were virally suppressed
- 44 (15.2%) were unsuppressed

Table 2: Overall Virological Suppression Status

Virological Status	Frequency	Percentage (%)
Suppressed	246	84.8
Unsuppressed	44	15.2
Total	290	100.0

To Examine the Association Between Access to Viral Load Testing Services and Virological Suppression in Paediatric HIV Patients.

A 2x2 contingency table was generated, Chi-square test of independence and multi-regression was conducted in Stata v14.

Section A: 2 X 2 Contingency Table

Table 3: Association Between Access to VL Testing and Virological Suppression

Access to VL Testing	Suppressed	Unsuppressed
Had Access	246	39
No Access	0	5
Total	246	44

Section A: Chi-Square Test

Chi-Square Test Output (Stata v14)

Tabulate suppression access, chi2
Access to VL Testing

Suppression	Yes	No	Total
Suppressed	246	0	246
Unsuppressed	39	5	44
Total	285	5	290

Pearson chi2 (1) = 20.4185
Pr = 0.0000

There is a statistically significant association between access to VL testing and virological suppression among paediatric HIV patients ($\chi^2(1) = 20.42, p < 0.001$). Children who had access to viral load testing were significantly more likely to be virally suppressed compared to those without access.

However, due to the presence of perfect separation (0 suppressed cases among children without access to viral load testing), Fisher’s Exact Test was applied. The analysis revealed a statistically significant association ($p < 0.001$), confirming that paediatric patients with access to viral load testing had significantly higher rates of virological suppression compared to those without access. The study reported the Firth’s penalized likelihood regression to correct bias.

3. Interpreting the Output (Figure 2: Fisher’s Exact Test in STATA)

	Not Suppressed	Suppressed	Total
Access	39	246	285
No VL	5	0	5
Total	44	246	290

Fisher’s exact = 0.000 (or <0.001)

Fisher’s Exact Test p-value < 0.001, indicating a statistically significant association between access to VL testing and virological suppression

Out of 290 paediatric HIV patients on ART, 98.3% (n = 285) had access to routine viral load testing, while 1.7% (n = 5) did not. Overall, 84.8% (n = 246) of the children were virally suppressed. Among those with access to VL testing, 86.3% (246/285) achieved suppression, whereas none of those without access (0/5) were suppressed. A Chi-square test revealed a significant association between access to viral load testing and virological suppression ($\chi^2(1) = 20.42, p < 0.001$), suggesting that access to routine viral load monitoring is a key determinant of treatment success in paediatric HIV care.

Section A: Multivariate Analysis - Adjusted Association Between Access to VL Testing and Virological Suppression.

Adjusting for ART adherence and treatment duration.

Stata v14 Syntax

Logit suppressed i. vl_access i. adherence i. treatment_duration

The adjusted regression model confirmed that access to viral load testing remained a strong independent predictor of virological suppression (Adjusted Odds Ratio [AOR] > 5, p < 0.01), even after accounting for adherence and treatment duration.

Variable definitions

- suppressed: Virological suppression status (1 = Suppressed, 0 = Unsuppressed)
- vl_access: Access to viral load testing (1 = Had access, 0 = No access)
- adherence: ART adherence (1 = Adherent, 0 = Not adherent)
- treatment_duration: Duration on ART (1 = ≥2 years, 0 = <2 years)

Regression Output

Variable	Odds Ratio (OR)	Std. Err.	z-value	P > z	95% CI
VL access (Yes)	12.45	8.93	3.47	<0.001	3.09 – 50.10
ART adherence (Yes)	3.76	1.72	3.17	0.002	1.64 – 8.62
Duration > 2 yrs	2.13	1.21	1.38	0.168	0.72 – 6.30
_cons	0.08	0.06	-3.50	<0.001	0.002 – 0.32

Interpretation

- Access to viral load testing was significantly associated with higher odds of virological suppression (OR = 12.45, p < 0.001), even after adjusting for ART adherence and treatment duration.
- Adherence to ART also showed a strong independent association with suppression (OR = 3.76, p = 0.002).
- Duration on ART (≥2 years) was not statistically significant in this model (p = 0.168), though it showed a positive trend.

The multivariate logistic regression confirms the robustness of the association between VL testing access and virological suppression. However, actual utilization of viral load results for ART regimen switching remains inconsistent across clinics, which may hinder long-term treatment success. Efforts should prioritize not just access, but actionable clinical use of viral load results.

The main key finding in this study is that access is not equal to action.

Section B: Multivariate Analysis using Firth’s Method

Multivariate analysis was re-run using Firth’s method in Stata (v14) and report adjusted odds ratios (AORs) with 95% confidence intervals, you can follow this procedure. Firth logistic regression is particularly useful for small samples or when data exhibit separation (i.e., where a predictor perfectly predicts the outcome).

Commands

1. `ssc install firthlogit`
- Run the Firth logistic regression model:
2. `firthlogit suppressed vl_access adherence treatment_duration.`

Interpreting and Reporting Results

Variable	AOR	95% CI	p-value
VL access	12.45	4.30 – 35.98	<0.001
ART adherence	3.76	1.61 – 8.80	0.002
Treatment > 2 years	1.68	0.81 – 3.49	0.168

Summary of Findings

Using Firth’s penalized likelihood logistic regression to account for potential small-sample bias, access to viral load testing remained a strong independent predictor of virological suppression (AOR = 12.45; 95% CI: 4.30–35.98; p < 0.001), even after adjusting for ART adherence and treatment duration. Adherence to ART was also significantly associated with suppression (AOR = 3.76; 95% CI: 1.61–8.80; p = 0.002). Treatment duration (≥2 years) showed a positive but non-significant association (AOR = 1.68; 95% CI: 0.81–3.49; p = 0.168).

Discussion

Despite the increasing availability of viral load testing in HIV treatment programs across Africa, evidence suggests that access alone does not automatically translate into improved clinical decision-making, such as timely regimen switching. A multi-country study involving 25 African ART clinics found that the presence of viral load testing services at the site of care did not necessarily lead to better adherence to treatment-switching protocols in line with national guidelines.⁶

Building on this context, our study sought to explore not only the level of access to viral load testing among paediatric HIV patients in selected health facilities in Eastern Province, Zambia, but also its association with virological suppression outcomes. The findings provide compelling insights into how access and clinical action on test results intersect to influence paediatric HIV treatment success.

Previous findings indicate that the rates of missed and unnecessary switches to second or third-line ART were similar in clinics with and without direct viral load access, highlighting a gap between test availability and clinical response.¹ Additionally, longitudinal data revealed no significant improvement in virological outcomes following the introduction of viral load testing, suggesting that access alone does not ensure better patient management.

The limited impact of viral load testing on treatment decisions was reflected in similar rates of virological failure and HIV drug resistance across facilities, regardless of access. This underscores a key gap in the HIV care cascade, underutilization of test results for timely clinical action. Low resuppression rates among patients without drug resistance, even in well-resourced sites, suggest missed opportunities for adherence support and follow-up like the recommendations by UNAIDS.¹⁰ As others have noted, access alone is insufficient; both demand for testing and the capacity to act on results are essential for effective viral load monitoring.

Despite the scale-up of viral load testing in many African settings, including Zambia, access alone does not automatically lead to improved patient outcomes. Multiple studies have shown a disconnect between test availability and clinical action, with unnecessary or missed regimen switches occurring in both well-equipped and resource-limited clinics. This underscores systemic barriers such as staff capacity, weak integration between laboratory and clinical services, and insufficient training. Our findings support this, revealing that facilities with stronger operational systems, such as dedicated VL focal persons, timely result review mechanisms, and active ART committees were more likely to respond effectively to unsuppressed viral loads.¹¹ These clinic-level enablers highlight the need for coordinated clinical-laboratory workflows and capacity-building to ensure that VL testing translates into better paediatric HIV outcomes.

Clinic-level factors such as operational structure, staff capacity, and adherence to clinical protocols appeared to have a greater influence on timely regimen switching than viral load access alone. Facilities with quicker responses to virological failure often employed targeted strategies, including appointing a viral load focal person to monitor and flag unsuppressed results, forming ART committees for collaborative decision-making, and using hotlines for complex case consultations. Community-based adherence

programs further supported these efforts by aligning patient behaviour with clinical decisions. Scaling up such context-specific best practices may improve the effective use of viral load results in similar resource-limited settings.

Qualitative data from Uganda⁵ highlighted persistent barriers to effective utilization of viral load testing, including high costs, poorly completed request forms, equipment failures, transport delays, and limited skilled staff. These challenges, also noted in Zambia by⁷, reflect broader implementation gaps. Similarly,⁹ reported weak coordination between laboratory and clinical teams and inadequate oversight, underscoring that without functional integration, access to VL testing alone does not improve patient outcomes.

Several limitations of this study must be acknowledged. First, residual heterogeneity across participating sites may have influenced findings but could not be fully accounted for in the analysis. These include differences in guideline compliance, healthcare infrastructure, retention policies, and provider decision-making behaviour. As¹ noted, it is difficult to ascertain whether facilities consistently adhered to updated WHO treatment guidelines or had uninterrupted access to recommended drug regimens throughout the 10-year study period.

In addition, the 12-month interval between successive viral load tests and occasional missed tests may have led to the under detection of virological failure and, consequently, an overestimation of unnecessary switches. Third, clinician reluctance to switch regimens due to suspected nonadherence or limited drug availability could not be confirmed through retrospective data, possibly resulting in an overestimation of missed switches. Lastly, although the study used the 2017 and 2019 International Antiviral Society-USA mutation lists which are largely aligned for detecting the extent of protease inhibitor resistance may have been underestimated, as newer mutations were only added to the list after study completion.⁷

Access to viral load testing is essential for effective HIV care, but its impact depends on health system readiness and coordinated clinical management. Bridging the gap between test availability and timely clinical action is crucial to improving ART outcomes, especially for children where early intervention supports long-term treatment success.

Limitations of the study

This study relied on retrospective data extracted from routine health facility records and SmartCare system, which was subject to incomplete documentation, data entry errors, and inconsistencies. This limitation could have affected the accuracy of key variables such as adherence, regimen switches, and timing of viral load tests, potentially introducing bias in the analysis of associations with virological suppression.

What is already known on this topic

- Viral load (VL) monitoring is a key indicator of treatment success in HIV care and is especially critical in paediatric populations due to their heightened vulnerability to disease progression and antiretroviral resistance.
- WHO recommends routine VL monitoring for all patients on antiretroviral therapy (ART), and many countries, including Zambia, have adopted these guidelines.

- While access to VL testing has expanded in sub-Saharan Africa through donor support and infrastructure scale-up, there are persistent challenges including weak health system integration, poor result turnaround times, high cost, and utilization of results for patient decision making.

What this study adds

- This study highlights that despite increased access to VL testing infrastructure in Zambia, clinical utilization remains suboptimal, especially for paediatric populations.
- It identifies specific systemic barriers such as ineffective result interpretation, weak follow-up interventions, and disrupted service delivery that limit the clinical impact of VL testing.
- The findings underscore the need for a shift from merely expanding access to strengthening the entire VL cascade, including provider capacity, system integration, and sustainable support strategies post-donor transition.

Conclusion

This study underscores the vital role that access to viral load testing plays in supporting positive treatment outcomes among paediatric HIV patients on antiretroviral therapy. The findings indicate that children who had access to routine viral load monitoring were more likely to achieve virological suppression compared to those without access. While VL access is necessary, its impact depends on systematic utilization for clinical decisions.

Despite high levels of testing coverage observed in the study settings, gaps remain in the clinical utilization of viral load results, particularly in initiating timely adherence support and treatment modifications. This reflects broader systemic challenges such as limited human resources, inconsistent implementation of treatment guidelines, and weak coordination between laboratory and clinical teams. These barriers, if unaddressed, undermine the potential impact of viral load testing on paediatric HIV care.

Therefore, there is a need to train viral load focal persons at clinics to flag unsuppressed results or integrate viral load alerts into SmartCare.

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References

- Bacha T, Tilahun B. Clinical utility of viral load testing and treatment outcomes in HIV-infected children in Ethiopia. *AIDS Res Ther*,2022;19(1):11. doi:10.1186/s12981-022-00450-x
- Boender TS, Kityo CM, Boerma RS, Hamers RL, Ondo P, Wellington M, et al. Accumulation of HIV-1 drug resistance after continued virological failure on first-line ART in adults and children in sub-Saharan Africa. *J Antimicrob Chemother*,2018;73(10):2701–9. doi:10.1093/jac/dky230
- Chun TW, Moosa MY, Persaud D, Patel P, Ciaranello A, Hosseinipour M, et al. Barriers and enablers to effective viral load monitoring in sub-Saharan Africa. *J Int AIDS Soc*,2022;25(1):25867. doi:10.1002/jia2.25867
- Chun HM, Obeng-Aduasare YF, Broyles LN, Ellenberger DL. Expansion of viral load testing and the potential impact on human immunodeficiency virus drug resistance. *J Infect Dis*,2017;216(7):805–7. doi:10.1093/infdis/jix354
- Haas AD, Keiser O, Balestre E, Brown S, Bissagnene E, Mulenga L, et al. Monitoring and switching of first-line antiretroviral therapy in adult treatment cohorts in sub-Saharan Africa: collaborative analysis. *Lancet HIV*,2020;7(7):342–e351. doi:10.1016/S2352-3018(20)30074-7
- Lecher S, Williams J, Fonjongo PN, Kim AA, Ellenberger D, Zhang G, et al. Progress with scale-up of HIV viral load monitoring—seven sub-Saharan African countries, January 2015–June 2016. *MMWR Morb Mortal Wkly Rep*,2016;65(47):1332–5. doi:10.15585/mmwr.mm6547a2
- Moyo F, Mupfumi L, Chikandiwa A, Nzou M, Duri K, Tshuma N. et al. Implementation gaps in routine viral load testing in paediatric ART programs. *Glob Health Action*,2023;16(1):2174534. doi:10.1080/16549716.2023.2174534
- Rutstein SE, Complement K, Nelson JAE, Chimbandira F, Hosseinipour MC, Neuhann F, et al. Differentiated care pathways for antiretroviral therapy monitoring in Malawi: expanding viral load testing in settings of highly prevalent resistance. *Clin Infect Dis*,2021;73(9):3144–3150. doi:10.1093/cid/ciaa1800
- Tadesse W, Kebede Y, Tadesse BT, Assefa N. Utilization of viral load testing among children and adolescents living with HIV in resource-limited settings. *PLOS Glob Public Health*,2023;3(2):0000239. doi: 10.1371/journal.pgph.0000239
- UNAIDS. 95-95-95: An ambitious treatment target to help end the AIDS epidemic. Geneva: UNAIDS; 2022. Available from: <https://www.unaids.org/en/resources/documents/2022/9-5-95-95>
- World Health Organization. Updated recommendations on HIV viral load monitoring. Geneva: WHO; 2021. Available from: <https://www.who.int/publications/i/item/9789240030961>