Factors Associated With An Interruption in Treatment of People Living With HIV in USAID-Supported States in Nigeria: A Retrospective Study From 2000–2020

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Abstract

Background: Patient interruption of antiretroviral therapy (ART) continues to limit HIV programs’ progress toward epidemic control. Multiple factors have been associated with program interruptions in treatment (IIT)—also referred to by the World Health Organization as loss to follow-up (LTFU)—including age, gender, CD4 count, and education level. Program implementers can prevent future IIT by understanding which clients are more likely to interrupt treatment. In this paper, we explore the factors associated with treatment interruptions in people living with HIV (PLHIV) in United States Agency for International Development (USAID)-supported facilities under the U.S. President’s Emergency Plan for AIDS Relief (PEPFAR) program in Nigeria.

Methods: A retrospective secondary cross-sectional analysis on data obtained from Nigeria's National Data Repository (NDR), representing a summarized record of 573,630 ART clients that received care at 484 PEPFAR/USAID-supported facilities in 16 states from 2000–2020 were used in this analysis. Interruption in treatment was recorded as no clinical contact for 28 days after the last scheduled appointment or expected clinical contact. Both univariate and multivariate logistic regression models were computed to explore the factors associated with IIT. The variables included in the analysis were sex, age group, zone, facility type, regimen line, multi-month dispensing (MMD), and viral load category.

Results: Of the 573,630 clients analysed in this study, 32% in the cohort have been recorded as having interrupted treatment. Of the clients investigated, 66% were female (32% had interruption in treatment), 39% were aged 25–34 at their last ART pick-up date (with 32% of them interrupted treatment), 62% received care at a hospital (38% interrupted treatment) and 38% were last receiving between three- to five-month MMD (with 10% of these interrupted treatments). Those less likely to interrupt ART were males (aOR = 0.93), clients on six-month MMD (aOR = 0.04), adults on 2nd line regimen (aOR = 0.14), and paediatrics on 1st line regimen (aOR = 0.09). Clients most likely to interrupt ART were located in the South West Zone (aOR = 1.91), received treatment at a hospital (aOR = 3.39) or medical center (aOR = 5.15), and had no viral load (VL) on record (aOR = 8.92). Age group was not significantly associated with IIT.

Conclusions: Sex, zone, facility type, regimen line, MMD, and VL were significantly associated with IIT. MMD of three months and longer (especially six months) had better retention on ART than those on shorter MMD. Not having a VL on record was associated with a considerable risk of IIT.

Background

Globally there are an estimated 38 million PLHIV in 2019, with 2.9 million of those in the Western and Central African region [1]. The prevalence of HIV/AIDS in Nigeria is estimated at 1.4 % of the population, with 1.8 million people living with HIV (PLHIV). The incidence rate decreased from 0.74 to 0.52 per 1 000 population from 2010 to 2019, ending with 100 000 new infections [2]. The UNAIDS 90-90-90 strategy aimed to have 90% of PLHIV know their status, and 90% of those to be retained on antiretroviral therapy (ART) (90% coverage) such that 90% of those are virally suppressed by 2020 [3]. More ambitious targets have also been set for 2030 to reach PEPFAR’s 95-95-95 goals for the care and treatment cascade [4].
Significant efforts have been deployed worldwide to make ART widely accessible to PLHIV following the “treat all” policy recommended by the World Health Organization (WHO) in 2016 [5]. In 2016, Nigeria started rolling out the “test and treat” policy [6]. The most recent estimate of ART coverage in Nigeria was 65% in 2019 [2], which is significantly below the coverage proportions targeted by UNAIDS and PEPFAR. There are currently an estimated 754,566 PLHIV in the 16 states supported by USAID under the PEPFAR program in Nigeria, with an estimated 467,567 PLHIV (62%) receiving ART [7]. Continuation of treatment is important because clients must achieve a suppressed viral load (VL), better client health outcomes, and epidemic control [8].

Clients are considered to have interrupted treatment when they are no longer receiving ART and have had no recorded clinical contact for 28 days after the last scheduled appointment [13] or expected clinical contact. There are several factors associated with clients interrupting treatment, such as their age, gender, CD4 count, and geographical location [9, 10]. Potential risk factors identified in various studies include clients’ educational level, the lack of a telephone, and risky sexual behaviour [8, 11, 12]. Understanding the profile of clients at risk of IIT—referred to by the World Health Organization as loss to follow-up (LTFU)—is invaluable in directing attention to them and minimizing this risk.

In this study, we explored the factors associated with treatment interruption by analyzing de-identified data of more than 500,000 clients enrolled in ART programs in 16 USAID-supported sites in Nigeria between 2000 and 2020. The results of this two-decade large-cohort study can help ART program implementers understand the factors associated with IIT and plan for their mitigation to achieve better client retention. Similar studies have been carried out at different times in different areas of Nigeria. Our study contributes to the understanding of IIT in Nigeria [9, 13].

**Methods**

**Study setting, design, and population**

We conducted a retrospective cross-sectional analysis of routinely collected data from clients that received ART in 16 of Nigeria’s 36 states and the Federal Capital Territory (FCT) in Nigeria, based on a record review of client line-lists in electronic medical records (EMR) databases integrated into the National Data Repository (NDR) in Nigeria. The data comprised clients from 468 USAID-supported facilities across the 16 states that are currently supported by USAID. Data from clients enrolled in care from January 1, 2000, to December 8, 2020, were included in the study.

The 16 states in the study cohort were grouped into five different zones within Nigeria: North Central, North East, North West, South, and South West (see Table 1).
Table 1
Grouping of the 16 states into zones and the number of HIV clients per state

| Zone         | State                                      |
|--------------|--------------------------------------------|
| North Central | Kwara (9 110), Niger (31 817)              |
| North East   | Adamawa (49 084), Bauchi (29 670), Borno (21 989), Yobe (8 239) |
| North West   | Jigawa (12 190), Kano (52 205), Kebbi (8 318), Sokoto (6 624) |
| South        | Akwa Ibom (223 922), Bayelsa (13 971), Cross River (79 436), Edo (33 250) |
| South West   | Lagos (73 495)                             |

Data Source and Management

The data were obtained from EMR databases integrated within the NDR. Data were collected using standardized national HIV data collection tools which record information on clients' demographic, clinical, and treatment information at each encounter. The client information is stored both in paper-based and EMR systems. Client information is uploaded to the NDR through Extensible Markup Language (XML) files extract from the EMR.

The original cohort data contained 671 133 records of clients. A unique identifier was created for each client using the date of birth, sex, unique ID, and patient hospital number because the provided unique IDs and patient hospital numbers were missing for 218,656 records and could not be used. A completeness check was done for each variable and any misspelled outcomes were changed to reflect true values. Cleaning the dataset involved removal of duplicated unique identifiers, entries with a missing multi-month dispensing (MMD) value, and records that did not follow a logical chronological sequence—e.g., with ART start data occurring before the date of birth or occurring before the outcome date. Cases where the recorded date of birth was before 1940, the ART start date was before 1980, or the last ART pickup date was after 2020 were excluded (Fig. 1).

We removed 519 duplicate entries from the cohort data set, as well as three entries with a missing MMD value and 11, 03 records that did not follow a logical chronological sequence—with the date of birth occurring before the ART start date, and/or occurring before the outcome date. An additional 896 records were excluded in cases when the date of birth occurred before 1940, the ART start date was before 1980, or when the last ART pickup date was after 2020 (see Fig. 1). From the 658 609 retained complete client records, 30 683 (5%) were recorded as dead; 11 890 (2%) were recorded as having stopped ART, and 42 406 (6%) were recorded as transferred out. Those records were removed before logistic regression analysis.

The outcome date for treatment interruption was calculated as the last pick-up date plus the number of days of ART dispensed plus 28 days, in line with the WHO guidelines [14]. For the analysis, clients with the recorded outcome as active, active-restart, and active-transfer-in were treated as active. By contrast, clients recorded as dead, stopped, or transferred out were excluded from the analysis; some cases were excluded if there was insufficient information to categorize the outcome of those clients as either active or interrupting.
treatment (Fig. 1). This was done to ensure that comparisons of IIT risks were made to currently active clients.

**Computed variables explored as predictors of IIT**

The “facility type” variable was created by searching key terms in the name of the facility provided and counting the number of matches. The 484 facilities were grouped by type, with the following number of clients per type: Clinic (11,926), health centre (91,348), hospital (410,199), medical centre (26,394), and one-stop shop (OSS) (40,546). If they did not match any of these groups, they were categorized as “other” (78,199). In Nigeria, clinics and health centers are similar and provide basic healthcare services; they are most commonly found in rural areas. Medical centers provide a higher level of care than clinics and health centres. Hospitals provide the highest level of healthcare services in the country. The OSS is a safe location where key populations (KPs) receive HIV treatment support. The current ART regimen line described the regimen line which the client was on at their last recorded visit. The VL variable was broken into three levels: “suppressed” – clients whose last VL on record was below 1,000 copies per millilitre (c/ml); “unsuppressed” – clients whose last VL on record was at least 1,000 (c/ml); and “not recorded” – clients who did not have a VL reading on record [6].

**Statistical Analysis**

The association of each variable with treatment interruption was tested using Pearson's chi-squared test. Both crude and adjusted logistic regression models were computed to explore associations with IIT. Backward elimination was used to determine the best set of variables to include using the Akaike information criterion (AIC) statistic to evaluate model performance. All regressions were computed using two models. The first model was a crude, univariate logistic regression and reported the unadjusted odds ratio (OR); the second model adjusted for all covariates and the adjusted odds ratio (aOR) was reported. Variables included in the analysis were sex, age group, zone, facility type, regimen line, MMD, and VL category. Statistical significance was defined using a two-tailed p-value < 0.000001. Multicollinearity tests were done using the variance inflation factor test. All data were analysed using the software R for Statistical Computing v4.0.2 [15].

**Results**

**Cohort characteristics**

Of the 573,630 clients included in our analysis, 183,046 (32%) since 2000 were classified as having interrupted treatment; the rest were considered active. Two-thirds of the clients initiated into ART were females and approximately one-third of males and females had interrupted treatment since the study period began. The largest age groups at ART start were 25- to 34 and 35- to 44-year-olds, accounting for 39% and 25% of the cohort, respectively. The largest age groups on ART at the client outcome date were still 25- to 34 and 35- to 44-year-olds; however, the proportion of the groups had shifted to 32% and 30%, respectively. Overall, we observed a proportional shift from younger age groups (below age 25) at ART start to more mature age groups at outcome date (Table 2). The South Zone of Nigeria which contains Akwa Ibom, the
state with the highest HIV prevalence in the country, had the largest representation within the cohort in the study, accounting for 53% of the clients initiated into ART, followed distantly by the North East, which contributed 16% of the cohort. The South West zone of Nigeria had the highest proportion of clients interrupting treatment (49%). Hospitals and health centers accounted for 62% and 14% of the clients registered to facilities, respectively. Likewise, those same facility types accounted for the highest number of clients interrupting treatment, with 38% and 16% of the clients enrolled in those facilities respectively (see Table 2).
Table 2
Patient characteristics stratified by treatment interruption

| Factors                  | Treatment interruptions |       |       |       | p-value  |
|--------------------------|-------------------------|-------|-------|-------|----------|
|                          | No (%)                  | Yes (%) | Total (%) |       |          |
| Sex                      |                         |        |        |       |          |
| Female                   | 258 926 (68)            | 119 540 (32) | 378 466 (66) | < 0.000001 |
| Male                     | 131 658 (67)            | 63 506 (33) | 195 164 (34) |          |
| Age group at ART start   |                         |        |        |       |          |
| 0–14                     | 18 059 (64)             | 10 126 (36) | 28 185 (5) | < 0.000001 |
| 15–24                    | 66 479 (65)             | 35 543 (35) | 102 022 (18) |          |
| 25–34                    | 152 473 (68)            | 71 631 (32) | 224 104 (39) |          |
| 35–44                    | 100 090 (70)            | 42 068 (30) | 142 158 (25) |          |
| 45–59                    | 48 021 (70)             | 20 715 (30) | 68 736 (12) |          |
| 60+                      | 5 462 (65)              | 2 963 (35) | 8 425 (1) |          |
| Age group                |                         |        |        |       |          |
| 0–14                     | 13 900 (60)             | 9 080 (40) | 22 980 (4) | < 0.000001 |
| 15–24                    | 38 231 (60)             | 25 956 (40) | 64 187 (11) |          |
| 25–34                    | 120 558 (65)            | 65 931 (35) | 186 489 (33) |          |
| 35–44                    | 123 625 (71)            | 49 653 (29) | 173 278 (30) |          |
| 45–59                    | 79 890 (74)             | 27 592 (26) | 107 482 (19) |          |
| 60+                      | 14 380 (75)             | 4 834 (25) | 19 214 (3) |          |
| Zone                     |                         |        |        |       |          |
| South                    | 217 601 (71)            | 87 480 (29) | 305 081 (53) | < 0.000001 |
| North Central            | 32 701 (86)             | 5 211 (14) | 37 912 (7) |          |
| North East               | 58 339 (64)             | 33 131 (36) | 91 470 (16) |          |
| North West               | 49 162 (65)             | 26 342 (35) | 75 504 (13) |          |
| South West               | 32 781 (51)             | 30 882 (49) | 63 663 (11) |          |
| Facility type            |                         |        |        |       |          |
| Clinic                   | 8 240 (80)              | 2 003 (20) | 10 243 (2) | < 0.000001 |
| Health Centre            | 66 806 (84)             | 12 587 (16) | 79 393 (14) |          |
| Factors                | Treatment interruptions |   |   |   |
|------------------------|-------------------------|---|---|---|
|                        | No (%)                  | Yes (%) | Total (%) | p-value |
| Hospital               | 217 374 (62)            | 135 496 (38) | 352 870 (62) |          |
| Medical Centre         | 12 516 (57)             | 9 337 (43)     | 21 853 (4)   |          |
| One-Stop Shop          | 38 383 (98)             | 883 (2)       | 39 266 (7)   |          |
| Other                  | 47 265 (68)             | 22 740 (32)   | 70 005 (12)  |          |
| Regimen line           |                         |             |             |          |
| Adult 1st Line         | 369 290 (68)            | 173 205 (32) | 542 495 (95) | < 0.00001 |
| Adult 2nd Line         | 9 770 (75)              | 3 198 (25)    | 12 968 (2)   |          |
| Adult 3rd Line         | 11 (100)                | 0 (0)         | 11 (0)       |          |
| Peds 1st Line          | 10 985 (63)             | 6 512 (37)    | 17 497 (3)   |          |
| Peds 2nd Line          | 509 (80)                | 128 (20)      | 637 (0)      |          |
| Salvage                | 19 (86)                 | 3 (14)        | 22 (0)       |          |
| MMD                    |                         |             |             | < 0.00001 |
| 1                      | 11 842 (12)             | 90 756 (88)   | 102 598 (18) |          |
| 2                      | 15 395 (18)             | 68 913 (82)   | 84 308 (15)  |          |
| 3–5                    | 199 678 (90)            | 21 098 (10)   | 220 776 (38) |          |
| 6                      | 163 669 (99)            | 2 279 (1)     | 165 948 (29) |          |
| VL                     |                         |             |             | < 0.00001 |
| 0 – Suppressed         | 272 968 (94)            | 18 237 (6)    | 291 205 (51) |          |
| Not recorded           | 90 281 (37)             | 156 449 (63)  | 246 730 (43) |          |
| Unsuppressed           | 27 335 (77)             | 8 360 (23)    | 35 695 (6)   |          |

The most common ART regimen line was the adult first-line regimen, having been prescribed to 95% of the cohort at their last visit date; 32% of these clients had interrupted treatment. Only 2% of clients were transitioned to second-line treatment, and 25% of these interrupted treatments.

Multi-month dispensing of three- to five-month and six-month ART regimens were the most common options, having been issued to 38% and 29% of clients respectively, at their last visit date. Most clients were issued one-month and two-month ART regimens; 90,756 (88%) and 68,913 (82%), respectively, had interrupted treatment; together accounting for 87% of all the clients interrupting treatment (50% and 37%, respectively). More than half of the cohort in the study, 291,205 (51%) had a suppressed VL, and only 6% of those had interrupted ART; 35,695 (6%) of clients in the cohort were recorded to have an unsuppressed VL.
and 23% of those interrupted ART. The remaining 246,730 (43%) of clients did not have a recorded VL; 63% of those had interrupted treatment.

**Factors associated with treatment interruption**

All variables in the univariate and multivariate logistic regression analysis were significant (p < 0.000001) (Table 3). Results from the multivariate analysis showed that male clients were 7% (95% CI 0.91–0.95, p < 0.000001) less likely to interrupt treatment; the adjusted ORs for all age groups were not statistically different from each other, indicating the age has little effect on treatment interruption. The North East (aOR = 1.49, 95% CI 1.45–1.54, p < 0.000001) and South West zones (aOR = 1.91, 95% CI 1.85–1.98, p < 0.000001) were associated with higher odds of treatment interruption, whereas the North Central zone had the lowest odds (aOR = 0.48, 95% CI 0.45–0.5, p < 0.000001) compared to the South zone. Clients receiving treatment at hospitals and medical centres accounted for 66% of the study population and both were associated with clients more likely to interrupt treatment compared to clients receiving treatment at clinics, adjusted ORs of 5.15 (95% CI 4.67–5.67, p < 0.000001) and 3.39 (95% CI 3.12–3.69, p < 0.000001) respectively. Clients that were switched to second-line regimens (aOR = 0.14, 95% CI 0.13–0.14, p < 0.000001) had lower adjusted odds of interrupting ART when compared with their counterparts on first-line regimens. Clients on MMD had the largest impact on treatment interruptions of all variables analyzed, with clients on six-month MMD 99 % (aOR = 0.01, 95% CI 0-0.01, p < 0.000001) less likely to interrupt treatment than those on one-month prescriptions. Clients that had no VL on record were 8.9 times (95% CI 8.7–9.15, p < 0.000001) more likely to interrupt ART compared to clients with suppressed VL. Backward and forward elimination of factors for the multivariate logistic regression model identified that the age group had the least improvement contribution to the model, reducing the Akaike Information Criterion (AIC) from 251 092.9 to 251 075.5, however, because this a principal demographic indicator and the model was not worsened, the age group variable was retained.
### Table 3
Factors associated with treatment interruption

| Factors                  | Univariate |          | Multivariate |          |
|--------------------------|------------|----------|--------------|----------|
|                          | OR [95% CI]| p (< 0.000001) | OR [95% CI]| p (< 0.000001) |
| Sex                      |            |          |              |          |
| Female                   | 1 [ref]    | 0        | 1 [ref]      | 0        |
| Male                     | 1.04 [1.03–1.06] | < 0.000001 | 0.93 [0.91–0.95] | < 0.000001 |
| Age group                |            |          |              |          |
| 0–14                     | 1 [ref]    | < 0.000001 | 1 [ref]      | 0        |
| 15–24                    | 1.04 [1.01–1.07] | 0.014073 | 0.91 [0.82–1.01] | 0.064017 |
| 25–34                    | 0.84 [0.81–0.86] | < 0.000001 | 1 [0.91–1.11] | 0.966892 |
| 35–44                    | 0.61 [0.6–0.63] | < 0.000001 | 0.99 [0.89–1.09] | 0.775042 |
| 45–59                    | 0.53 [0.51–0.54] | < 0.000001 | 0.97 [0.88–1.01] | 0.579241 |
| 60+                      | 0.51 [0.49–0.54] | < 0.000001 | 1.12 [1–1.25] | 0.058843 |
| Zone                     |            |          |              |          |
| South                    | 1 [ref]    | 0        | 1 [ref]      | 0        |
| North Central            | 0.4 [0.38–0.41] | < 0.000001 | 0.48 [0.45–0.5] | < 0.000001 |
| North East               | 1.41 [1.39–1.43] | < 0.000001 | 1.49 [1.45–1.54] | < 0.000001 |
| North West               | 1.33 [1.31–1.36] | < 0.000001 | 0.89 [0.86–0.92] | < 0.000001 |
| South West               | 2.34 [2.3–2.38] | < 0.000001 | 1.91 [1.85–1.98] | 0        |
| Facility type            |            |          |              |          |
| Clinic                   | 1 [ref]    | 0        | 1 [ref]      | 0        |
| Health Centre            | 0.78 [0.74–0.82] | < 0.000001 | 0.82 [0.75–0.9] | < 0.000001 |
| Hospital                 | 2.56 [2.44–2.69] | < 0.000001 | 3.39 [3.12–3.69] | < 0.000001 |
| Medical Centre           | 3.07 [2.9–3.24] | < 0.000001 | 5.15 [4.67–5.67] | < 0.000001 |
| OSS                      | 0.09 [0.09–0.1] | < 0.000001 | 0.17 [0.16–0.2] | < 0.000001 |
| Other                    | 1.98 [1.88–2.08] | < 0.000001 | 1.35 [1.24–1.48] | < 0.000001 |
| Regimen line             |            |          |              |          |
| Adult first line         | 1 [ref]    | 0        | 1 [ref]      | 0        |
| Adult.2nd.Line           | 0.7 [0.67–0.73] | < 0.000001 | 0.14 [0.13–0.14] | 0        |
| Factors          | Univariate                          | Multivariate                        |
|-----------------|-------------------------------------|-------------------------------------|
|                 | OR [95% CI]                         | p (< 0.000001)                      | OR [95% CI]                         | p (< 0.000001) |
| Adult.3rd.Line  | 0 [0–5.91e + 14]                    | 0.686815                            | 0 [0–1.58e + 21]                    | 0.728008       |
| Peds.1st.Line   | 1.26 [1.23–1.3]                     | < 0.000001                          | 0.28 [0.25–0.32]                    | < 0.000001     |
| Peds.2nd.Line   | 0.54 [0.44–0.65]                    | < 0.000001                          | 0.09 [0.07–0.12]                    | < 0.000001     |
| Salvage         | 0.34 [0.1–1.14]                     | 0.079702                            | 0.03 [0.01–0.13]                    | < 0.000001     |
| MMD             |                                     |                                     |                                     |                |
| 1               | 1 [ref]                             | 0                                   | 1 [ref]                             | 0              |
| 2               | 0.7 [0.67–0.73]                     | < 0.000001                          | 0.78 [0.76–0.81]                    | < 0.000001     |
| 3–5             | 0.1 [0.09–0.1]                      | < 0.000001                          | 0.02 [0.02–0.02]                    | < 0.000001     |
| 6               | 0.04 [0.03–0.04]                    | < 0.000001                          | 0.01 [0–0.01]                       | < 0.000001     |
| VL              |                                     |                                     |                                     |                |
| Suppressed      | 1 [ref]                             | 0                                   | 1 [ref]                             | 0              |
| Not recorded    | 7.1 [6.89–7.32]                     | < 0.000001                          | 8.92 [8.7–9.15]                     | < 0.000001     |
| Unsuppressed    | 1.99 [1.9–2.09]                     | < 0.000001                          | 2.2 [2.11–2.29]                     | < 0.000001     |

**Discussion**

In this study, we investigated risk factors that were associated with treatment interruptions in a large cohort of clients receiving ART in Nigeria. Our results show that MMD of more than three months was highly associated with reduced treatment interruption, while six months of MMD had the best retention. These results are similar to findings in Malawi and Zambia where six-month regimens of MMD were ideal for retention and shorter MMD were less protective [16]. Other studies have also found that one- and two-month ART regimens have greater odds of treatment interruption. More specifically, 49.4% and 26.7% of interruption in treatment associated with one- and two-month ART regimen, respectively, compared with our study which has 78% of interruption in treatment associated with a two-month ART regimen [17, 18]. Findings from a similar study indicated 49% of clients on one-month regimens had interrupted treatment [9], while that proportion was 50% in this cohort. The higher proportion of ART interruptions associated with shorter dispensing durations can be explained by the requirement for frequent visits for the client that was associated with a higher rate of ART interruption [19].

Virally suppressed clients were shown to have a lower risk of ART interruptions compared to clients with an unsuppressed VL, while clients with no VL record had the highest risk. The higher level of interruption is logically associated with virally unsuppressed clients, likely due to poor adherence. Also, the high treatment interruption levels associated with clients without a recorded VL may be indicative of the poor quality of
clinical care, which was associated with ART interruption [19]. Increasing the frequency of VL testing and making it accessible to more clients could encourage client involvement in ART programs.

Further, receiving treatment at a medical center or hospital increased the likelihood of treatment interruption compared to other facility types. A potential reason could be the higher client volumes at these sites and possibly busier, metropolitan schedules. Nevertheless, with higher client turnout in an urban settlement, chances are that there is increased workload for health workers and this may result in a shorter duration of consultations and poor quality of service. Similarly, clients at facilities in the North East and South West states were associated with higher rates of IIT. Potential reasons for these high rates are that the North East zone of Nigeria has been experiencing security and other challenges which make travel and attending a clinic more difficult, whereas the South West zone contains Lagos, a major urban state with general proximity and better access to healthcare facilities [20, 21]. Age and sex were shown to not have a considerable association with treatment interruption when compared and adjusted for the other variables in our study, results similar to those found in other studies which did not find a stronger association of older age with IIT [22]. Other studies which did associate an elder age group with IIT explained the occurrence as a possible reflection of inaccurate classification of IIT after the clients' death [9]. Earlier studies have shown a higher likelihood for males to interrupt treatment and recommended male-targeted interventions [9, 13]; this may have resulted in improved odds for males to adhere to treatment.

The 32% treatment interruption proportion is similar to the 33% client interruption rate in Nigeria following a cohort from 2004–2017 [9]. The proportion of treatment interruption may vary between studies depending on the level at which the study is carried out. Studies at the facility level in Nigeria identified that 56% of clients interrupted ART at the Lagos University Teaching Hospital [23], while an earlier study carried out on randomly sampled data (2004–2012) from 35 sites in Nigeria identified 75% of clients interrupting treatment [24]. Transferring to another program may be one of the principal reasons for failure to return to the same clinic [25]. For that reason, studies focused above the facility level may be better at identifying interruptions by accounting for transfers between programs.

Our study was based on a large cohort of over half a million clients receiving ART over 20 years; this suggests that the sample size is robust and is representative of the whole country. A key limitation of our study, however, is the availability of client information only at their last visit date. We do not know when a client transitioned from one-month dispensing to MMD and cannot compare rates of ART interruption longitudinally. A further limitation is that the six-month MMD program has been in place only since late 2019, that period may not be long enough to adequately monitor the effects of this switch on treatment interruption.

For further analyses, we suggest comparing treatment interruption rates longitudinally to account for changes in MMD, regimen lines, and the regimen itself. Allowing more time for the six-month MMD program to be evaluated would lead to more conclusive results on whether this has led to a reduction in treatment interruption in Nigeria.

Conclusions
Sex, zone, facility type, regimen line, MMD, and VL were significantly associated with IIIT. Multi-month dispensing of three months and longer (especially six months) was associated with better treatment continuity than those on shorter courses of MMD. Not having a VL on record was associated with a considerable risk of IIIT.

**Declarations**

**Ethical approval and consent to participate**

Ethical approvals for this study were obtained in Nigeria and the United States. Informed consent was waived from all subjects or, if subjects are under 18, from a parent and/or legal guardian by the expedited institutional review board (IRB) approvals granted by both the National Health Research Ethics Committee of Nigeria (NHREC), reference number NHREC/01/01/2007, and the HML IRB in the United States, reference number 772EQH20. Data were anonymised and handled confidentially during all phases of the research. All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were granted approval by the institutional review board (IRB) of the National Health Research Ethics Committee of Nigeria (NHREC), reference number NHREC/01/01/2007, and the HML IRB in the United States, reference number 772EQH20.

**Consent for publication**

NA.

**Availability of data and materials**

The datasets generated and/or analysed during the current study are not publicly available due the data being representative of a cohort of ART clients in Nigeria who's personal records are protected by relevant national data protection regulations, but are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare no competing interests.

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Authors Contributions

S.T, T.C, J.A, and C.W.K completed the data analysis and initial drafts. P.P, C.C, F.A, D.S.D, E.O, and M.R completed the study design and final drafts. All the remaining authors contributed to the data collection and data analysis and made critical inputs into the revision and finalization of the manuscript. All authors read and approved the final manuscript.

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**Figures**

**Figure 1**

The data cleaning process, data excluded, and cohort subset analyzed