BMC Infectious Diseases

RESEARCH

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Effect of facility- versus community-based HIV testing services on the diagnosis of advanced HIV disease in Uganda: a quasi-experimental study

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Abstract

Background Advanced HIV disease (AHD) at first diagnosis remains a significant barrier to HIV epidemic control. We evaluated whether health facility-based or community-based HIV testing services (HTS) better impact the yield of AHD at diagnosis among newly diagnosed people with HIV (PWH) in rural eastern Uganda.

Methods We designed a quasi-experimental study and applied instrumental variable analysis, a causal inference methodology, to compare the effect of facility-based HTS versus community-based HTS on the yield of AHD at diagnosis among newly diagnosed PWH. The exposure was HTS comparing community-based versus facility-based, and the outcome was AHD at diagnosis, defined as CD4 < 200 cells/μL or WHO clinical stage 3 or 4 disease at baseline. The instrumental variable was the HTS access radius that reflects the HTS geographical coverage for each health facility. The instrumental variable ensured the categorization of health facilities as offering HTS within a 5 km radius only or both within and beyond 5 km. The relevance of the instrumental variable was assessed using the F-statistic and independence from measured covariates. We used a two-stage residual inclusion approach to estimate the effect of HTS on AHD at diagnosis. Causal effect was reported as an odds ratio (OR) and 95% confidence interval (CI).

Results Of 1,233 participants included in the analysis, AHD prevalence was 1.9% (24/1,233). The instrumental variable was strongly correlated with HTS (First-stage F-statistic = 28.05, $p < 0.0001$) and uncorrelated with AHD and all measured covariates. Facility-based HTS has no significant effect on AHD at diagnosis compared to community-based HTS (OR 1.20, 95% CI 0.49–2.90).

Conclusions Persons with AHD at diagnosis are a minority. Facility- and community-based HTS do not differ in identifying AHD among newly diagnosed PWH, but moderate effects cannot be excluded. These findings support efforts to implement both strategies for HIV testing to reach and test persons with advanced HIV.

Keywords Advanced HIV disease, HIV testing service, Instrumental variable analysis, Late HIV diagnosis, Uganda

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Background

Diagnosis of human immunodeficiency virus (HIV) in the early stages of infection is necessary for early initiation of antiretroviral therapy (ART), reducing HIV-related morbidity and mortality [1, 2], and preventing further transmission. However, certain people with HIV (PWH) who present late for HIV testing are often found to have advanced HIV disease (AHD) at diagnosis—they present with a CD4 count < 200 cells/μL or WHO clinical stage 3 or 4 disease [3]. AHD is associated with a high risk of morbidity, hospitalization, and mortality [4, 5].

Sub-Saharan Africa has a high HIV and AHD burden. Of 40.8 million PWH by the end of 2024 [6], 26.3 million (64.4%) of them were in sub-Saharan Africa [7]. Additionally, the region has an estimated 1.8 million PWH with AHD based on the analysis of 13 Population-based HIV Impact Assessment household survey data conducted between 2016 and 2021 [8]. However, the magnitude of AHD varies between and within countries despite efforts to scale up HIV testing and linkage to care. A study in Tanzania reported that 62.2% of PWH presented with AHD at diagnosis, with a mortality rate of 16 per 100 person-years and a loss to follow-up rate of 34 per 100 person-years [9]. In Uganda, approximately 30% of PWH present with CD4 cell counts below 200 cells/μL, and 15% have counts below 100 cells/μL at diagnosis [10], indicating a substantial burden of AHD. Health facility–based studies have estimated AHD prevalence at 21% in western Uganda [11] and 35% in central Uganda [12]. Early HIV testing could improve the identification of people with AHD.

Community-based HTS (CB-HTS) and health facility-based HTS (FB-HTS) are two strategies that have been widely applied to identify PWH. The community-based approach, which includes outreach and home-based testing among others, has proven successful in increasing HIV testing uptake, reaching underserved populations, and promoting early HIV diagnosis [13, 14]. The health facility-based approach involves routine testing, diagnostic testing, index client testing, and testing through drop-in centers (service delivery points targeting subpopulations such as key populations, priority populations, and vulnerable populations without access to health FB-HTS). Although they are individually effective, it remains unclear which of the two HIV testing services is more likely to result in the identification of PWH with AHD at diagnosis.

Therefore, we applied instrumental variable analysis, a causal inference methodology, to compare FB-HTS versus CB-HTS on the yield of AHD at diagnosis among newly diagnosed PWH. Our findings will provide evidence to inform the design and targeting of HTS aimed at increasing the detection of persons with AHD.

Methods

Study design

We applied a quasi-experimental methodology to retrospective medical record data. The HTS was not randomly assigned but program-driven, and therefore, to establish cause-and-effect, we used instrumental variable analysis, a causal inference approach. The method controls for both measured and unmeasured confounders by using an external factor (instrumental variable) that is correlated with an exposure (relevance criterion) but does not affect the outcome directly except through its effect on the exposure (exclusion criterion) and is not correlated with factors that affect the outcome (exogeneity criterion) [15, 16]. This makes instrumental variable analysis a powerful statistical approach for estimating causal effects when randomized trials are impractical or infeasible. Figure 1 shows the instrumental variable analysis graphic illustration. Examples of commonly used and recommended instrumental variables in public health and clinical care evaluations include geographic location, distance, calendar time, genetic variation, and patient preferences [17–21]. We adhered to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement in reporting this quasi-experimental study [22].

Data source and ethical approval

We used routinely collected HIV program data from 23 accredited ART sites located in 14 districts across rural eastern Uganda. The estimated adult population in this region is 1,163,459 people from the 2025 demographic data, and the HIV prevalence is about 4.2% based on the 2022 national HIV serosurvey. The health facilities here provide HIV testing to identify recent HIV infection among newly diagnosed PWH. The sites represent diverse socioecological contexts, including pastoralist, fishing, and high-mobility communities. HIV testing is provided through either facility-based or community-based approaches by trained healthcare providers at each HTS/ART-accredited health facility. Both approaches follow the same national HTS guidelines to ensure standardized care.

The choice of which approach to use is at the discretion of individuals seeking HIV testing, although CB-HTS largely targets those who live far from health facilities. Individuals who test positive for HIV through CB-HTS are linked to a health facility for chronic HIV care in accordance with national HIV treatment guidelines. Between March and April 2025, we retrieved data from the electronic medical records system for the period May 2020 to July 2023 and cross-verified with HTS registers to ensure accuracy. We cross-checked the data for duplicates by performing a record-level comparison of all participants' unique identification numbers and found no

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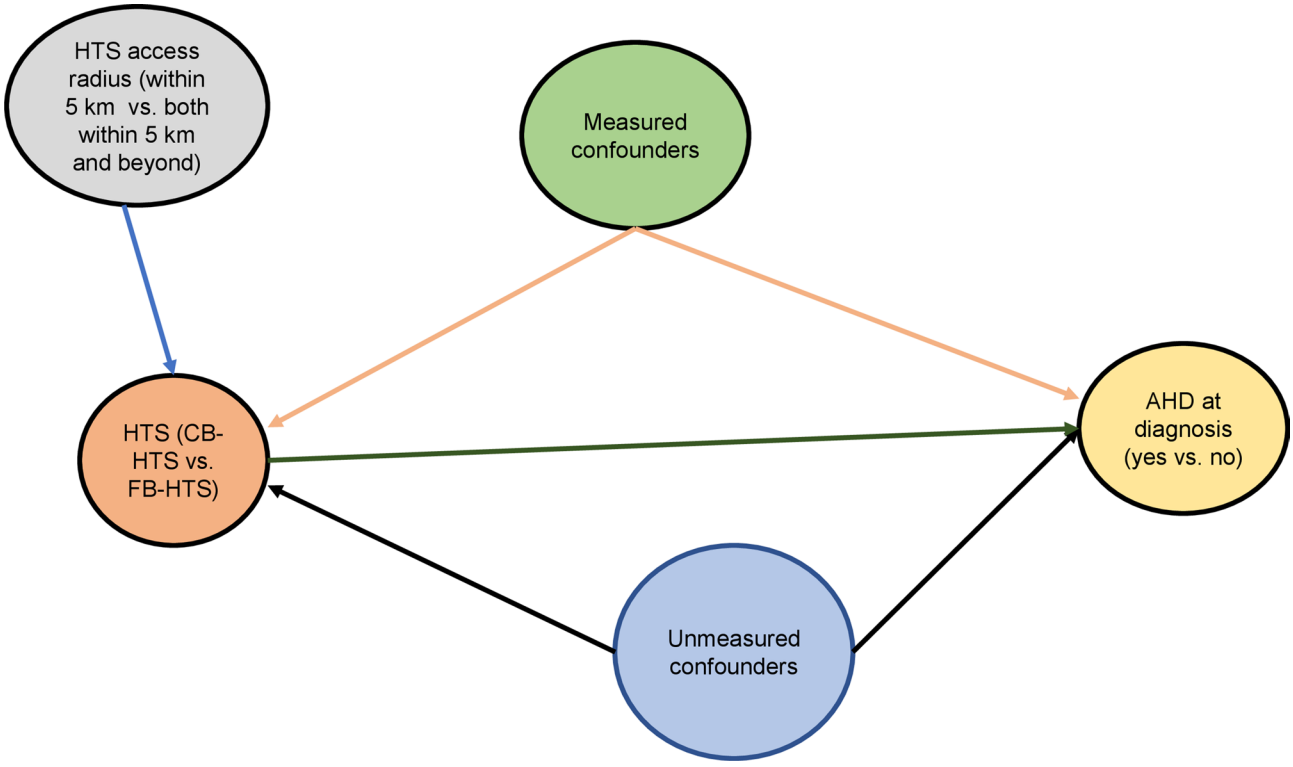


Fig. 1 Directed acyclic graph (DAG). The DAG demonstrates the use of the instrumental variable (HTS access radius) to estimate the effect of HIV testing service (HTS) modality on advanced HIV disease (AHD) at diagnosis in the presence of both measured and unmeasured confounders. The diagram illustrates how the HTS access radius influences the HTS modality but affects AHD at diagnosis only through its effect on the HTS modality, thereby helping to address confounding

duplicates. Ethical approval was obtained from the Mbale Regional Referral Hospital Research and Ethics Committee (MRRHREC) (Ref: MRRH-2025-558). A waiver of informed consent was granted due to the retrospective nature of the study and use of de-identified records. Administrative clearance was obtained from the heads of all health facilities per national research guidelines. The study was conducted in accordance with the Declaration of Helsinki, which outlines the ethical principles for research involving human subjects, including beneficence, nonmaleficence, autonomy, and justice.

Study variables and measurements

The primary exposure was HTS, classified as CB-HTS or FB-HTS and coded as 0 versus 1, respectively. CB-HTS included home-based HTS, HTS at educational establishments for sexually active youth, outreach, and drop-in centers. Conversely, FB-HTS included routine and diagnostic testing through entry points such as outpatient, antenatal, and inpatient settings. The primary outcome was AHD, defined dichotomously as yes (CD4 count < 200 cells/mm^3 or WHO stage 3 or 4, coded 1) and no (CD4 ≥ 200 cells/mm^3 and WHO stage 1 or 2, coded 0), based on clinical assessments at diagnosis. We used the HTS access radius, a measure of HTS geographical coverage for each health facility, as an instrumental variable. HTS access radius strongly influences the type of HTS accessed by PWH, with those within 5 km more likely to use FB-HTS and those beyond 5 km most likely to access CB-HTS. Second, the 5 km cut-off was reasonable because it reflects the standard measure of geographic access in Uganda's health system. Individuals residing within a 5 km radius of a health facility are considered to have adequate access, whereas those living beyond this distance are regarded as having limited access. This natural geographic variation (HTS access radius) affects the exposure (HTS) but is unlikely to directly impact AHD at diagnosis (the outcome), except through its effect on HTS.

Thus, the HTS access radius fulfills the relevance, exclusion restriction, and exogeneity criteria required for a valid instrumental variable.

Covariates included demographic and clinical factors, namely age group (15–24, 25–34, 35–44, and ≥ 45 years), sex (male, female), marital status (married versus not married), HIV testing history (first-time versus repeat tester), HTS approach (provider-initiated versus client-initiated), reason for HIV testing (index, prevention of mother to child transmission of HIV [PMTCT], self-initiated, APN, and other reasons), HIV testing history (ever

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tested versus never tested), multiple sexual partners (yes versus no), and presumptive TB (yes versus no).

Statistical analysis

Categorical variables were summarised as frequencies and percentages, and numerical variables as means with standard deviations. Comparisons across the HTS access radius were performed using Chi-square tests when all expected cell counts for categorical variables were ≥ 5; otherwise, Fisher's exact test was applied. Differences in numerical variables were evaluated using two-sided t-tests. Statistical significance was defined as $p < 0.05$. We used a two-stage residual inclusion (2SRI) approach to estimate the effect of the HTS on AHD, appropriate for binary outcomes. In the first stage, we modeled the HTS as a function of the instrumental variable and covariates using a logistic regression model and obtained the residuals. In the second stage, we modeled the probability of AHD using a logistic regression that included the response residuals from the first stage and covariates. The inclusion of response residuals helps correct for endogeneity of the HTS. The strength of the instrumental variable (relevance criterion) was assessed using the F-statistic from the first-stage model, with a threshold of >10 indicating strong relevance. In sensitivity analyses, a logistic regression using generalized estimating equations (GEE) to account for clustering by district was performed, with and without adjustment for potential confounders. We also tested the exclusion restriction assumption using outcome balance checks across instrumental variable levels, as well as the exogeneity assumption using covariate balance checks. Data were analyzed using Stata version 15.0 statistical software program.

Results

Study profile

We retrieved 1,338 records of newly diagnosed PWH and excluded 105 due to missing data, leaving 1,233 records for analysis. Of these, 553 were from CB-HTS and 680 from FB-HTS. Among newly diagnosed PWH in CB-HTS, 9 (1.6%) had AHD at diagnosis, compared to 15 (2.2%) in FB-HTS (Fig. 2).

Distribution of participant characteristics by HTS access radius

Of the 1,233 participants (Table 1), 1,094 (88.7%) were from facilities providing HTS both within and beyond a 5 km radius, and 139 (11.3%) were from facilities providing services only within a 5 km radius. Sociodemographic and clinical characteristics were generally similar between the two groups, with no statistically significant differences in age distribution ($p = 0.511$), mean age ($p = 0.632$), sex ($p = 0.766$), marital status ($p = 0.279$), presumed TB at HIV diagnosis ($p = 0.246$), CD4 testing at diagnosis ($p = 0.507$), or multiple sexual partnerships ($p = 0.918$). The only statistically significant difference was in HTS ($p = 0.028$). The prevalence of AHD at diagnosis

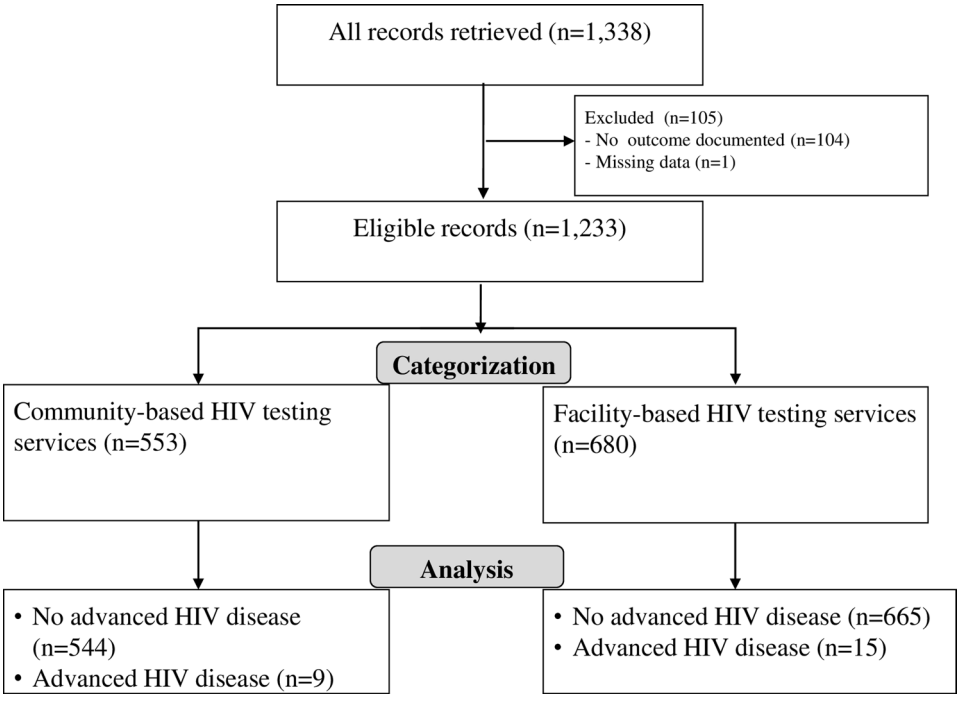


Fig. 2 Study profile. Depicts a cohort of newly diagnosed PWH, stratified by HTS delivery in rural eastern Uganda and grouped according to their AHD-at-diagnosis profile

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Table 1 Distribution of participant characteristics by HTS access radius

Variables	Level	Overall (*n* = 1233)	HTS access radius		*P*-value
			Both within a 5 km radius and beyond (*n* = 1,094)	Within a 5 km radius only (*n* = 139)	
Age group (years)	15–24	210 (17.0)	191 (17.5)	19 (13.7)	0.511
	25–59	966 (78.3)	852 (77.9)	114 (82.0)	
	≥ 60	57 (4.6)	51 (4.7)	6 (4.3)	
	mean (SD)	36.4 (11.8)	36.3 (11.9)	36.8 (11.2)	0.632
Sex	Female	755 (61.2)	672 (61.4)	83 (59.7)	0.766
	Male	478 (38.8)	422 (38.6)	56 (40.3)	
Marital status	Never/single	389 (31.5)	337 (30.8)	52 (37.4)	0.279
	Married	716 (58.1)	643 (58.8)	73 (52.5)	
	Separated	128 (10.4)	114 (10.4)	14 (10.1)	
Presumed TB at HIV diagnosis	No	1085 (88.0)	958 (87.6)	127 (91.4)	0.246
	Yes	148 (12.0)	136 (12.4)	12 (8.6)	
Tested for CD4 at HIV diagnosis	No	110 (8.9)	95 (8.7)	15 (10.8)	0.507
	Yes	1123 (91.1)	999 (91.3)	124 (89.2)	
CD4 category (cells/ul, *n* = 1,123)	< 200	20 (1.8)	19 (1.9)	1 (0.8)	0.714
	≥ 200	1103 (98.2)	948 (98.1)	119 (99.2)	
Baseline WHO clinical stages	I/II	1209 (98.1)	1071 (97.9)	138 (99.3)	0.508
	III/IV	24 (1.9)	23 (2.1)	1 (0.7)	
Multiple sexual partnerships	No	355 (28.8)	316 (28.9)	39 (28.1)	0.918
	Yes	878 (71.2)	778 (71.1)	100 (71.9)	
HTS	Community	553 (44.8)	478 (43.7)	75 (54.0)	0.028
	Health facility	680 (55.2)	616 (56.3)	64 (46.0)	
AHD at diagnosis	No	1209 (98.1)	1071 (97.9)	138 (99.3)	0.432
	Yes	24 (1.9)	23 (2.1)	1 (0.7)	

Note: AHD: Advanced HIV disease; HTS: HIV Testing Services; Column percentages are presented in brackets after the corresponding column frequencies

Table 2 Effect of HTS on AHD at diagnosis among newly diagnosed PWH

	HTS		Instrumental variable analysis	Adjusted GEE analysis	Unadjusted GEE analysis
AHD at diagnosis	CB-HTS (*n* = 553)	FB-HTS (*n* = 680)	OR (95% CI)	aOR (95% CI)	OR (95% CI)
No	544 (98.4)	665 (97.8)	1	1	1
Yes	9 (1.6)	15 (2.2)	1.20 (0.49–2.90)	1.39 (0.59–3.30)	1.35 (0.51–3.56)

Note: AHD: Advanced HIV Disease; CI: Confidence Interval; GEE: Generalized Estimating Equations; OR: Odds Ratio. For HTS, the column percentages are presented in brackets after the corresponding column frequencies

was low at 1.9% (24/1233), and did not differ significantly between groups (2.1% versus 0.7%, $p = 0.432$).

Instrumental variable regression analysis model diagnostics

The instrumental variable (HTS access radius) was strongly correlated with the HTS ($p = 0.028$), and the first-stage F-statistic was 28.05 (df = 12, 1220, $p < 0.0001$). The instrumental variable showed no correlation with AHD at diagnosis and all measured covariates (all $p > 0.05$), as would have been the case in a randomized controlled trial (Table 1). These findings support the validity of the assumptions for instrumental variable analysis and the credibility of findings.

Effect of the HTS on AHD at diagnosis among newly diagnosed PWH

Table 2 shows that the prevalence of AHD at diagnosis was slightly lower in those tested through CB-HTS (1.6%) compared to FB-HTS (2.2%). The instrumental variable analysis showed no significant effect of FB-HTS on AHD at diagnosis compared to CB-HTS (odds ratio [OR] 1.20; 95% confidence interval [CI] 0.49–2.90). Similarly, unadjusted GEE analysis yielded an odds ratio of 1.35 (95% CI 0.51–3.56), and the adjusted GEE model showed an odds ratio of 1.39 (95% CI 0.59–3.30) for AHD at diagnosis for FB-HTS versus CB-HTS.

Discussion

This study compared the effect of FB-HTS versus CB-HTS on the yield of AHD at diagnosis. Findings show no difference between FB-HTS and CB-HTS on AHD at

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diagnosis among newly diagnosed PWH. The absence of a statistically significant difference implies that both HTS have similar effectiveness on AHD at diagnosis. We did not find any published studies focused on our research question, but existing evidence shows that CB-HTS consistently achieves higher uptake than FB-HTS. A systematic review reported that 81% of men offered a CB-HTS accepted HIV testing, with testing uptake significantly higher than FB-HTS [23]. Another review found that CB-HTS increased HIV testing uptake from 5.8% to 37% compared with FB-HTS [24]. CB-HTS also reaches populations underserved by health facilities. In Mozambique, community index testing reached males nearly two-fold higher than facility-based testing: 53% versus 27% [25]. In Tanzania's Bukoba study, venue-based community testing reached more males (69%) and young people aged 15–24 years (42%) when compared with facility-based provider-initiated testing [26].

FB-HTS often yields higher HIV positivity rates than CB-HTS. For instance, in Tanzania, client-initiated FB-HTS yielded 6.6% positivity, compared to 5.2% for provider-initiated testing [27]. In Bukoba, health facility-based provider-initiated testing achieved 3.7% positivity compared with 1.8% for home-based and 2.1% for venue-based testing [26]. Despite lower positivity rates, CB-HTS identifies more PWH, with data showing 96% in one review [23], including early detection of incident HIV, with higher median CD4 counts (400–438 cells/μl) than FB-HTS [24]. Therefore, CB-HTS appears to improve early HIV diagnosis before progression to AHD compared to FB-HTS.

Implications of findings

The study findings are relevant for programmatic planning, as they support the continued integration of CB-HTS into national HIV testing strategies. CB-HTS expands access to underserved populations and facilitates earlier HIV diagnosis, yet its effectiveness in identifying people with AHD at diagnosis remains a concern. Our results suggest CB-HTS does not compromise the identification of people with AHD at diagnosis among newly diagnosed PWH when compared to FB-HTS. From a policy perspective, the comparable performance between FB-HTS and CB-HTS indicates that health systems can invest in either of them without compromising the identification of AHD at diagnosis among newly diagnosed PWH.

Therefore, rather than prioritizing one strategy over the other, both strategies should be equipped with adequate clinical tools, referral mechanisms, and linkage-to-care processes. Enhancing the clinical capacity of CB-HTS teams and maintaining quality standards across both strategies may improve the overall effectiveness of HIV testing programs in identifying people at the highest risk of morbidity and mortality. To further advance both strategies, robust evidence on their cost-effectiveness, particularly regarding implementation at scale and sustainability, will be essential to guide policy and resource allocation. To further inform future strategies regarding the costing, scale, and sustainability of CB-HTS in particular, data are needed to determine whether the full spectrum of CB-HTS facilities available to PWH was utilized, or whether specific types of CB-HTS facilities were preferred, irrespective of distance or proximity.

Study strengths and limitations

The primary strength of our study is the use of instrumental variable analysis to mitigate bias from both measured and unmeasured confounding, which is a common limitation in observational studies. The instrumental variable met all requirements for cause-and-effect estimation, hence enhancing the robustness of our conclusions. Estimates from the instrumental variable analysis indicated a marked reduction in confounding relative to both unadjusted and conventionally adjusted estimates, underscoring the value of causal inference methods over traditional multivariable approaches. Nevertheless, the reliance on routine programmatic data may introduce measurement limitations, especially regarding the accurate classification of AHD. We acknowledge that some individuals were assessed only by WHO clinical staging, as no CD4 testing was done at the baseline for programmatic reasons, such as machine breakdown. Consequently, a small number of such participants may have been misclassified with respect to AHD. This limitation reflects routine programmatic constraints and should be considered when interpreting the findings. Our data included fewer people with AHD at diagnosis, which may have led to a wide confidence interval around the effect estimate, reflecting considerable uncertainty. While we evaluated the effect of CB-HTS versus FB-HTS on AHD at diagnosis among newly diagnosed PWH, future research should compare the effectiveness of these approaches on HIV positivity. These limitations should be considered when interpreting the findings.

Conclusion and recommendation

Our study did not detect a statistically significant difference between FB-HTS and CB-HTS in identifying AHD among newly diagnosed PWH, but moderate effects cannot be excluded. These findings support the dual implementation of both strategies for HIV testing in rural eastern Uganda and similar settings in sub-Saharan Africa to achieve equitable HTS access and early HIV detection.

Abbreviations

AHD	Advanced HIV disease
ART	Antiretroviral therapy

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CB-HTS	Community-based HTS
DAG	Directed Acyclic Graph
FB-HTS	Facility-based HTS
GEE	Generalized Estimating Equations
HIV	Human Immunodeficiency Virus
HTS	HIV testing services
PMTCT	Prevention of mother-to-child transmission of HIV
PWH	People with HIV

Acknowledgements
The authors would like to acknowledge the Ministry of Health, PEPFAR Tracking with Recency Assays to Control the Epidemic (TRACE) initiative, Francisco, Uganda Virus Research Institute, Makerere University Monitoring Evaluation Technical Support Program (METS) for the coordination, supervision, and oversight training materials, Quality assurance for the Recent Infection Surveillance and the support rendered by the facility in charge of the HIV clinic care health facilities during the process of data collection for this study.

Author contributions
JI, SMS, SA, and FB conceptualized and designed the study. SMS acquired the data. JI and FB analyzed and interpreted the data.JI and FB drafted the manuscript. JI, SA, and FB critically revised the manuscript and approved it for submission.

Funding
None.

Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the Mbale Regional Referral Hospital Research and Ethics Committee (MRRHREC) (Ref: MRRH-2025-558). A waiver of informed consent was granted due to the retrospective nature of the study and use of de-identified records. Administrative clearance was obtained from the heads of all health facilities per national research guidelines. The study was conducted in accordance with the Declaration of Helsinki, which outlines the ethical principles for research involving human subjects, including beneficence, nonmaleficence, autonomy, and justice.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 29 October 2025 / Accepted: 26 December 2025
Published online: 30 December 2025

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