# HIV care continuum in Rwanda: a cross-sectional analysis of the national programme

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## Summary

**Background** **Rwanda has made remarkable progress towards HIV care programme with strong national monitoring and surveillance. Knowledge about the HIV care continuum model can help to improve outcomes in patients. We aimed to quantify engagement, mortality, and loss to follow-up of patients along the HIV care continuum in Rwanda in 2013.**

**Methods** **We collated data for individuals with HIV who participated in the national HIV care programme in Rwanda and calculated the numbers of individuals or proportions of the population at each stage and the transition probabilities between stages of the continuum. We calculated factors associated with mortality and loss to follow-up by fitting Cox proportional hazards regression models, one for the stage of care before antiretroviral therapy (ART) initiation and another for stage of care during ART.**

**Findings** **An estimated 204 899 individuals were HIV-positive in Rwanda in 2013. Among these individuals, 176 174 (86%) were in pre-ART or in ART stages and 129 405 (63%) had initiated ART by the end of 2013. 82·1% (95% CI 80·7–83·4) of patients with viral load measurements (n=3066) were virally suppressed (translating to 106 371 individuals or 52% of HIV-positive individuals). Mortality was 0·6% (304 patients) in the pre-ART stage and 1·0% (1255 patients) in the ART stage; 2247 (3·9%) patients were lost to follow-up in pre-ART stage and 2847 (2·2%) lost in ART stage. Risk factors for mortality among patients in both pre-ART and ART stages included older age, CD4 cell count at initiation, and male sex. Risk factors for loss to follow-up among patients at both pre-ART and ART stages included younger age (age 10–29 year) and male sex.**

**Interpretation** **The HIV care continuum is a multitrajectory pathway in which patients have many opportunities to leave and re-engage in care. Knowledge about the points at which individuals are most likely to leave care could improve large-scale delivery of HIV programmes.**

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## Introduction

Scale-up of antiretroviral therapy (ART) for treatment of HIV infection is one of the largest pharmacological interventions of all time.[1,2] The benefits of ART extend beyond individuals, decreasing the likelihood of sexual transmission from individuals with undetectable plasma viral loads, as shown by the HIV Prevention Trials Network 052 study[3] and other observational and modelling analyses.[4] In many regions, and particularly sub-Saharan Africa, programmes such as the US President's Emergency Plan for AIDS Relief (PEPFAR)[5] and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) have increased access to treatment by more than 100 times in less than a decade.[6] Despite progress, HIV continues to be a leading cause of death in sub-Saharan Africa (in 2013 1·1 million people [1·0 million to 1·3 million] died of AIDS-related causes).[7]

Among sub-Saharan African countries, Rwanda has made remarkable progress towards rebuilding a shattered health system in the two decades after the 1994 genocide.[8,9] Rwanda began its ART scale-up in 2004, and, by 2007, Botswana and Rwanda were the first two countries in sub-Saharan Africa to reach universal ART coverage (defined as having ≥80% of eligible patients on treatment according to current guidelines). However, the successful delivery of ART to achieve universal coverage cannot be accomplished in the absence of a thoughtful and robust system to monitor and evaluate care that helps to guide implementers through programmatic and logistical barriers. For example, poor engagement in care by HIV-positive individuals substantially decreases the effectiveness of expanded access to ART.

The HIV care continuum theoretical framework has recently gained attention for its use in quantification of the engagement in care, from testing and diagnosis stages through to treatment and viral suppression.[10] Despite the successes noted above, uncertainties remain about areas of the continuum of care that need most improvement to ensure continued success by the Rwanda national HIV programme and areas that are its greatest strengths to find out whether lessons can be learned for other settings. Using the HIV care continuum as a framework, we aim to assess the Rwanda national HIV programme by quantifying the engagement of HIV-positive individuals in care for the year 2013 and reporting factors associated with mortality and follow-up in ART and pre-ART stages.

## Research in context

### Evidence before this study

The HIV care continuum is a theoretical framework commonly used to evaluate HIV programmes across various settings. Assessment of HIV programmes suggests that linkage of care and retention of patients are challenging and that testing and diagnosis remains problematic in low-resource settings. We searched Medline and Embase to identify studies about the HIV care continuum in Rwanda, but could identify no studies. We used the following search terms (HIV OR antiretroviral) AND (care cascade OR continuum) AND Rwanda. Our search included all studies published from Jan 1, 2007, to Dec 31, 2014. We used no language restrictions because of the importance of French in the region. In the same databases, we searched with the terms "cascade" or "continuum" and "HIV" or "antiretroviral therapy" (without Rwanda) and found one study (by Hallett and Eaton) that suggested an alternative multitrajectory approach to the HIV care continuum. Our search through recent conferences revealed two more studies, one that investigated characteristics of patients disengaging and re-engaging in care and one that suggested that measures of suboptimum behaviours should be used to complement the current framework.

### Added value of this study

This is the first study to evaluate the HIV care continuum in Rwanda. It shows the strengths of Rwanda's national HIV programme, which has an efficacy to rival those of resource-rich settings. By plotting the multiple trajectories by which individuals living with HIV engage in care, we identified areas in which Rwanda's programme could improve, such as tendencies for delayed initiation of antiretroviral therapy when patients were eligible at linkage and a tendency for some to exit and re-enter care.

### Implications to all available evidence

Beyond implications for the Rwanda national HIV programme, our study further supports need for an expanded HIV care continuum that reflects the many trajectories by which individuals living with HIV engage in care.

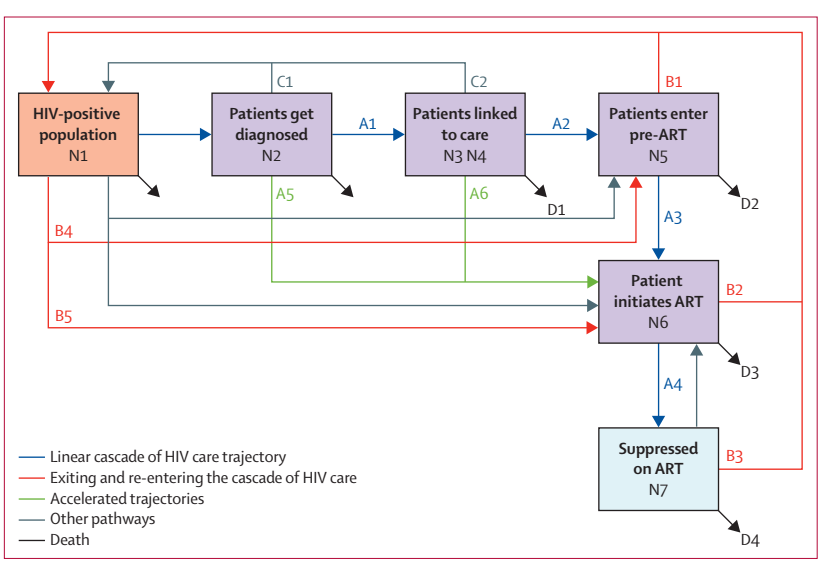


***Figure 1:*** **The HIV care continuum**
Findings for each label (eg, A1) are in table. Other pathways (grey) include delayed engagement and virological failures. People disengaging through red lines can only re-engage through red lines and similarly for grey lines. In this manner, patients cannot be diagnosed or linked to care more than once. Red exit lines include individuals that never re-engage in care and the grey entry lines include symptomatic individuals who will engage in care without ever being tested. ART=antiretroviral therapy.

## Methods

### The framework

The conventional model of a continuum of care is linear, in which patients migrate through the system from seroconversion to viral suppression. However, not all patients engage in care in a linear manner. Some patients have accelerated trajectories to viral suppression with ART after they skip a pre-ART period, such as women diagnosed through antenatal care programmes and patients with tuberculosis. Furthermore, the conventional model does not account for the cyclical aspects of engagement and re-engagement in care. We extended this framework to capture the many entries and exits to the continuum for HIV-positive patients in care in Rwanda (figure 1). Our modification adds transition pathways between the various stages of care to reflect more closely the reality of patients in Rwanda. The stages of care include diagnosis, linkage to care, pre-ART care, start of ART, and viral suppression (figure 1). Additional stages could include adherence to ART and eligibility for ART. Adherence to ART is not routinely assessed within the Rwandan national HIV surveillance system and so we did not include it in these analyses. We account for ART eligibility in our analysis, but we do not include it as a stage of the continuum. This study was approved by the Rwanda Medical Research Council.

### Study setting and sources of data

Rwanda has a population of about 10·5 million people distributed across five provinces. According to the 2005 and 2010 Rwandan Demographic Health Survey,[11] the prevalence of HIV remains unchanging at about 3% of the adult population. Thus, the HIV epidemic in Rwanda is mature and stable. Operating under the authority of the Ministry of Health, the Rwanda Biomedical Centre monitors and evaluates HIV care programme in Rwanda. The Ministry of Health, with the use of the UNAIDs mathematical modelling programme Spectrum,[12] estimates that about 204 899 people were HIV-positive in Rwanda in 2013. Bounds of this estimate are 171 781 and 226 225 people; however, this estimate differs from

estimates obtained with DHS age-specific prevalence in conjunction with national age distributions by only a few hundred people and the error bars about the DHS estimates are 5%.

Because no single data source can inform the entire HIV care continuum in Rwanda, we collated four principle data sources: the TRACnet database,[13] electronic medical records (EMR), the IQ Charts database, and an unpublished Rwandan Ministry of Health study investigating linkage from diagnosis in 8598 newly diagnosed patients at 20 health facilities from 2010 to 2011. Each source of data complements the other to capture each step in the HIV care continuum in Rwanda.

The primary data source was the TRACnet database. Launched in 2003, TRACnet is a national surveillance database specific to HIV care. It includes data for all patients that are linked to HIV care; these data are aggregated at the health facility level and collected monthly. Data are obtained for all of the greater than 500 health facilities providing HIV care in Rwanda, of which 465 provided ART in 2013. Data are collected at the individual level before aggregation and TRACnet identifiers are monitored to minimise double counting across clinics. TRACnet is all-inclusive, containing data for patients receiving public and private sector care (0·34% of patients use the private sector). We used TRACnet data for the year 2013 (176 225 patients) to inform the pre-ART and ART stages of the HIV care continuum.

The secondary data source was electronic medical records. Rwanda is in the process of converting to a national database of electronic medical records for all citizens, irrespective of HIV status. At present, these data remain stored locally at the health facility, rather than in a centralised system. Our team (including two authors; JIF and ER) visited ten representative health facilities across all five provinces to extract data from electronic medical records for all patients with HIV at those establishments (two facilities per province). The ten facilities had individual-level data for 21 995 patients from Jan 15, 1997 (however, patients that died before the ART scale-up were excluded) to Feb 28, 2014. These data capture many variables, including viral load measurements, dates of diagnosis, and linkage to care. We used electronic medical record data to inform the viral suppression stage of the HIV care continuum and transitions from and to that stage.

We also used IQ Charts, a database of health indicators for all HIV patients receiving care at 110 (24%) of the 465 health facilities providing ART in Rwanda. These data are individual-level data that pertain to 87 613 patients from 2004 to 2011 (about 50% of HIV patients receiving care). Health indicators include CD4 cell count measurements, WHO disease stage, linkage date, dates of ART initiation, and exit dates (including transfers to other health facilities, loss to follow-up, and death). We used the IQ Charts database to inform the probabilities of transitions between stages, as well as to draw inferences on mortality and loss to follow-up.

Finally, a Rwandan Ministry of Health study investigated linkage from diagnosis in 8598 newly diagnosed patients at 20 health facilities from 2010 to 2011.[14] These data provided probabilities for transitions early in the continuum between diagnosis and linkage to care.

### Variables and definitions

Mortality and loss to follow-up were ascertained and recorded within hospital medical records and include deaths that occur outside of health-centre settings. Family members and community often follow up with health-care providers about unobserved deaths, and few deaths remain unaccounted for in patients lost to follow-up. Loss to follow-up was defined as failing to engage in care for 3 months consecutively. All pre-ART patients are prescribed monthly co-trimoxazole, and over the entire study period all patients were expected to see a health-care provider and collect drugs on a monthly basis. We limited mortality, loss to follow-up, and re-engagement in care to events that occurred in 2013.

To model factors associated with mortality and loss to follow-up, we included age, sex, marital status, method of diagnosis (antenatal care, voluntary counselling and testing, or other), CD4 cell count at enrolment and at ART initiation, tuberculosis status, WHO disease stage, whether the health facility was religious, the type of health facility (health centre or hospital), and the staff-to-patient ratio (capacity).

### Statistical analyses

We first calculated the proportions of individuals at each stage and the transition probabilities between stages of the HIV care continuum. To determine factors associated with mortality, we fitted Cox proportional hazards regression models, one for the stage of care before ART (pre-ART stage) and another for the stage of care when ART was given (ART stage). We adjusted for both CD4 cell counts and age between models, all other variables were baseline variables at enrolment. Because three of the variables were at the facility level, a random effect for the health facility was added to create a hierarchical model. We verified all conditions for survival analysis by use of tests based on the Schoenfeld residuals and all assumptions were met. The overall dataset for survival analysis contained 4·0% missing values and we analysed only complete cases. All tests were two-sided and done at the 0·05 significance level. We did all analyses with SAS 9.3 (Cary, NC, USA) and R 3.1.1 (Vienna, Austria).

### Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full

access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

We estimate that 204 899 individuals were HIV-positive in Rwanda in 2013 (table). This number serves as the initial state for analyses related to the HIV care continuum (figure 1). Statistics in the middle of the continuum (N1–N6) had the strongest evidence because they were collected through the TRACnet system, rather than estimated. They are extremely precise and many steps were taken to minimise bias. Among people in Rwanda who were HIV-positive, 176 174 (86%) were retained in either pre-ART or ART care in 2013 (table). 129 405 (63%) HIV-positive individuals initiated or had already initiated ART.

Numbers and proportions at the ends of the continuum are estimated (N7). Until recently, only one testing unit for viral monitoring existed within Rwanda and so little opportunity existed to monitor viral loads. Within the EMR database, 82·1% (95% CI 80·7–83·4) of patients with measured viral loads (n=3066) were virally suppressed at a cutoff of 40 copies per mL. When this proportion is applied to all patients on ART, this translated into an estimated 106 371 (95% CI 104 557–108 055; 52%) virally suppressed HIV-positive individuals on ART in 2013. With the IQ Charts database, we estimated the percentage of patients who

| | Description | Findings | Data source |
|---|---|---|---|
| **Stages of the HIV care continuum** | | | |
| N1 | Estimated size of HIV-positive population | 204 899 (100%) | MOH estimate |
| N2 | Number of total diagnoses | Unknown | None |
| N3 | Number of patients that have linked to care | 183 515 (89·6%) | TRACnet, not directly measured. |
| N4 | Number of patients linked to care at assessment | 176 174 (86·0%); 46 820 in pre-ART | TRACnet, directly measured |
| N5 | Number of patients in pre-ART | 58 182 (28·4%); of which 46 820 (22·9%) at the end of 2013 | TRACnet, directly measured |
| N6 | Number of patients initiating ART | 129 405 (63·2%) | TRACnet, directly measured |
| N7 | Number virally suppressed | 106 371 (51·9%) | EMR estimate* |
| **Links along the HIV care continuum** | | | |
| A1 | From diagnosis to linkage to care | 50·0% of diagnosed cases linked within 3 months and 32·6% were staged (see A5) | RBC–MOH study |
| A2 | From linkage to care to pre-ART initiation | 70·4% (95% CI 69·4–71·4) of patients who linked to care initiated pre-ART | IQ Charts |
| A3 | From pre-ART to ART | 93·1% of eligible patients on ART | RBC estimate using Spectrum |
| A4 | From ART to viral suppression | 82·2% of patients on ART who achieved viral suppression | EMR estimate* |
| A5 | From diagnosis directly to ART through antenatal care | 16·7% of diagnosed cases linked to ART through ANC | RBC–MOH study |
| A6 | From linkage to ART in 2013 | 26·5% initiated ART within 1 month of linkage† | IQ Charts |
| **Exiting and re-entering care** | | | |
| B1 | Loss to follow-up at pre-ART | 3·9% (2247) of individuals in pre-ART lost to follow-up | TRACnet, directly measured |
| B2 | Loss to follow-up on ART | 2·2% (2847) of individuals on ART lost to follow-up; 1850 not virally suppressed | TRACnet, directly measured |
| B3 | Loss to follow-up virally suppressed | 1·0% (997) of virally suppressed patients on ART | EMR estimate |
| B4 | Returning to pre-ART | 13·7% (698) of individuals lost to follow-up in pre-ART or later return to pre-ART | TRACnet, ratio of measurements |
| B5 | Returning to ART | 26·3% (1340) of individuals lost to follow-up in pre-ART or later return to ART | TRACnet, ratio of measurements |
| **Other pathways** | | | |
| C1 | Loss to follow-up at diagnosis | 50·0 % of diagnosed cases did not link within 3 months of diagnosis | RBC–MOH study |
| C2 | Loss to follow-up at linkage to care | 3·7% of those linked to care lost after first visit | IQ Charts |
| **Mortality** | | | |
| D1 | From linkage to care to death | 0·46% died before being retained in care | IQ Charts 2004–11 |
| D2 | From pre-ART to death | 304; 9·7 deaths per 1000 person-years | TRACnet |
| D3 | From ART to death | 1255; 6·5 deaths per 1000 person-years | TRACnet and EMR 2006–14 |
| D4 | From viral suppression to death | 822; 3·6 deaths per 1000 person-years | EMR 2006–14 |

All values from TRACnet and EMR are from 2013, unless otherwise indicated, and all values from IQ Charts are from 2011. MOH=Ministry of Health. RBC=Rwanda Biomedical Centre. EMR=electronic medical records. ART=antiretroviral therapy. ANC=antenatal care. *On the basis of suppression among those with available viral load data. †The cut-off was chosen based on the Rwanda HIV guidelines, which suggest that psychosocial and laboratory preparations for ART be completed within 1 month.

***Table*: HIV care continuum 2013 statistics and transitions with data sources**

were not retained in care after linkage and those who died shortly after linkage (table). Adding these values to the number of HIV-positive patients retained in care, we estimate that 183 515 (90%) HIV-positive individuals had linked to care. This excluded people who engaged in care and died before 2013. Therefore, the percentages of HIV-positive individuals at each step of the 2013 HIV care continuum were 90% linked to care, 86% retained in care, 67% ART-eligible, 63% on ART, and 52% virally suppressed.

At linkage to HIV care, after staging, 70% of patients transitioned to pre-ART. Patients eligible for treatment at linkage (straight to ART stage) were most often eligible due to low CD4 cell counts or opportunistic infections. About 40·1% (95% CI 38·6–41·3) of accelerated ART initiation was through antenatal care according to 2011 data. 66·0% (64·6–67·4) of patients that were ART-eligible at linkage started ART within 1 month (our linkage cutoff). Health-care providers suggest that many of the 34% of patients that are not put on treatment within 1 month have co-infections (eg, tuberculosis) and are therefore first placed on drugs for this and are stabilised before starting ART. Data for this process are not available at present.

Using Spectrum, the Rwanda Biomedical Centre estimates that 93% of all eligible patients were taking ART in accordance with 2013 Rwanda ART guidelines (table). These guidelines included treatment at a CD4 count cutoff of 350 cells per µL, option B+ for prevention of mother-to-child transmission, and immediate initiation of treatment for discordant couples and a range of co-infections (eg, hepatitis B). In 2014, Rwanda ART guidelines were revised and the CD4 count threshold was increased to 500 cells per µL.

Among HIV-positive people in Rwanda receiving care, 304 (0·6%) patients died in the pre-ART stage and

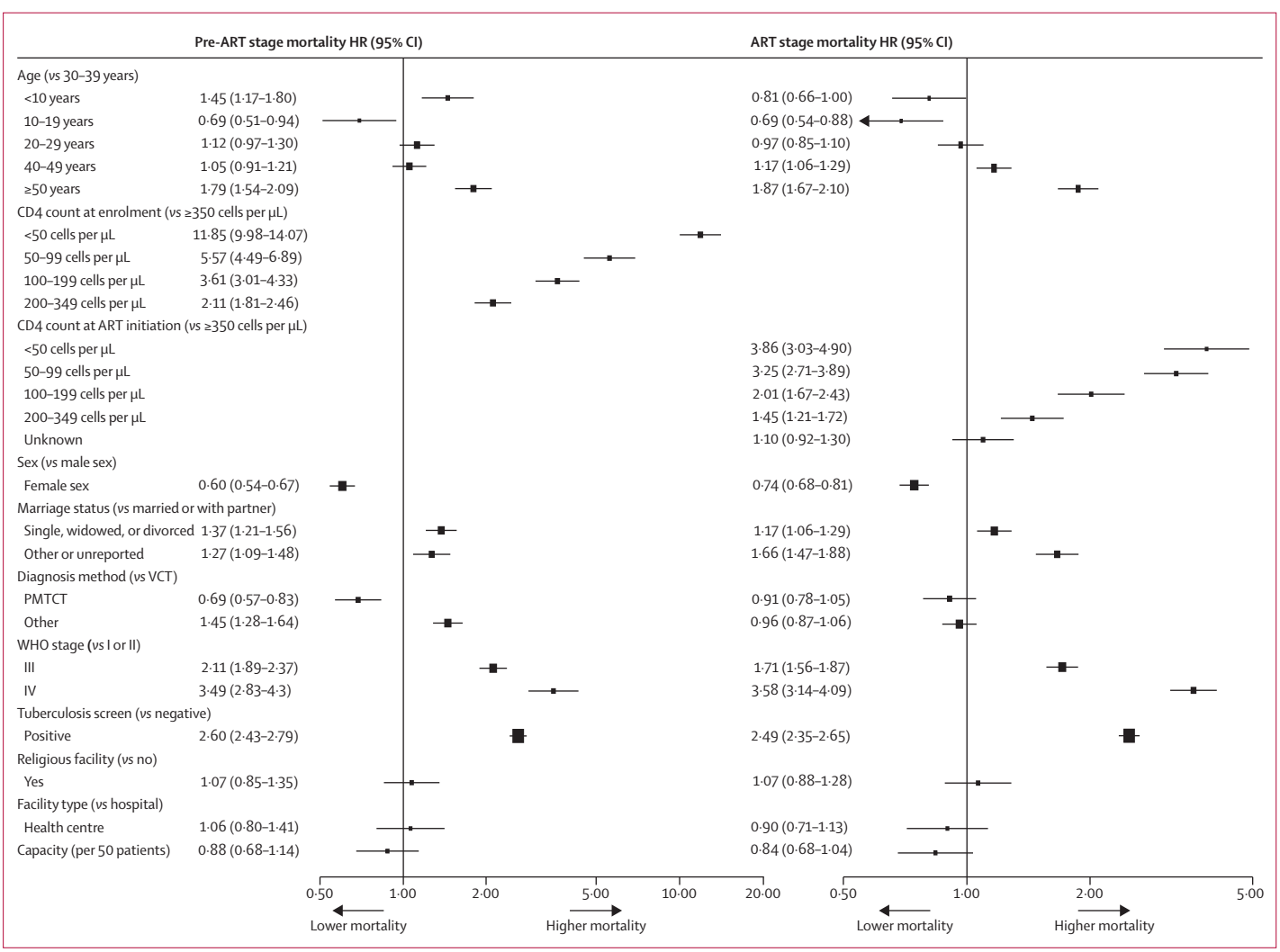


***Figure 2:*** **Factors associated with mortality in the pre-ART and ART stages of the HIV care continuum**
ART=antiretroviral therapy. HR=hazard ratio. VCT=voluntary counselling and testing. PMTCT=prevention of mother to child transmission.

1255 (1·0%) patients died in the ART stage. Mortality was lower in the ART period than in pre-ART because many more people were in this stage and the length of time in pre-ART is often short. Loss to follow-up was higher for patients in the pre-ART period (2247; 3·9%) than in patients in the ART period (2847; 2·2%), and was even lower for those who were virally suppressed (estimated at 997; 1·0%). One reason for such low proportions of loss to follow-up is that transfers to other centres are recorded as transfers rather than loss to follow-up. In the past 10 years (2004–14), 20% of patients that have been retained in care have transferred to another health facility at least once (TRACnet data).

TRACnet measures the number of patients returning to care after being declared lost to follow-up. The number of patients returning to care (2038) was two fifths as large as the number of patients lost to follow-up in 2013 (5094), implying that the actual proportion of patients disengaged from care was actually lower than the 3·9% and 2·2% reported for pre-ART and ART, respectively (table). Moreover, although the numbers lost to follow-up was larger in the pre-ART stage than in the ART stage, rates of return were higher in the ART stage than in the pre-ART stage (table), suggesting that some patients disengage from pre-ART care and then come back for ART.

Late initiation of ART (lower CD4 cell count at start of treatment) increased risk of mortality (figure 2). None of the measured structural variables were significantly associated with mortality (figure 2). More deaths occurred in hospitals with good capacity (most trained medical staff per patient) most likely due to confounding by indication—individuals with the poorest health are sent to these centres. Social support and female sex were both protective in the pre-ART period. Being diagnosed through a method other than voluntary counselling and testing or antenatal

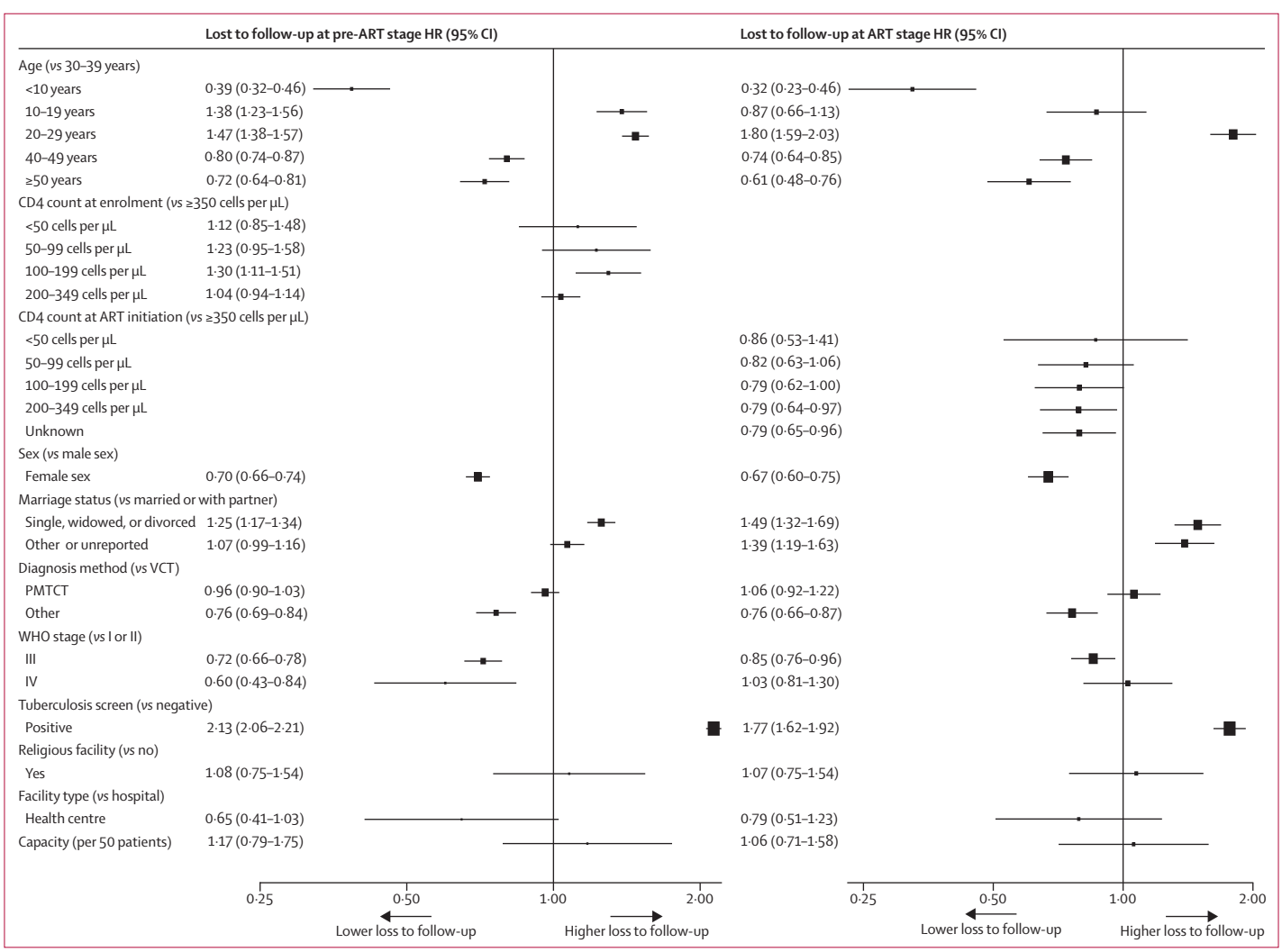


***Figure* 3: Factors associated with loss to follow-up in the pre-ART and ART periods of the HIV care continuum**
ART=antiretroviral therapy. HR=hazard ratio. VCT=voluntary counselling and testing. PMTCT=prevention of mother to child transmission.

care increased the risk of mortality because this category includes patients diagnosed while in hospital (figure 2). Children had a higher mortality risk in the pre-ART stage than did all other age groups except for individuals aged 50 years and older. Associations were similar in the ART stage for most variables, but the higher mortality for children and method of diagnosis were no longer statistically significant (figure 2). Patients age 10–29 years (*vs* age 30–39 years) and men (*vs* women) were more likely to be lost to follow-up at both pre-ART and ART stages (figure 3).

## Discussion

A high proportion of patients are retained in care and have suppressed viral loads in Rwanda. Our quantification of the HIV care continuum for the country also shows areas in which changes to the programme and procedures of data monitoring might improve health outcomes; mainly, the delay between positive diagnoses and engagement in HIV care and insufficient data for the stages of the continuum of care from diagnosis to linkage to care. Patients are given a unique identifier on linkage to HIV care, rendering surveillance of the transition from diagnosis to linkage extremely difficult. The internal, unpublished study by the Ministry of Health found that only 50% (n=8598) of new diagnoses link to care within 6 months of their diagnosis.[14] The proportion of unlinked patients who sought care at other facilities to avoid stigma is not known. Notwithstanding, this is the area of HIV care that stands to improve most in Rwanda. Overall in our findings, mortality and loss to follow-up were low. Nonetheless, mortality was associated with late engagement in care (either with low CD4 cell counts or opportunistic infections), being of male sex, and not having a partner, suggestive of lower social supports. To our knowledge, this is the first nationwide analysis of engagement in care in sub-Saharan Africa that uses the continuum framework.

In 2013, Hallett and Eaton[15] showed the linear model of the HIV care continuum to be insufficient to explain trends in HIV testing, linkage to care, retention in pre-ART care, and retention during ART, and called for a re-conceptualisation of the HIV care continuum. Here we show transition probabilities and the many pathways between continuum stages in which delays can be seen in linkage to care from diagnosis and delays from the pre-ART to the ART stages. Moreover, the cyclical model we have applied to Rwanda's HIV care programme allowed us to consider disengagement and re-engagement in care at different stages along the continuum. Better understanding of the time between disengagement and re-engagement will inform whether loss to follow-up, as presently measured, is an appropriate measure of disengagement. These features, which focus on how patients engage in care, differ from other re-conceptualisations that focus on suboptimum outcomes.[16]

Rwanda was among the first countries in sub-Saharan Africa to achieve universal ART coverage in 2008, and continues to show improvements in the responsiveness of its HIV care programme each year. In particular, the proportion of treated HIV-positive individuals with suppressed viral loads is similar to those in many programmes in high-income countries (eg, the programme in British Columbia, Canada).[17] Our re-conceptualisation of the continuum of HIV allows us to identify features of the Rwanda programme for HIV care that can help to explain its success.

First, a programme with a national focus optimises the overall operationalisation of HIV care through a centralised surveillance data that is responsive to the needs of the HIV-positive population. For example, the centralised surveillance systems were able to identify the 20% of patients that transferred health facilities while on ART and not misclassify them as loss to follow-up. National programmes optimise programming logistics and can minimise unfavourable events, such as ART stock-outs. Cohort analyses within centralised surveillance systems remain the gold standard to monitor the progress of outcomes of patients to improve quality of care.[18] As Rwanda moves to an even more robust centralised surveillance system with electronic medical records linked through a single ministry of health identifier, these analyses will become even more informative.

Second, having decentralised clinical services optimises the delivery of HIV care. As a geographically small but densely populated country, Rwanda has eliminated many barriers to access of care by offering localised clinical services. Decentralised services can reduce travel burden, one of the highest predictors of retention in care.[19] Complementary to decentralised clinical care, population outreach programmes run by a large network of HIV-positive individuals in Rwanda include regular home visits to individuals who are lost to follow-up or have documented poor adherence and running of antistigma campaigns and other support group activities.

Third, evidence of high health-seeking behaviour in Rwanda might also help to explain the success of the programme. This feature is best observed among the high proportion of men accompanying their female partners to antenatal clinics. Although this behaviour has been encouraged throughout most of sub-Saharan Africa, the uptake in Rwanda (about 85% of men accompany their partners to at least one visit) has been much higher than in other settings (on average about 45%).[20] Hallett and Eaton[15] validate that an expanded HIV care continuum model should account for health-seeking behaviour by including measures that reflect these behaviours and our findings in Rwanda support this.

Finally, leadership at the Rwanda Biomedical Centre and the Rwanda Ministry of Health has shown strong governance to support an understaffed and under-resourced health system with observable population-level

health improvements. In the Rwandan HIV care programme, this improvement is evidenced by the high retention of patients in care and has translated into decreased mortality and improved life expectancy.

Our study does have limitations. No single data source exists that can provide information about all stages of the HIV care continuum and health-seeking pathways between them in Rwanda. We collated data sources to quantify engagement at each stage and predict mortality along the continuum. Furthermore, although our study uses data from 2013 to quantify almost every stages of the continuum, progression probabilities (table) were calculated from 2011 because the IQ Charts database ended in that year. Another limitation is the uncertainty about the total size of the HIV-positive population. To this end, we did triangulate the estimate with multiple sources, which were in agreement. Nonetheless, with respect to the proportions at each stage, our estimates would change substantially if we had used the upper and lower bounds of the estimates. Lastly, poor understanding of causes of mortality prohibits this analysis from making conclusions on the contribution of HIV and AIDS to outcomes along the continuum. However, a strength of this study is the successful collation of several sources of data to show how nationwide routine surveillance and monitoring can be used to inform the proportion of engaged patients and mortality along the HIV care continuum at the national level.

Quantification of the dynamic transition of patients through the HIV care system can help to identify weaknesses and potential bottlenecks in the engagement of individuals at its various stages. By doing this, we have shown the success of Rwanda's national HIV care programme. Some of the lessons learned from Rwanda's success can be applied to other countries in the region, particularly the need for a strong centralised monitoring and surveillance system.

#### Contributors

SN, SK, ER, AB, and EJM contributed to study concept and design. SN, SK, JIF, and EJM drafted the manuscript. All authors contributed to acquisition, analysis, or interpretation of data and critical revision of the manuscript for important intellectual content. SN, SK and ER contributed to statistical analysis. SN, AB, JC, and EJM obtained funding. Administrative, technical, or material support was provided by SN, ER, JIF, JC, and EJM. SN, AB, and EJM supervised the study.

#### Declaration of interests

We declare no competing interests.

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