Household survey of HIV incidence in Rwanda: a national observational cohort study

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Summary

Background In Rwanda, HIV prevalence among adults aged 15–49 years has been stable at 3% since 2005. The aim of this study was to characterise HIV incidence across Rwanda.

Methods We did a nationally representative, prospective HIV incidence survey for the period of 2013–14, which used two-stage sampling. We randomly selected 492 villages in the first sampling stage and 14 households per village in the second stage. Participants completed a questionnaire and 14 140 people were tested for HIV. 13 728 participants were HIV negative, and were enrolled in the incidence cohort. Participants were retested and surveyed again after 12 months. Weights were calculated as the inverse of the probability to select the villages and the households.

Findings The study period was from Nov 5, 2013, to Nov 15, 2014. Among 14 222 respondents from 6792 households, 14 140 were tested for HIV and 13 728 were HIV negative. Of 12 593 people who participated in the endpoint data collection activities, 5965 (47·4%) were men and the mean age was 30 years (SD 10·8). 11 237 (89·2%) participants lived in rural areas, 4826 (38·3%) were single, and 7140 (56·7%) were married or cohabitating. During the year, 35 participants had seroconversion, including 13 men and 22 women, resulting in an overall incidence of 0·27 per 100 person-years (95% CI 0·18–0·35). Incidence was 0·21 per 100 person-years (0·10–0·32) in men and 0·32 per 100 person-years (0·19–0·45) in women. Our findings suggested multiple breakouts, with multiple seroconversions occurring in three villages and two households. Incidence was higher in adults aged 36–45 years (0·37 per 100 person-years, 0·12–0·62; adjusted hazard ratio [aHR] 4·49, 95% CI 1·30–14·70) relative to those aged 16–25, higher in western province (0·57 per 100 person-years, 0·31–0·87; aHR 5·90, 1·33–25·28) relative to the northern province, and higher in urban areas (0·65 per 100 person-years, 0·23–1·07; aHR 3·10, 1·28–6·99) than in rural areas.

Interpretation The incidence of HIV in Rwanda was higher than that previously estimated from models, with outbreaks seeming to contribute to the ongoing epidemic. Characterisation of incident infections can help the national HIV programmes to plan for preventive interventions tailored to the most at risk populations.

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Introduction

HIV remains a leading cause of death and disability worldwide.[1] In 2015, there were 1·1 million HIV-related deaths, 2·1 million new HIV infections, and 36·7 million people living with HIV.[2] Most of the burden of HIV is in sub-Saharan Africa, where 73% of deaths and 65% of new infections occurred in 2015 and where 70% of people living with HIV live.[2] The global response to the epidemic has been impressive. As of 2015, 17 million people were receiving antiretroviral therapy (ART), which has contributed to an estimated 43% reduction in AIDS-related deaths since 2003.[2] In 2016, the UN General Assembly agreed to fast-track the end of the HIV epidemic by achieving three global goals by 2020: to reduce new HIV infections to fewer than 500 000 per year globally, to reduce AIDS-related deaths to fewer than 500 000 per year, and to eliminate HIV-related stigma and discrimination.[3] In Rwanda, HIV incidence peaked in the mid-1990s and seemed to decline after the implementation of population prevention measures, including screening of donated blood, health education, and prevention services such as provision of condoms. This decline was accelerated with the national scale-up of ART.[4] At the end of 2015, 160 000 people in Rwanda were receiving treatment and 86% of those on ART had viral suppression (fewer than 40 copies per mL).[5]

To reduce new HIV infections, countries will need to understand incidence nationally, subnationally, and within different populations. HIV incidence remains the most informative measure for understanding the nature of an HIV epidemic, such as where and in whom new infections are occurring. WHO recommends various methods to measure incidence.[6] The gold standard is direct measurement of incidence in a cohort of uninfected individuals. Although this is the ideal method, it is resource intensive and not always feasible. The most common alternative option to measure incidence is mathematical modelling of data that affects incidence (eg, HIV prevalence and risk behaviour). Limitations of this approach include the robustness of the data used in modelling and the methods used.[7]

Research in context

Evidence before this study

Rwanda has a mature HIV epidemic with prevalence remaining stable at 3% in the adult population for the past decade. The HIV programme of Rwanda has been successful at reaching impressive goals with respect to the HIV continuum of care and providing antiretroviral therapy (ART) and care to those eligible to receive it. Despite a strong surveillance programme, Rwanda has depended on mathematical models and programs to estimate the incidence of HIV. We searched PubMed for relevant studies in English using the search terms "HIV incidence", "household survey" and "longitudinal cohort" up to Jan 15, 2017. We identified only one study, which was on the measurement of HIV incidence in a national cohort in Swaziland with 6 months of follow-up. We also found UNAIDS spectrum modelling from Rwanda for the year 2015, which estimated an HIV incidence of 0·15 per 100 person-years.

Added value of this study

This study provides a nationally representative estimate of HIV incidence in Rwanda and insights into the factors affecting incidence, which was nearly twice as high as the UNAIDS estimate for 2015. Our estimates for incidence were higher than those from previous mathematical models. Single young adults were among the drivers of HIV incidence. Our data also suggest that outbreaks are involved in the occurrence of new infections.

Implications of all available evidence

With HIV programmes increasing in complexity, better information is needed for decision makers. Nationally representative prospective incidence surveys are feasible and could provide crucial information to other HIV programmes. Investment in primary data collection, such as incidence studies, is likely to have profound implications for modelling of the HIV epidemic.

Modelling involves a larger degree of uncertainty and more room for error than direct measurement of incidence.

The national HIV control programme in Rwanda had yet to investigate incidence in a national cohort study since the start of ART scale-up in 2004. The programme has relied heavily on mathematical models from the UNAIDS Spectrum/Estimation and Projection Package (EPP) for key indicators, including the number of people living with HIV, incidence, AIDS-related deaths and number of adults and children in need of ART.[8] These estimates are crucial for national planning, quantification of commodities, policy directions, and assessments of interventions. However, the limitations of national models for subnational planning persist, as many biases can be introduced in model assumptions and because the national situation might not always represent what is happening at the local level.[9] To inform national programming towards ending the epidemic, Rwanda's Ministry of Health collaborated with the Global Fund to Fight AIDS, Tuberculosis and Malaria (the Global Fund) and other partners to organise the first study on national HIV incidence, the Rwanda HIV incidence survey. Thus, to obtain the most accurate and comprehensive HIV marker estimates, this study relied on the gold standard of measuring HIV incidence longitudinally in a cohort. Although community-based cohort studies have been done in eastern and southern Africa,[10–14] to our knowledge few cohort studies[15] have been designed to measure national incidence rates. The aims of our analyses are to estimate HIV incidence in the general population during a 12-month period, to understand where new infections are occurring and who they are occurring in, and to understand which variables are associated with new HIV incidence.

Methods

Sampling

We constructed a national prospective HIV incidence cohort by first surveying a nationally representative cohort in 2013 and then following up all HIV-negative individuals for 1 year. The initial sampling survey was administered in all five Rwandan provinces by use of two-stage sampling. In the first stage, we randomly selected 492 villages. We used districts as sampling strata, and we selected a representative sample in each district by using probability proportional to the size of the village.[16] In the second stage, we systematically selected 14 households per village. The sampled villages covered all five provinces of Rwanda and each of the 30 districts of Rwanda, with 58 villages in urban areas and 434 in rural areas. The survey design took into account the clustering of data in both the set-up and analysis. After selection of villages, we comprehensively listed all households in the selected villages using records of all the residential households to construct a sampling frame from which sample households were randomly selected. The study population was restricted to women aged 15–49 years and men aged 15–59 years who usually lived in sampled residential households. The sampling methods are the same as those used by the Rwanda Demographic and Health Survey.[16] The survey protocol was reviewed and approved by the Rwanda National Ethics Committee and the National Institute of Statistics of Rwanda.

The survey involved both individual interviews and blood sample collection. The data collection team consisted of interviewers and lab technicians. The interviewers visited the selected households and recorded questionnaires on to personal digital assistants (PDAs). At the completion of the interview, participants who consented to have a blood sample taken were immediately

received by the lab technician and nurse counsellor for counselling and blood sample collection in their household. Two questionnaires (household and individual) were used for interviews and both administrated by trained interviewers. The household questionnaire was used to identify eligible participants for the interview in the selected household on the basis of the primary inclusion criteria, age, and usual residency within the household. An individual identification number was assigned to each eligible participant. The individual questionnaire covered sociodemographic characteristics, sexual behaviour during the past 12 months, knowledge and attitudes towards HIV and related services, attitudes towards and use of condoms, voluntary HIV counselling and testing during the past 12 months, sexually transmitted infections during the past 12 months, male circumcision, exposure to HIV programmes, and contraceptive methods used. Both questionnaires were loaded onto PDAs that study staff used to do interviews.

Participants were also tested for HIV with rapid tests and ELISA tests. Those who tested negative for HIV were enrolled into the study cohort and those who tested positive were included only in the baseline survey. The study cohort was followed up for 12 months from the time of the first HIV test to the endpoint (last HIV test), with no special intervention or education. Two follow-up visits were done, in February and May, 2014. These visits aimed to check whether eligible participants were staying in the same villages and to collect new addresses for the participants who resettled, as well as ensuring that people were still willing to participate in the HIV incidence survey. To avoid eventual social stigma related to serological status, all study participants were visited, irrespective of their new HIV status, but only HIV-negative participants were included in the incidence cohort.

Data were collected with the structured questionnaire programmed into the interviewers PDAs and backed up on a daily basis in the Rwanda Biomedical Centre Servers. Data editing and cleaning were done, including checking of the range, structure, and internal consistency of the data. Baseline, follow-up, and endpoint data were linked through participant identification numbers. All selected participants were enrolled after they provided a signed consent form.

HIV testing

At baseline, blood samples were collected and labelled and HIV testing was done for all eligible participants who consented to the test. Rapid HIV tests were done at the nearest health facility so that the results could quickly be returned to the participants. Specimen result request vouchers were given to the respondents to refer them to their nearest counselling and testing centre to access their test results. After the rapid HIV test was done, dried blood samples were sent to the national reference laboratory for quality control and HIV status confirmation by ELISA. Respondents who tested positive for HIV were given post-test counselling and enrolled in the HIV care and treatment services.

	Weighted number of participants (%)	HIV infection		
		Weighted number of participants tested	Weighted number of infections	Prevalence (95% CI)
Overall	14 782 (100%)	14 691	439	3·0% (2·6–3·4)
Age (years)				
15–19	3420 (23·1%)	3407	15	0·4% (0·3–0·7)
20–24	2453 (16·6%)	2435	25	1·0% (0·7–1·5)
25–29	2458 (16·6%)	2437	50	2·1% (1·6–2·7)
30–34	2143 (14·5%)	2125	93	4·4% (3·6–5·4)
35–39	1478 (10·0%)	1469	73	5·0% (4·0–6·2)
40–44	1135 (7·7%)	1130	82	7·2% (5·8–8·9)
45–49	987 (6·7%)	982	63	6·4% (5·0–8·2)
50–54	407 (2·8%)	405	24	6·0% (4·0–8·8)
55–59	301 (2·0%)	300	14	4·8% (2·9–8·0)
Sex				
Female	7716 (52·2%)	7678	270	3·5% (3·1–4·0)
Male	7066 (47·8%)	7013	169	2·4% (2·1–2·8)
Marital status				
Single	6331 (42·8%)	6281	67	1·1% (0·8–1·4)
Married or cohabiting	7598 (51·4%)	7561	278	3·7% (3·3–4·1)
Divorced, separated, or widowed	853 (5·8%)	849	94	11·1% (9·2–13·4)
Residence				
Urban	1927 (13·0%)	1887	105	5·6% (4·6–6·7)
Rural	12 855 (87·0%)	12 804	334	2·6% (2·4–2·9)
Province				
East	3373 (22·8%)	2360	75	1·9% (1·4–2·5)
North	2362 (16·0%)	3738	44	2·6% (2·2–3·2)
South	3739 (25·3%)	3366	98	2·2% (1·8–2·8)
West	3286 (22·2%)	3260	102	3·1% (2·6–3·8)
Kigali	2022 (13·7%)	1967	120	6·1% (5·1–7·2)
Education				
None	2160 (14·6%)	2150	86	4·0% (3·3–4·9)
Primary	9426 (63·8%)	9387	274	2·9% (2·6–3·3)
Vocational	269 (1·8%)	268	15	5·6% (3·4–9·1)
Secondary	2542 (17·2%)	2518	53	2·1% (1·6–2·7)
Higher	385 (2·6%)	368	11	3·1% (1·7–5·5)
Religion				
Other	461 (3·1%)	453	28	6·2% (4·3–8·8)
Catholic	6511 (44·0%)	6482	162	2·5% (2·1–2·9)
Protestant or Adventist	7479 (50·6%)	7428	227	3·1% (2·7–3·4)
Muslim	332 (2·2%)	328	22	6·9% (4·6–10·2)
Wealth index				
Lowest	2696 (18·2%)	2684	83	3·1% (2·5–3·8)
Second	2842 (19·2%)	2836	73	2·6% (2·1–3·2)
Middle	2813 (19·0%)	2807	76	2·7% (2·2–3·4)
Fourth	3128 (21·2%)	3109	89	2·9% (2·3–3·5)
Highest	3302 (22·3%)	3255	118	3·6% (3·1–4·3)

Table 1: **Participant characteristics and HIV prevalence results at baseline**

	Weighted number of participants at endpoint	Weighted number of infections	HIV incidence per 100 person-years (95% CI)
Overall	13 056	35	0·27 (0·18–0·36)
Age (years)			
16–25	5097	12	0·24 (0·11–0·37)
26–35	4163	9	0·21 (0·07–0·35)
36–45	2260	8	0·37 (0·12–0·62)
46–55	1270	5	0·38 (0·04–0·72)
≥56	266	1	0·36 (0·00–1·08)
Sex			
Male	6182	13	0·21 (0·10–0·32)
Female	6874	22	0·32 (0·19–0·45)
Province			
North	2249	2	0·09 (0·03–0·22)
South	3432	7	0·20 (0·05–0·37)
East	3000	3	0·14 (0·02–0·27)
West	2929	17	0·57 (0·31–0·87)
Kigali	1409	6	0·40 (0·05–0·69)
Marital status			
Single	5007	18	0·35 (0·19–0·51)
Married or cohabiting	7397	12	0·16 (0·04–0·24)
Divorced	331	1	0·36 (0·00–1·01)
Widowed	320	4	1·30 (0·06–2·54)
Residence			
Rural	11 636	26	0·22 (0·13–0·31)
Urban	1420	9	0·65 (0·23–1·07)
Paid for sex in the past 12 months			
No	13001	33	0·25 (0·16–0·34)
Yes	55	2	3·67 (0·00–8·64)
Circumcised			
No	4715	8	0·17 (0·05–0·29)
Yes	1464	5	0·34 (0·04–0·64)
Experienced rape or forced sex in the past 12 months			
No	8160	26	0·31 (0·19–0·43)
Yes	58	2	3·32 (0·00–7·93)
Had sexually transmitted infection during past 12 months			
No	12 480	32	0·25 (0·16–0·34)
Yes	575	3	0·55 (0·00–1·15)
Currently pregnant			
No	6355	20	0·31 (0·17–0·45)
Yes	458	1	0·22 (0·00–0·65)

***Table 2*: HIV incidence by selected demographic characteristics and risk factors**

The participants' blood samples were processed and the processsed serum was packed into cryovials by the trained lab technician at the laboratory of the nearest health facility before being sent to the national reference laboratory. The dried blood spot specimens prepared at the health facility laboratory each day were processed and tracked by recording the participant identification number on a specimen transportation manifest from the health facility laboratories and on receipt at the national reference laboratory in Kigali. All samples at baseline and end of follow-up were tested with both ELISA and rapid diagnostics, in accordance with the national HIV testing algorithm. At the health facility, HIV rapid tests were done with whole blood obtained by venepuncture. Colloidal gold (Shanghai Kehua Bioengineering, Shanghai, China) and Determine HIV-1/2 Ag/Ab Combo (Alere, Matsudo, Japan) were used as screening tests and the Uni-Gold HIV test (Trinity Biotech, Bray, Ireland) as confirmation. To confirm the survey testing results, the dried blood spot samples were tested at the national reference laboratory with a fourth-generation HIV enzyme immunoassay (fourth-generation Vironostika HIV-1/2 antigen/antibody, BioMérieux, Lyon, France) as a screening test and a third-generation HIV enzyme immunoassay (Murex HIV-1.2.O, Murex Biotech, Dartford, UK) as a confirmation test in a serial testing algorithm. The processed serum samples in cryovials were used if the results with dried blood spots were indeterminate. All blood specimens received from the field were registered electronically against the respondent's identification number with a barcode reader. Each specimen was assigned a unique laboratory number during the registration process, and laboratory testing and storage in the repository was based on that number. The Emory University, Projet San Francisco Lab in Kigali did the laboratory quality control in which 10% positive and 5% negative specimens were retested with the testing algorithm already described. Specimens with discordant results between two laboratories were resolved by repetition of the testing algorithm.

Processed serum samples in cryovials were stored at –80°C before the start of testing. After testing was completed, results were added to the new survey data file. The unique random identification number originally assigned to each study respondent's questionnaire and venous blood sample served as the means for merging the survey and testing files.

Statistical analysis

We estimated HIV incidence in the cohort as the number of HIV seroconversions per 100 persons-years of follow-up. HIV incidence was the primary endpoint for our study.

We calculated sampling weights on the basis of a separate sampling probability for each sampling stage and for each sampling cluster. We weighted all analyses to adjust for the complex sampling methods and non-response to achieve a nationally representative analysis. Weights were the inverse of the probability to select the village times the probability to select the household.

The incidence analysis was based on the participants who were identified and consented to participate at the study endpoint. To better understand HIV incidence, we used simple descriptive statistics and Cox proportional hazards regression with 95% CIs. We used the Cox regression to investigate the effect of independent variables on seroconversion over 1 year of follow-up. We also calculated

hazard ratios adjusted for age, sex, province, marital status, residence, and having experienced rape or forced sex in the past 12 months. Incidence was calculated per 100 person-years, with each participant counted as contributing exactly 1 person-year. All analyses were done in Stata version 13.

We mapped villages where new infections occurred using Arch GIS version 10.3. To establish whether observed villages and households with multiple infections were to be expected or not, we estimated probabilities of these events by use of the binomial distribution.

Role of the funding source

The main funder (the Global Fund), which contributed more than 95% of the study budget, had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The other funders (Government of Rwanda, WHO Rwanda, and UNAIDS Rwanda), provided technical guidance on study design, data collection and analysis, and 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

Of 14456 eligible participants from 6792 sampled households, we obtained a sample of 14222 respondents, giving an individual response rate of 98·4%. This sample included 7419 women and 6803 men. Blood samples for HIV testing were obtained for 14140 (99·4%) of the 14222 respondents.

Of a weighted total of 14691 participants tested for HIV (table 1), 439 were HIV seropositive, which aligns well with previous national prevalence estimates.[16] HIV prevalence was higher in women than in men and urban areas than in rural areas. The difference in HIV prevalence by sex was also present in both urban and rural areas: in urban areas, prevalence was 7·2% (95% CI 5·7–9·1; n=59, weighted n=67) in women compared with 4·0% (2·9–5·4; n=33, weighted n=38) in men. Similarly, in rural areas, prevalence was 3·0% (2·6–3·5; n=194, weighted n=203) in women and 2·2% (1·8–2·5; n=126, weighted n=131) in men.

At the end of both follow-up visits, 12611 people consented to participate in the endpoint data collection and blood samples were provided by 12593 (91·7%) of 13728 people who were negative for HIV at baseline and completed the surveys. Endpoint data were collected from 6628 (52·6%) women and 5965 (47·4%) men. The mean age of people who completed the study was 30 years (SD 10·8). 11237 (89·2%) of these people lived in rural areas, 4826 (38·3%) were single, and 7140 (56·7%) were married or cohabitating.

During the year of follow-up from Nov 5, 2013, to Nov 15, 2014, 35 cohort members had seroconversion, resulting in an HIV incidence of 0·27 per 100 person-years (95% CI 0·18–0·36) in adults who were HIV negative at baseline (table 2). Incidence increased with age. Incidence was lowest in adults aged 26–35 years and highest in adults aged 46–55 years. HIV incidence was higher in women than in men, higher in widowed, never married, and divorced people than in married or cohabiting people, and higher in urban areas than in rural areas (table 2). More generally, 22 (63%) of 35 new infections were in women and 13 (37%) were in men. Half of all new infections were in people who had never been married (18 [51%] infections) and a third (12 [34%] infections) were in people in relationships. Additionally, although divorced and widowed people had increased incidence of HIV compared with people in relationships, they only contributed 15·43% (five infections) of the overall HIV incidence.

We further investigated the associations between HIV and other variables (table 3). Incidence was higher in adults aged 36–45 years than in the 16–25-year age group. Incidence was also 5·90 times higher in the western province than in the northern province. HIV incidence was higher in urban areas than in rural areas. The incidence was also very high in people who had experienced rape or forced sex in the past year. Compared with being single, being in a relationship was associated with a reduced hazard of seroconversion.

	HR (95% CI)	aHR (95% CI)
Age (years)		
16–25 (reference)	1	1
26–35	0·8 (0·4–2·0)	2·0 (0·8–5·1)
36–45	1·4 (0·6–3·3)	4·49 (1·3–14·7)
46–55	1·3 (0·5–3·6)	3·70 (0·9–14·6)
Sex		
Male (reference)	1	1
Female	1·4 (0·7–2·7)	1·14 (0·6–2·4)
Province		
North (reference)	1	1
South	2·3 (0·5–11·3)	2·3 (0·5–11·1)
East	1·5 (0·3–8·3)	1·5 (0·3–8·1)
West	6·5 (1·5–28·0)	5·9 (1·3–25·3)
Kigali	4·1 (0·8–21·1)	1·7 (0·3–10·0)
Marital status		
Single (reference)	1	1
Married or cohabitating	0·4 (0·2–0·8)	0·2 (0·1–0·5)
Divorced	0·8 (0·1–7·0)	0·3 (0·0–2·9)
Widowed	3·3 (1·1–9·6)	0·9 (0·2–4·0)
Residence		
Rural (reference)	1	1
Urban	2·9 (1·4–6·0)	3·1 (1·3–7·0)
Experienced rape or forced sex in the past 12 months		
No (reference)	1	1
Yes	10·9 (3·5–59·9)	10·2 (2·0–37·7)

HRs were calculated with bivariate analyses and aHRs were calculated with multivariate analyses. aHRs were adjusted for age, sex, province, marital status, residence, and having experienced rape or forced sex in the past 12 months. HR=hazard ratio. aHR=adjusted hazard ratio.

Table 3: **Bivariate and multivariate analyses of HIV incidence**

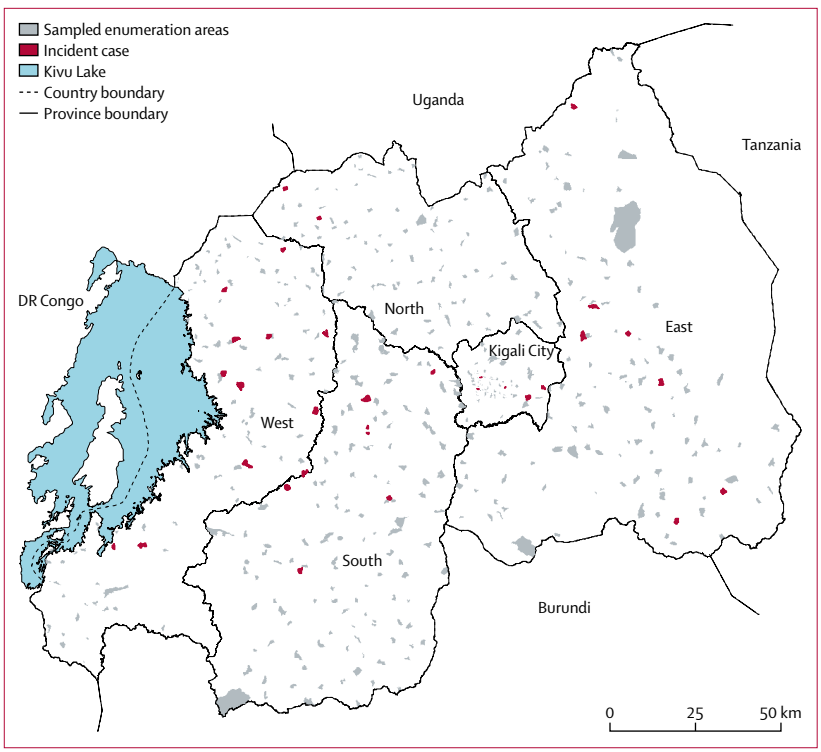

Figure: **Distribution of new infections across the provinces of Rwanda**

With 17 incident cases, a larger than expected number of infections occurred in the western province, which does not represent a large portion of the overall population of Rwanda (figure). Three villages in the western province had multiple infections. Two pairs of infections also occurred within households, although one pair consisted of two brothers and the other pair consisted of a mother and her daughter. On the basis of the number of participants, number of households, and the estimated HIV incidence of 0·27 per 100 person-years, the probability of observing two or more such households is very low (0·0012). Similarly, the estimated probability of seeing two or more villages with three or more households with incident infections was 0·0001. Thus, these multiple cases within villages and households, which accounted for nine infections, suggest that HIV outbreaks had a role in the spread of HIV in Rwanda. The three villages are all located on the northern shores of Lake Kivu, a large lake making up much of Rwanda's western border. The people infected in the three villages were mostly farmers and there was no indication that any of them were migrant workers, such as fishermen.

Discussion

New infections of HIV occur in Rwanda with an estimated incidence of 0·27 infections per 100 person-years. For a long time, HIV incidence in Rwanda has been estimated with mathematical models, and this study provides informative insights into the results of these models and the current state of the HIV epidemic in Rwanda.

The incidence of HIV in Rwanda is comparatively low in a region where wide variations occur across groups and demographics.[17] This incidence is, however, somewhat larger than might be expected in a country with a stable prevalence of 3%. Other nearby countries have reported high incidences within different populations and at different times. This intranational geographical heterogeneity is consistent with findings from a systematic review showing that incidence ranged from 0·8% to 7·5% in Tanzania, 2·3% to 16·4% in Kenya, 1·8% to 17·0% in South Africa, and 0·5% to 9·0% in Uganda.[17] In the past, the incidence of HIV in Rwanda could have been underestimated by more than 50% in mathematical models; the estimates provided by this survey therefore provide more accurate data for future planning. According to the UNAIDS Spectrum/EPP model,[8,9] the estimated incidence of HIV in Rwanda for 2014–15 was 0·08% (95% CI 0·05–0·14) and the estimated number of new infections among adults and children was 7·34 (5·38–9·28).[18] These estimates were used by the national HIV programme for strategic planning activities. However, questions of large confidence intervals and uncertainty of the model assumptions were the subject of regular discussions between the country monitoring and evaluation team and the UNAIDS reference group.[8] These new results, which suggest slightly more than 14000 new infections per year (0·27% incidence in a projected population of 5 392 209 aged 15–49 years), will probably be used in future to better adjust the model estimates to provide more accurate data for decision making. Follow-up surveys are needed to establish the accuracy of our findings. Given the coverage of ART in Rwanda, and relatively low HIV-associated mortality compared with other sub-Saharan African countries, this somewhat high incidence seems potentially inflated. Although young people (aged 15–24 years) did not have discernibly higher incidence than any other age groups, they make up a large proportion of Rwandan society and consequently account for the largest number of new infections. Efforts aimed at single young adults might help to curb the current HIV incidence.

The incidence was largely driven by young adults and single people, who accounted for more than half of all new infections. These infections are probably a result of low condom use (51·1%) among 15–24 year olds and relatively low comprehensive knowledge (60%) about HIV among 14–25 year olds.[16] These results are particularly concerning given that HIV is a chronic disease that requires lifelong treatment. Local outbreaks were another potential driver of incidence: nine (26%) of the 35 seroconversions occurred in people from three villages. We could not identify the origin of the infection from individuals in those villages. Specifically,

none of the people infected seemed to have been migrant workers, to have engaged with sex workers, or to be in discordant couples. Outbreaks are likely to be caused by acute infections, so these results possibly suggest that having multiple sexual partners is more common than previously reported among young rural Rwandans and that this has a role in the spread of HIV infection in rural areas where condom use has also been reported to be very low.[16]

We also noted that the HIV incidence was higher in adults in urban areas than in rural areas, which stresses the importance of geographical locations to HIV dynamics. This finding has also been reported across sub-Saharan Africa.[17,19] The trend towards higher incidence in urban than in rural settings and the shift towards a growing urban population will require extra vigilance in future HIV care in urban settings. In South Africa, adults with multiple sexual partners also had higher HIV incidence (2·2% per 100 person-years) than those who reported only one partner (1·4% per 100 person-years).[20] Previous estimates suggested that most heterosexual HIV transmission in urban Zambia and Rwanda occurs within married and cohabiting couples;[21] however, the risk of HIV infection is probably a result of extra-marital relationships. We did not see such a trend in our study. However, compared with people in relationships, incidence was higher among widowed, never married, and divorced people and these people are more likely to have different casual partners than are stable couples. Despite the evidence that male circumcision reduces susceptibility to HIV,[22] we did not find a significant difference between HIV incidence in circumcised and non-circumcised men.

Our analysis has both strengths and limitations. This is the largest prospective household HIV incidence survey ever done in Rwanda, with a high rate of participation and retention. The study enrolled a large sample, which we weighted at the national and provincial levels. The first limitation is the small number of seroconversions, which limited our ability to evaluate risk factors with greater certainty and to adjust for confounding variables within analyses of risk factors. Second, because of the few infection events, our study might be biased by temporal trends that we were unable to examine in any post-hoc analysis. Follow-up incidence surveys will be needed to ensure robust data for policy decision making. Third, by only testing HIV status at the end of the year, we were unable to discern the time of infection and estimate hazard ratios and other measures that could have been more informative such as acute infections and follow-up time from enrolment to the time of HIV infection. Additionally, although we used precise testing steps to eliminate false positives, more recent protocols suggest use of a third highly specific enzyme immunoassay serial confirmatory test. Fourth, given the small number of infections, exploration of the differences between the characteristics of infected and uninfected individuals is challenging and should be interpreted with caution. It is possible that not all participants answered all questions truthfully, especially questions related to sexual behaviour.

Despite the progress made in HIV control globally, more data are needed to precisely understand the magnitude of the HIV epidemic in specific countries. Our results showed that new HIV infections have been underestimated in previous measures based on mathematical models. Reaching the 90-90-90 global targets will require both resources and evidence to improve decision making. Our data can provide greater precision in decision making as Rwanda tries to meet its commitment to end AIDS by 2030.

Contributors

SN designed the study and had full access to the data. SN takes full responsibility for the data, accuracy of analysis, and final decision for submission. SN, AM, MM, and ER conceived the study. SN, ER, SK, EJM, ABS, AM, JPU, and MM analysed the data and interpreted the results. SN, ER, SK, EJM, ABS, AM, JPU, and MM drafted the manuscript. HCB and EJM critically revised the manuscript. ER and SK did the statistical analysis and SN obtained the funding. SN, ER, AM, and JPU provided administrative, technical, and material support. SN supervised the study.

Declaration of interests

We declare no competing interests.

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