BMJ Open

Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study

Ladislas Nshimiyimana ,[1] Noella Bigirimana,[1] Jean-Claude S Ngabonziza,[1,2] Jean-Paul Rwabihama,[3] Robert Rutayisire,[1] Muhammed Semakula,[3] Gilbert Rukundo,[1] Hassan Mugabo,[4] Josue Mutabazi,[5] Beatrice Mukamana,[1] Jean-Baptiste Mazarati,[6] Rigveda Kadam,[6] Olukunle Akinwusi,[6] Khairunisa Suleiman,[6] Claude Mambo Muvunyi,[1,2] Paula Akugizibwe[6]

To cite: Nshimiyimana L, Bigirimana N, Ngabonziza J-CS, *et al*. Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study. *BMJ Open* 2024;**14**:e083410. doi:10.1136/bmjopen-2023-083410

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2023-083410).

Received 19 December 2023
Accepted 11 September 2024

Check for updates

For numbered affiliations see end of article.

Correspondence to
Mr Ladislas Nshimiyimana; ladislas.nshimiyimana@rbc.gov.rw; ladi8n@gmail.com

ABSTRACT

Objective To evaluate the use of antigen-based rapid diagnostic tests (Ag-RDTs) alongside a digital tool to deliver household-level COVID-19 testing by community health workers (CHWs), in line with Rwanda's ambition to decentralise COVID-19 testing.

Design This was an operational pilot study to evaluate the impact and operational characteristics of using the digital e-ASCov tool combined with Ag-RDTs to support COVID-19 symptom screening and rapid testing by CHWs across eight districts in Rwanda. A total of 800 CHWs selected from both rural and urban areas were trained in delivering Ag-RDTs for COVID-19 testing and using the e-ASCOV application for data capture on a smartphone. Laboratory technicians repeated a subset of Ag-RDTs to assess the concordance of results obtained by CHWs. The study also assessed CHWs' experience of the intervention using a mixed-methods approach.

Setting Eight rural, urban and semiurban districts in Rwanda.

Participants A total of 19 544 individuals were enrolled and screened for signs and symptoms of COVID-19.

Interventions Community-based screening for COVID-19 by CHWs using the digital tool e-ASCov combined with rapid testing using Ag-RDTs.

Main outcome measures Number of participants screened and tested; concordance of Ag-RDT results between CHWs and laboratory technicians; feasibility of study procedures by CHWs and CHWs perceptions of the digital tool and Ag-RDT testing.

Results From February to May 2022, CHWs screened 19 544 participants, of whom 4575 (23.4%) had COVID-19-related symptoms or a history of exposure to the infection. Among them, 86 (1.9%) were positive on Ag-RDTs. Concordance of Ag-RDT results between CHWs and laboratory technicians was 100%. Of the 800 trained CHWs, 746 (93.3%) were independently able to conduct household-based COVID-19 screening, perform the Ag-RDTs and send data to the central server. Most CHWs (>80%) found Ag-RDTs and e-ASCOV easy to use.

Conclusions This study demonstrated the feasibility of deploying a digital tool and Ag-RDTs for household-level SARS-CoV-2 detection in Rwanda. The findings support a broader roll-out of digitally supported rapid testing by CHWs to broaden access to testing for priority diseases.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study was built on a well-established community health worker network, leveraging existing personnel and operational structures to introduce a new intervention with minimal disruption to the health system.
⇒ Digitisation of the study process helped to ensure that standardised procedures were followed for screening and data management despite the dispersed settings in which study activities took place in the communities.
⇒ The study used only Android smartphones; challenges related to different phones were not assessed. However, the application met the requirement for installation and use in all smartphone versions.
⇒ The study did not include control districts or other comparators, as this was not feasible during the emergency response to the pandemic.

INTRODUCTION

As of 9 February 2022, Rwanda had reported 129 210 cases of COVID-19, over 4.5 million tests conducted and 1449 deaths.[1] Of the 4.5 million tests, 73.3% were antigen-based rapid diagnostic tests (Ag-RDTs), while 26.7% were PCR tests. Most COVID-19 cases were reported during three major waves in which rapid surges of infection took place in a short period of time,[1] underscoring the importance of widespread testing to enable the rapid detection of SARS-CoV-2 and contain its transmission.[2]

While the epidemic was initially concentrated in urban settings, with the capital city, Kigali, accounting for 29.1% (28 267 of 97 190) of cumulative cases,[3] over time an increasing number of cases were detected in more rural areas of the country. Lower access to health facilities in less urbanised settings highlighted the need to expand community-based testing. Even outside of an emergency, the opportunity costs associated with travel to health facilities present significant barriers to care-seeking in many settings,[4] which were further heightened by movement restrictions and economic constraints during the COVID-19 pandemic.[5]

The increased availability of point-of-care testing for COVID-19, specifically Ag-RDTs, created new opportunities to bring testing closer to patients given the limited laboratory infrastructure available to deliver the gold-standard testing using PCR, especially in rural areas. COVID-19 testing with Ag-RDTs in Rwanda was initially delivered by trained clinicians or laboratory professionals and had not been formally offered by community health workers (CHWs) at the household level. However, the country's extensive network of CHWs was already involved in the diagnosis of other diseases, including symptom screening and referral for tuberculosis (TB). For example, between 2020 and 2021, 26.3% of the 5435 TB cases in Rwanda were referred by CHWs.[6] Consequently, there was a basis on which to review the COVID-19 testing process and consider expanding Ag-RDT testing at the community level through trained CHWs. Extending diagnostic ability using CHWs promises tremendous potential for expanded access but also presents challenges in terms of accurate and timely data reporting.

Accurate testing and timely data reporting are critical for the effective management of the COVID-19 response, particularly during periods of rapid transmission when such data provide early alerts of impending waves and hotspots to which intensified resources should be directed. CHWs could thus play a role not only in expanding access to diagnosis, but in supporting the development of community health surveillance approaches, which the WHO has highlighted as a core pillar of pandemic preparedness.[7]

Digital tools play an important role in enabling the rapid transmission of data to support real-time monitoring and epidemiological surveillance and ease CHWs' path to making decisions with clinical implications. Digital solutions provide real-time guidance and standardisation of processes at the point of care and at the management level and enable visibility into procedures being implemented at decentralised sites.[8]

Leveraging Rwanda's widespread CHW network, the 'e-ASCov project' was initiated and piloted by the Rwanda Biomedical Centre (RBC) and partners to evaluate the use of digital tools and Ag-RDT testing by CHWs in 2020. The pilot project was rolled out in two urban and two rural districts in Rwanda, whereby CHWs were trained and equipped with innovative digital technology to support community-based screening and referral of people with COVID-19 symptoms. The RBC-developed e-ASCov mobile application was installed on the phones of participating CHWs to support them with COVID-19 symptom screening and referral and ensure that related data are systematically captured and rapidly transmitted to national data servers to guide national surveillance and response efforts.

This study sought to build on the original e-ASCov pilot, and the opportunities offered by the expansion of Ag-RDT testing, by expanding e-ASCov to include instructions and data capture for administration of Ag-RDTs, and mechanisms for real-time reporting. At the time it was designed, to the authors' knowledge, this was the first study that evaluated the ability of CHWs to perform SARS-CoV-2 Ag-RDT testing, capture and transmit results in Rwanda and the broader African region. Thus, the study would provide grounds to review and update COVID-19 laboratory testing guiding principles in Rwanda vis-a-vis the possibility to decentralise RDT-based diagnosis at the community level by trained CHWs.

METHODS

This was an operational pilot study to evaluate the impact and operational characteristics of using the digital tool e-ASCov combined with Ag-RDTs to support symptom screening and delivery of rapid testing by CHWs at the household level.

Study setting and population

The study took place in eight districts in four provinces in Rwanda, including the four districts selected in the e-ASCov pilot. Four additional districts were selected based on infection rates (those with the highest infection rates at the time the study began) and geographical location. In terms of geographical location, a spread of rural, urban and semiurban districts was included, with prioritisation of rural districts as residents had restricted access to health facilities in these areas compared with the rest of the population. Districts with land borders were also prioritised due to a greater risk of COVID-19 transmission because of higher levels of movement between countries.

A total of 800 CHWs were selected for this study across 34 health centres (100 per district), representing around 5% of the total CHW workforce in the studied districts. Villages were selected randomly depending on the number of CHWs required per health centre, with all active CHWs included from selected villages. Online supplemental table 1 provides an overview of the study districts and CHWs included in the project by district. Within these districts, the intervention was fully integrated into the CHWs' routine package of care, which is accessible to all residents. As a result, the eligible population for this project was any person resident in the study districts.

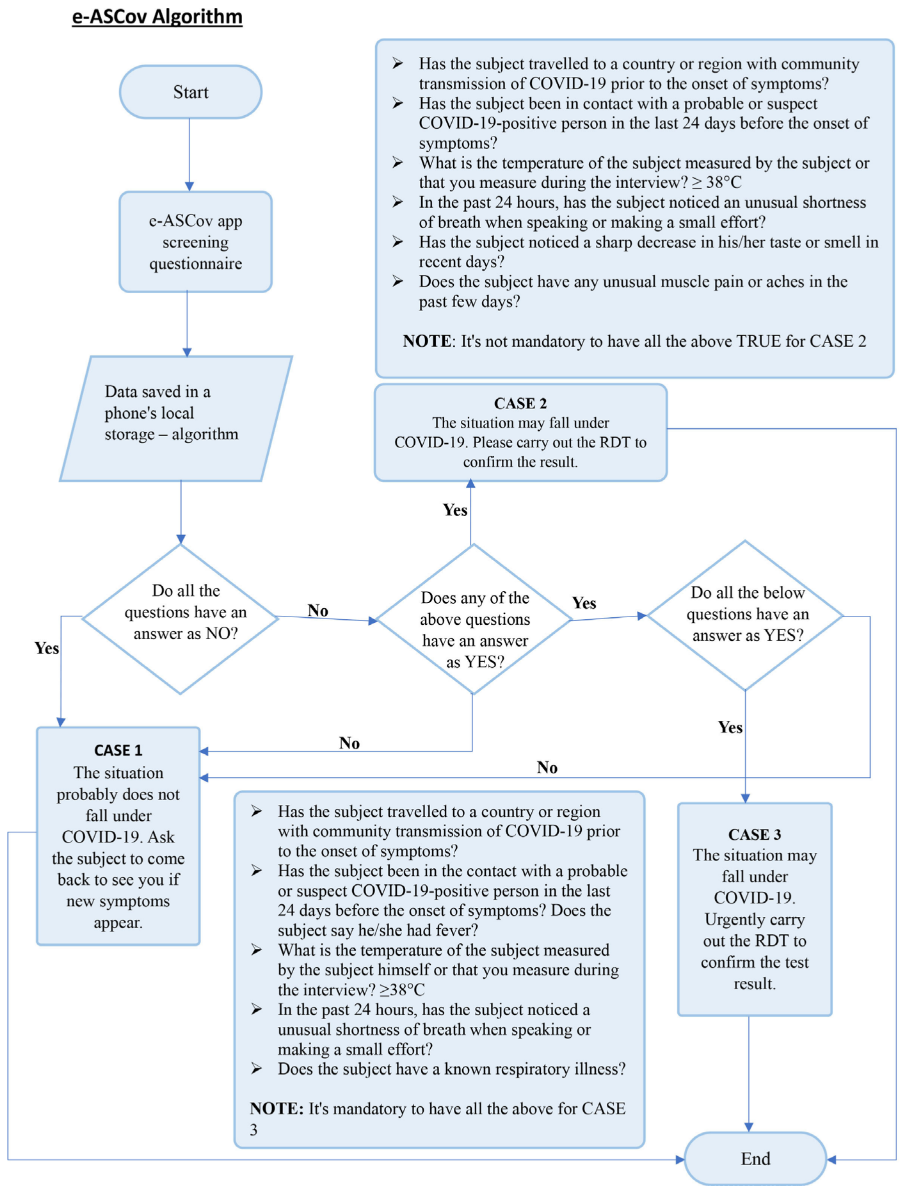

Figure 1 e-ASCov algorithm used in pilot study. RDT, rapid diagnostic test.

Digitally enabled screening and rapid testing

This study was built on the e-ASCov pilot, described previously,[9] in which CHWs identified individuals suspected to have COVID-19 and referred them for testing. The e-ASCov tool was an existing, field-tested mobile application for symptom screening to identify possible COVID-19 cases. CHWs verbally administered a screening questionnaire to individuals in their communities, which focused on signs and symptoms suggesting a risk of COVID-19, recording individual's response in the e-ASCov application. Based on the responses, an algorithm built into the application assigned participants to one of three risk levels (low risk, suspected case and urgent case)—with the latter two categories being referred for Ag-RDT testing.

The algorithm used for screening was updated to align with the latest guidance from Rwanda's Ministry of Health (figure 1), with inbuilt skip logic determining which of the case categories an individual fell into.

For this study, the RDT toolkit (developed by Dimagi)[10,11] was integrated into e-ASCov, to provide instructions for administering RDTs, a timer, and data capture for the test and result (figure 2). Originally developed to support rapid diagnostic testing for malaria, the toolkit is readily customisable for different conditions for which RDTs are used. It was thus adapted to support delivery of the SARS-CoV-2 Ag-RDTs and translated to make instructions available in Kinyarwanda.

When a CHW was prompted to conduct a test after the e-ASCov questionnaire, the workflow automatically transitioned into the RDT toolkit without the CHW having to change applications. This presented a set of instructions in Kinyarwanda. The CHW collected nasal samples for the Ag-RDT using nasopharyngeal swabs and were thereafter instructed to start the timer after initiating the test.

Rapid testing by the CHWs was conducted according to manufacturer's instructions using a validated Ag-RDT

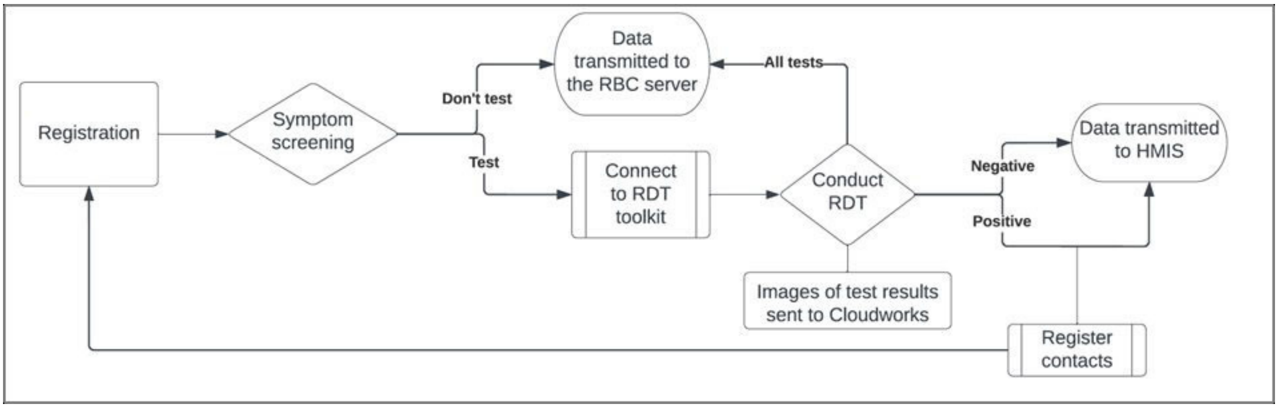

Figure 2 Study workflow. HMIS, health management information system; RBC, Rwanda Biomedical Centre; RDT, rapid diagnostic test.

(Panbio COVID-19 Ag Rapid Test Device, Abbott), which was already recommended by Rwanda's COVID-19 Laboratory Testing Guiding Principles and routinely used.[12] Using the timer on the application, CHWs read the Ag-RDT result after the processing time and recorded the result in the e-ASCov tool. There was also an option to capture and transmit images of the test result to enable validation of the result by the central team at RBC. As e-ASCov was fully integrated within the broader Ministry of Health digital system for reporting on COVID-19, data were subsequently transmitted to RBC servers in real time.

Patients who tested positive on the Ag-RDTs were referred to a nearby facility if their risk was classified as 'urgent' (case 3 in figure 1) or would otherwise be referred to the existing home-based care programme, which includes guidance on isolation and self-monitoring of symptoms. In addition, their contacts were registered and tested using the same procedure.

Evaluation of the concordance and performance of Ag-RDT

To assess the concordance of Ag-RDT results between CHWs and the laboratory technician, 499 CHWs were randomly selected and shadowed by a laboratory technician for a period of time. During that time, the CHWs administered Ag-RDTs and read the result independently, then re-read by the field trainer (observer). The result interpreted by the CHW was blinded to the laboratory technician as an operator. The laboratory technician then repeated the Ag-RDT and reported their result independently. The results from the tests performed by the laboratory technician were considered final and communicated to clients.

Assessment of the experience

The study assessed CHWs' experience of the intervention using a mixed methods approach. First, a self-administered questionnaire with close-ended questions was provided to CHWs. Second, qualitative data were collected using focus group discussions with CHWs in four districts (Rubavu, Huye, Nyagatare and Gasabo). The questions focused on e-ASCov and the administration of Ag-RDTs, in terms of usability, satisfaction, enablers and barriers, and the perceived continuity of the intervention. Interviews were conducted in Kinyarwanda and recorded with the aid of smartphones and tablet devices, then later transcribed and translated into English. Copies of questions asked as part of the focus group discussions are available in online supplemental methods.

Training and mentorship

CHWs and supervising staff at participating facilities underwent 1–2 days of theory and practical training at the district level. A refresher training was conducted on general COVID-19 information including the use of personal protective equipment (PPE), detecting symptoms of COVID-19 and follow-up of COVID-19 cases. CHWs were then further trained on screening and data capture using e-ASCov. Finally, qualified staff from the NRL provided training on how to conduct Ag-RDTs. This included a demonstration with the aid of a practical video, following which the CHWs conducted Ag-RDT testing under the supervision of facilitators. The community health supervisor and the training facilitators at the respective health centres were responsible for ensuring the distribution of materials to the CHWs and accountability in the use of these materials.

Pretraining and post-training tests were conducted to confirm participants' level of knowledge. Trainees' feedback on the digital tool also informed further refinement of the application during the training process. During implementation, ongoing mentorship was provided through existing supervisors at facilities, with additional support from RBC, particularly for resolving any operational and technological issues that arose during the study. Refresher training and technical support around using the digital tool were provided as needed, and the proportion of CHWs who needed such support was monitored.

Data management and analysis

Sample size and sampling techniques

The target sample size for Ag-RDT testing was determined by feasibility considerations, with a target of delivering up to 6816 tests to symptomatic individuals plus direct contacts of confirmed cases. Based on data from the first pilot phase of e-ASCov, in which 30% of all individuals screened were eligible for testing based on symptoms, it was estimated that close to 20 000 individuals would need to be screened to achieve the testing target. Each CHW, therefore, aimed to screen 20–25 individuals during the study period.

Data collection and sharing

Participants were given a unique number, which was used to identify the collected data. Demographic and clinical data, test results and images linked to these data were stored in e-ASCov and transmitted to the local RBC servers for integration into the national COVID-19 data system. The e-ASCov app included validation rules that prevented the skipping of mandatory questions and therefore prevented missing data.

All the information obtained in this study was kept and handled in accordance with applicable laws and/or regulations. Data were stored and archived to the RBC server in compliance with national data security guidelines per the Rwanda Information Security Authority,[13] with only authorised personnel processing the information. Data encryption and anonymisation principles were applied to safeguard confidentiality. Any access to and use of the data was subjected to the approved data-sharing agreements between different institutions that formed the study team.

Ethical Declaration

Ethical approval and consent to participate

Ethical clearance to conduct this study was obtained from the Rwanda National Ethics Committee (RNEC) No.920/RNEC/2021. As this intervention was integrated into routine Ministry of Health programming included in the CHWs' package of services, RBC secured a formal waiver of informed consent for community members to take part in the household-level COVID-19 testing through the RBC's CHWs. Thus, no additional informed consent forms were required from individuals. However, the CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation.

Regulatory

This study was conducted in accordance with the protocol and with consensus ethical principles derived from international guidelines, particularly the Declaration of Helsinki and Good Clinical Practice Guidelines: ICH GCP E6 (R2). Several measures were taken to minimise the risk of infection for CHWs or other members of the household during community-based testing, including previously described training and provision of PPE to CHWs. In addition, CHWs were trained on how to assess the households of individuals who were eligible for testing, to determine whether an appropriate space was available (in terms of size, distance from other household members and adequate ventilation). If the household did not contain such a space, testing was conducted outside of the house, in the household compound.

An author reflexivity statement is provided in online supplemental methods.

Patient and public involvement

Patients and the community were involved in the pilot, with the experience and findings used to inform the design of this study.

RESULTS

Number tested and screened

A total of 19 544 individuals were enrolled in the study and screened for signs and symptoms of COVID-19 (table 1). Of these, 4575 (23.4%) had signs and symptoms suggestive of COVID-19 infection and were thus eligible for testing with Ag-RDTs (table 1).

The proportion of those screened who reported symptoms of COVID-19 was highest in urban areas, with the highest rates observed around the capital city, Kigali, in Gasabo (35.0%) and Nyarugenge (31.2%) (table 1).

Table 1 Number of participants screened and tested

District	All screened	Number with symptoms (eligible for testing)	Percentage screened eligible for testing	Negative	Positive	Invalid	Positivity rate (%)
Gasabo	1708	598	35.0	558	14	26	2.3
Huye	1625	435	26.8	414	4	17	0.9
Kirehe	3009	787	26.2	717	8	62	1
Musanze	2549	563	22.1	513	13	37	2.3
Nyagatare	2498	465	18.6	443	1	21	0.2
Nyarugenge	2226	694	31.2	621	21	52	3
Rusizi	3254	359	11.0	345	1	13	0.3
Rubavu	2675	674	25.2	634	24	16	3.6
Total	19 544	4575	23.4	4245	86	244	1.9

Table 2 Concordance of COVID-19 testing between community health workers and laboratory technicians

Testing by community health worker	Retesting by laboratory technicians	
	Positive	Negative
Positive	3	0
Negative*	0	496
Invalid	0	0
Total	3	496
Observed agreement (%)	**100**	
Expected agreement (%)	**98.78**	
Cohen's kappa	1.0	

The Cohen's kappa agreement was assessed beyond the agreement by chance and considered the observed agreement and the expected agreement by chance, their value >0.8 show a perfect agreement or very good agreement.
*The test were administered using rapid test Ag-RDT by both CHWs and laboratory technicians.
Ag-RDT, antigen-based rapid diagnostic test; CHWs, community health workers; NRL, National Reference Laboratory.

The overall positivity rate in the study was 1.9%, and by district, was highest in the border district of Rubavu (3.6%) and Nyarungenge district (3.0%), which forms part of the capital city. A total of 244 tests, representing 5.3% of all tests conducted, were automatically flagged by e-ASCov as 'Invalid: Control Failed', as over 20 min elapsed with no result being entered in the application. The test was repeated for individuals with invalid results. There were no missing data (table 1).

Contribution to case-finding in districts

During the study period, a total of 378 COVID-19 cases were diagnosed in the eight districts. Of these, 86 were diagnosed through the study intervention, with CHWs thus accounting for 22.8% of all diagnosed COVID-19 cases during the study period (online supplemental table).

Concordance of results between CHW and laboratory technician

A total of 499 participants were tested for COVID-19 using Ag-RDT by CHWs and laboratory professionals for the concordance evaluation. Of these, three positive cases and 496 negative cases were identified by both CHWs and laboratory professionals. All the Ag-RDT results obtained by CHWs were confirmed by professional laboratory technicians, with a perfect agreement of 100% between results from the CHWs and the laboratory technicians (Cohen's kappa of 1.0) (table 2).

Feasibility

Overall, 746 out of 800 CHWs (93.3%) were able to independently conduct all study procedures without support from supervisors. This included screening using the e-ASCov application, administering nasal swabs for the Ag-RDTs and conducting the test, reporting results and sending data to the national RBC server. The remaining proportion (6.7%) of CHWs required substantive support to implement one or more of the above steps.

Qualitative assessment: satisfaction, usability and acceptability

Respondent profiles

A total of 349 CHWs participated in qualitative assessments of the testing experience. The mean age of these participants was 44 years with a range of 20–72 years. Of these, 42.1% had completed primary education and 44.1% had completed secondary education. Only 4.3% had received a university education, while 9.5% had undergone vocational training.

CHW perceptions of e-ASCov

Respondents were asked a number of questions related to their experiences with using the digital tool, with findings summarised in online supplemental table 2. The majority reported positive feedback on the experience, with main areas identified for improvement including:

- Duration of training: 28.7% of participants believed the length of training was only partly sufficient, while 16.3% believed that it was not sufficient to cover all the skills they needed to learn.
- Access to internet: close to half (48.7%) of the participants reported only partial satisfaction with internet access during the study.
- Time taken to enter data: one in five respondents stated that the time required for data entry was long, while one in three did not believe that it was short enough.

Despite these challenges, all respondents expressed the need for future use of e-ASCov, with 99.7% recommending that it should be scaled up to other disease areas.

CHW perceptions of CHW-led Ag-RDT testing

A small proportion of respondents (0.9%) expressed challenges with administering tests, although the majority (89.6%) still believed this was easy and 9.5% indicated it was slightly easy. While only 57.8% responded that the training was sufficient, 93.9% still found it easy to read Ag-RDT results, while 84.8% found it easy to report results through e-ASCov (online supplemental table 3).

DISCUSSION

This study successfully leveraged previous investments in a screen-and-refer model to enable CHWs to deliver near-patient, high-quality screening and testing for COVID-19 in Rwanda using Ag-RDTs and a mobile application. Although implementation took place during a period of low COVID-19 transmission in Rwanda, nearly a quarter of the 19 544 participants screened had signs and symptoms of COVID-19. Rates of COVID-19 were particularly high in the Kigali metropolis, where over 30% of screened individuals were identified as potential COVID-19 cases.

This indicated a higher frequency of respiratory and other symptoms in urban areas, highlighting a need for expanded and more targeted COVID-19 case finding in communities. Overall, 1.9% of tested individuals were positive for SARS-CoV-2—a significant decline from the earlier screen-and-refer e-ASCov pilot where the positivity rate was 7.5% preceding scale-up of Rwanda's COVID-19 vaccination programme.

The CHWs demonstrated an excellent capacity to perform the COVID-19 Ag-RDT. There was full concordance (100%) between the Ag-RDTs run by CHWs and those performed by laboratory professionals, which demonstrates that trained CHWs are capable of delivering Ag-RDTs with comparable quality to laboratory personnel, making the case for task-shifting of rapid diagnostic testing to the lowest levels of care providers. While PCR testing is known to be more sensitive than antigen-based rapid testing, Ag-RDTs still have a valuable role to play in detecting cases especially in resource-limited settings.[14]

Wide variations were observed in the Ag-RDT positivity rate in the study, with the highest rate found in Rubavu, a district at the border with the Democratic Republic of Congo. Across multiple disease areas, cross-border mobility has often been associated with increased spread of disease.[15 16] While this prompted widespread restrictions on international movement, especially in the earlier stages of the pandemic response, there is a lack of conclusive evidence on the effect of these restrictions on the incidence of COVID-19.[17] Nevertheless, our study highlights the role of enhanced testing to better identify high transmission areas and evaluate what measures can most effectively reduce disease transmission. Expanding access to testing through CHW-led diagnosis, as was conducted in this study, is one such way to intensify testing, particularly in environments where there is a higher risk of transmission such as densely populated urban settings and border districts.

The urban districts, Nyarugenge and Gasabo, also reported high COVID-19 positivity rates of 3.0% and 2.3%, respectively, at the time when the national positivity rate was below 1%. Community-based testing methods supported by digital tools, as deployed in this study, could be a useful approach for earlier identification of high-transmission areas such as these, by facilitating near-patient access to testing. Disaggregated data on vaccination status and previous infection per district were not collected by this study; these would be useful in interpreting the symptoms and positivity rates seen in the different districts. Towards the end of the study, there was a reduction in COVID-19 incidence and people with COVID-19 symptoms, which was also observed nationwide in both urban and rural areas.

During the study, the testing conducted by CHWs accounted for 22.8% of all cases identified in the study districts, although only 5% of the overall CHWs in the study districts were involved in the study. The disproportionately high contribution of CHWs to identifying COVID-19 cases illustrates the significant potential of this cadre of health workers to expand case finding for COVID-19 and other diseases if engaged at a larger scale.

The use of a digital tool played an important role in enabling CHWs to carry out COVID-19 testing in the community, by providing decision support and facilitating data entry. The FGDs with CHWs provided insights into this experience.

> Was understandable and didn't take much time, the way that tools were made makes everything easy, so we were 100% confident. – *An FGD participant.*

While some CHWs interviewed in the FGDs acknowledged that they initially faced difficulties with using the digital tool and indicated the need for a longer period of training, most were comfortable with the tool by the end of the study. The training was delivered in most study sites within 2 days, but the speed of learning differed across the sites and between participants. Across CHWs, training first-time users of smartphones on how to navigate the telephone took the longest time.

It was observed that younger CHWs were the fastest learners due to strong digital literacy, while CHWs with more advanced age (60 years and above) faced more challenges and required closer support from the facilitators and supervisors.[18]

> At first time the phones were going to be hard for us. Saving the information obtained from the people failed to work completely. They helped us and showed it to us how to proceed. We continued to try and end up by becoming familiar with the system. I am 90% confident. – *An FGD respondent.*

In addition to expanding access to testing, the process used in this study—Ag-RDTs combined with a digital tool—strengthened surveillance systems, and decongested health facilities and laboratories in study areas. The ability of CHWs to report directly to the national database, using unique patient codes, which has been part of Rwanda's testing architecture since the start of the pandemic, greatly enhanced the benefit of this intervention. Together the findings demonstrate the value of investing in strong digital health systems that can easily be built on to improve services.

CHWs involved in the study agreed, almost unanimously, on the need for continued delivery of Ag-RDTs by CHWs, and use of e-ASCov to support this process. Some pointed out that they were building on their experience with delivering other RDTs such as for malaria, and that expanding the range of diseases for which testing is offered would enhance quality of life for the people in their communities.

> This method of COVID testing I found is not a difficult thing, because otherwise we as CHW usually do malaria treatment…although performing malaria test and COVID-19 tests seems to be different, it is not difficult…If you know that you're going to help

> a patient who comes to you to get better life, that's something I found possible and we do, it's not too difficult. – *An FGD CHW respondent.*

> I suggest to introduce the diseases that we are normally treating in the [e-ASCov] system…it will be helpful and delivering information will be so quick. *An FGD CHW respondent.*

In other settings, the use of digital tools in community-based testing has demonstrated several benefits, including improving the assessment of disease risk based on embedded algorithms to guide appropriate triage of patients[19] and improve diagnostic accuracy.[20] The COVID-19 pandemic response also led to an unprecedented surge in the use of digital solutions to support healthcare delivery and decision-making.[8 21] However, the proliferation of different tools can increase fragmentation of the digital health architecture and contribute to misalignment between data systems,[22] limiting full visibility into patient data across different disease areas.[23] Hence, it is important to consider the fit and interoperability of digital tools within the existing digital health architecture before implementing new approaches.

Inclusion of other diseases into e-ASCov to accelerate community-based testing would help to avoid the fragmentation of the digital health architecture and enable more efficient use of resources by facilitating the diagnosis of other diseases. Increasing the ease of differential diagnosis is particularly important, given that over one in five patients in this study had illness-related symptoms that were not diagnosed as COVID-19. Such people could benefit from point-of-care testing for other diseases that may be causing symptoms similar to COVID-19, particularly febrile and respiratory illnesses. Based on the findings of this study, and the national plan to digitise the CHWs services, we are jointly developing a robust integrated community health information system that will also incorporate the contents of e-ASCov. We intend to evaluate the effectiveness and impact of the planned integrated system once developed, particularly on conditions with overlapping clinical presentations such as TB, pneumonia, COVID-19 and malaria. Demonstrating the value of an integrated community health system in Rwanda can set a precedent for other nations in Africa and in other regions to implement similar systems.

Limitations of the study include that it did not evaluate the cost-effectiveness of the evaluation, as its primary objective was to investigate if non-conventional medical staff can perform Ag-RDT testing for COVID-19, to bring testing closer to the community. Future studies would be valuable to assess the cost-effectiveness of the intervention. Although the study provides a general demonstration of the value of using CHWs to deliver community-based testing, the specifics of the intervention (eg, the number of CHWs, training required) would need to be tailored to the specific setting if rolled out more broadly.

Point-of-care diagnostics, such as Ag-RDTs, are also critical to expand access to testing and have been successfully applied as part of testing approaches for other diseases, including HIV. Evidence from systematic reviews of HIV point-of-care testing by non-laboratory workers and lay workers have demonstrated the value of point-of-care diagnostics in expanding access to health services,[24 25] reducing diagnosis delays, allowing timely treatment initiation and facilitating linkage to care.[26]

Beyond its immediate benefits for detecting diseases like COVID-19, improved community surveillance could also be used to predict and potentially avert epidemic outbreaks in the future. For example, in India's early COVID-19 response, regular analysis of syndromic data deepened the precision of hotspot predictions.[27] Establishing systems for routine collection of such data could thus be beneficial for overall pandemic preparedness.

In summary, this study demonstrated the value of a digital tool combined with Ag-RDT testing to support household-level SARS-CoV-2 detection and contact tracing by CHWs in Rwanda. The study fed into Rwanda's vision for decentralising COVID-19 services and healthcare more broadly. It also provides evidence to support the inclusion of COVID-19 rapid testing within the portfolio of diagnostic services that are already provided by CHWs in the country. The operational model—namely, point-of-care tests by CHWs, supported by digital tools for real-time clinical guidance, process management and data capture and transmission—could be scaled up nationally to enable greater access to decentralised testing for COVID-19 and other diseases across the rest of the country. Together, the findings indicate an opportunity to roll out digitally supported rapid testing for COVID-19 and other diseases to support healthcare service delivery closer to the community and evidence-based decision-making. Although this study was conducted during the COVID-19 pandemic, when Rwanda needed urgent solutions to maximise early detection and control of the disease and COVID-19 is currently endemic,[28] the lessons from this study can also be adapted for early warning of outbreaks and surveillance of other diseases. As an example, the digital approaches used in this study have subsequently been applied in the development of a national community health information system, by designing digital symptom screening and decision support integrated across the full package of services delivered by CHWs. This system has been piloted in Rwanda since 2023.

Author affiliations
[1]Rwanda Biomedical Centre, Kigali, Rwanda
[2]University of Rwanda, Kigali, Rwanda
[3]Republic of Rwanda Ministry of Health, Kigali, Rwanda
[4]Research Innovation and Data science, Rwanda Biomedical Centre, Kigali, Rwanda
[5]Independent Consultant, Kigali, Rwanda
[6]FIND, Geneva, Switzerland

X Ladislas Nshimiyimana @Ladi8n

Acknowledgements The authors would like to thank the community health workers who participated in the intervention as well as the district teams, Rwanda National Reference Laboratory, community health workers who supported the field data collection, local leaders, community members and heads of health facilities. RBC, Ministry of Health and FIND for their support. The authors would also like to thank Dimagi for the support with the technical documentation and integration of the Ag-RDT-Toolkit, and the e-ASCov project group who conducted the preceding pilot in four districts with financial support from the French National Agency for Research on AIDS and Emerging Infectious Diseases (ANRS COV17). Medical writing support was provided by Talya Underwood, Principal Writer, of Anthos Communications, according to Good Publication Practice guidelines.

Contributors The guarantor, LN, accepted full responsibility for the work and/or the conduct of the study, had access to the data and controlled the decision to publish. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Conceptualisation: LN, NB, PA, RK, OA, J-BM, J-PR and MS; Data curation: NB, HM, JM, PA, OA and MS; Formal analysis: NB, PA, HM and GR; Funding acquisition: RK; Investigation: LN, J-BM, PA, J-CSN, RR, HM, GR and BM; Methodology: PA, LN and MS; Project administration: LN; Resources: LN, J-BM, PA, J-CSN, CMM and NB; Software: JM, OA, GR, HM and MS; Supervision: LN, J-BM, PA and KS; Validation: PA; Visualisation: LN; Writing–original draft preparation: LN and PA; Writing–review and editing: all authors.

Funding The study was funded by FIND, UK (FCDO 40105983), Switzerland (81066910), Netherlands (SDD 4000004160), Canada (DFATD 7429348), The Kingdom of Saudi Arabia (FIND–ACT-A DX PARTNERSHIP 20.08.2020), The Rockefeller Foundation (2020 HTH 059), Germany (BMZ Covid-19 Diagnostic and Surveillance Response 27.07.2021), Australia (DFAT 76442), Kuwait (M239/2020), and The Government of Portugal and Partners (ANF, BCP, CGF, APIFARMA). Medical writing support was funded by FIND, according to Good Publication Practice guidelines.

Competing interests The authors J-BM, OA, KS, PA and RK disclose that they are employed by FIND. The other authors declare that no conflicts of interest exist.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval Ethical clearance to conduct this study was obtained from the Rwanda National Ethics Committee (RNEC) No.920/RNEC/2021. As this intervention was integrated into routine Ministry of Health programming included in the CHWs' package of services, RBC secured a formal waiver of informed consent for community members to take part in the household-level COVID-19 testing through the RBC's CHWs. Thus, no additional informed consent forms were required from individuals. However, the CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Data are available on reasonable request addressed to Rwanda Ministry of Health.

ORCID iD

Ladislas Nshimiyimana http://orcid.org/0000-0002-5551-6990

REFERENCES

1 Rwanda Biomedical Centre. Coronavirus Disease COVID-19, Available: https://rbc.gov.rw/index.php?id=727
2 World Health Organization. Why testing is important, 2022. Available: https://www.who.int/multi-media/details/why-testing-is-important
3 Rwanda Biomedical Centre. COVID-19 updates, 25 May 2022, Available: https://rbc.gov.rw/index.php?id=727)
4 World Health Organization. National surveys of costs faced by tuberculosis patients and their households, 2015. Available: https://www.who.int/publications/i/item/9789240065536
5 Ahmed SAKS, Ajisola M, Azeem K, *et al*. Impact of the societal response to COVID-19 on access to healthcare for non-COVID-19 health issues in slum communities of Bangladesh, Kenya, Nigeria and Pakistan: results of pre-COVID and COVID-19 lockdown stakeholder engagements. *BMJ Glob Health* 2020;5:e003042.
6 Republic of Rwanda Ministry of Health. National tuberculosis and other respiratory communicable diseases program [Annual report 2020-2021 2023], Available: https://www.ccm.rw/fileadmin/user_upload/Annual%20report%20TB%20%20ORD%202020%202021.pdf
7 Ihekweazu C. WHO Hub for Pandemic and Epidemic Intelligence, Available: https://cdn.who.int/media/docs/default-source/blue-print/07_chikwe-ihekwazu_day-1_who_grif_24-25feb2022.pdf?sfvrsn=5aacbcdf_7
8 Majam M, Msolomba V, Venter F, *et al*. Monitored Implementation of COVID-19 Rapid Antigen Screening at Taxi Ranks in Johannesburg, South Africa. *Diagn (Basel)* 2022;12:402.
9 Rwanda Biomedical Centre. Use of digital tools by community health workers in the management of Covid-19 pandemic in Rwanda, Available: https://rbc.gov.rw/rnhrr/article?code=103
10 Dimagi. Digital Solution for COVID-19 RDTs 2021, Available: https://www.dimagi.com/blog/find-covid-19-rdt-solution
11 CommCare. COVID-19 Template App: COVID-19 RDT Tracking, Available: https://confluence.dimagi.com/display/commcarepublic/COVID-19+Template+App%3A+COVID-19+RDT+Tracking?_ga=2.242944000.300957840.1697095310-828340193.1697095309
12 Ministry of Health Rwanda. COVID-19 Clinical Management Guidelines. 2021.
13 Government of rwanda. Law N° 058/2021 OF 13/10/2021 Relating to the Protection of Personal Data and Privacy, Available: https://cyber.gov.rw/index.php?eID=dumpFile&t=f&f=229&token=742569646abebc43d1ad81e3d3bee2f4f11f9639
14 Wagenhäuser I, Knies K, Hofmann D, *et al*. Virus variant-specific clinical performance of SARS coronavirus two rapid antigen tests in point-of-care use, from November 2020 to January 2022. *Clin Microbiol Infect* 2023;29:225–32.
15 Suk JE, Van Cangh T, Beauté J, *et al*. The interconnected and cross-border nature of risks posed by infectious diseases. *Glob Health Action* 2014;7:25287.
16 Ehrlich R, Montgomery A, Akugizibwe P, *et al*. Public health implications of changing patterns of recruitment into the South African mining industry, 1973-2012: a database analysis. *BMC Public Health* 2017;18:93.
17 Emeto TI, Alele FO, Ilesanmi OS. Evaluation of the effect of border closure on COVID-19 incidence rates across nine African countries: an interrupted time series study. *Trans R Soc Trop Med Hyg* 2021;115:1174–83.
18 van Deursen AJ. Digital Inequality During a Pandemic: Quantitative Study of Differences in COVID-19-Related Internet Uses and Outcomes Among the General Population. *J Med Internet Res* 2020;22:e20073.
19 Roy T, Marcil L, Chowdhury RH, *et al*. The BRAC Manoshi Approach 2011, Available: https://brac.net/sites/default/files/portals/Manoshi-book-v3-1.pdf
20 Laktabai J, Platt A, Menya D, *et al*. A mobile health technology platform for quality assurance and quality improvement of malaria diagnosis by community health workers. *PLoS One* 2018;13:e0191968.
21 Karanja S, Aduda J, Thuo R, *et al*. Utilization of digital tools to enhance COVID-19 and tuberculosis testing and linkage to care: A cross-sectional evaluation study among Bodaboda motorbike riders in the Nairobi Metropolis, Kenya. *PLoS One* 2023;18:e0290575.
22 Atun R, de Jongh T, Secci F, *et al*. Integration of targeted health interventions into health systems: a conceptual framework for analysis. *Health Policy Plan* 2010;25:104–11.
23 Muinga N, Magare S, Monda J, *et al*. Digital health Systems in Kenyan Public Hospitals: a mixed-methods survey. *BMC Med Inform Decis Mak* 2020;20:2.
24 Vojnov L, Taegtmeyer M, Boeke C, *et al*. Performance of non-laboratory staff for diagnostic testing and specimen collection in

HIV programs: A systematic review and meta-analysis. *PLoS ONE* 2019;14:e0216277.
25 Kennedy CE, Yeh PT, Johnson C, *et al*. Should trained lay providers perform HIV testing? A systematic review to inform World Health Organization guidelines. *AIDS Care* 2017;29:1473–9.
26 Pham MD, Agius PA, Romero L, *et al*. Acceptability and feasibility of point-of-care CD4 testing on HIV continuum of care in low and middle income countries: a systematic review. *BMC Health Serv Res* 2016;16:343.
27 FIND. Use of digital tools and data science to strengthen COVID-19 management: India case study 2021, Available: https://www.finddx.org/wp-content/uploads/2023/05/20210501_digital_health_report_india_FV_EN.pdf
28 Alpana R, Rajat A, Gauri A, *et al*. COVID-19 pandemic to endemic. *Int J Clin Virol* 2022;6:043–9.