Feasibility of a short message service (SMS) intervention to deliver tuberculosis testing results in peri-urban and rural Uganda

Diana Babirye[a,1], Priya B. Shete[a,b,c,1,*], Katherine Farr[a,b], Talemwa Nalugwa[a], Christopher Ojok[a], Mariam Nantale[a], Denis Oyuku[a], Irene Ayakaka[a], Achilles Katamba[a,d], J. Lucian Davis[a,e], Diana Nadunga[f], Moses Joloba[f], David Moore[g], Adithya Cattamanchi[a,b,c]

[a] Uganda Tuberculosis Implementation Research Consortium, Makerere University, P.O. Box 21696, Kampala, Uganda
[b] Division of Pulmonary and Critical Care Medicine, University of California San Francisco and Zuckerberg San Francisco General Hospital 5K1, 1001 Potrero Avenue, San Francisco, CA 94110, USA
[c] Curry International Tuberculosis Center, University of California San Francisco, 300 Frank H. Ogawa Plaza, Suite 520, Oakland, CA 94612-2037, USA
[d] Clinical Epidemiology Unit, Department of Medicine, Makerere University, P.O. Box 7072, Kampala, Uganda
[e] Department of Epidemiology of Microbial Diseases, Yale School of Public Health, 60 College Street P.O. Box 208034 New Haven CT 06520-8034, New Haven, CT, USA
[f] National Tuberculosis Reference Laboratory, Ministry of Health, Plot 106-1062 Butabika Road, Luzira, Kampala, Uganda
[g] London School of Hygiene and Tropical Medicine, Keppel St, Bloomsbury, London WC1E 7HT, UK

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ABSTRACT

Background: Pre-treatment loss to follow-up is common for patients diagnosed with tuberculosis (TB) in high-burden countries. Delivering test results by Short-Messaging-Service (SMS) is increasingly being considered as a solution, but there is limited information about its feasibility as a public health tool in low resourced settings.
Objective: We sought to assess the feasibility of utilizing SMS technology to deliver TB test results during routine TB diagnostic evaluation in Uganda.
Methods: We conducted a single arm interventional pilot study at four community health centers in Uganda that referred sputum samples to a district hospital for GeneXpert-MTB/RIF (Xpert) testing (Cepheid, USA). Using existing GxAlert-software (SystemOne,USA), we set up an automated SMS platform to send Xpert results to patients and referring health centers. We assessed each step of the SMS delivery cascade for consecutive patients who presented to these four community health centers between December 2015 and March 2016 and underwent Xpert testing.
Results: Of 233 patients enrolled, 161 (69%) had phone numbers recorded on individual Xpert referral forms. Phone numbers were entered into Xpert device software in the correct format for 152 (94%) patients. GxAlert-software generated an automated SMS reporting Xpert results for 151 (99%) patients and delivered it successfully to mobile phone service providers for 145/151 (96%). Of the 123 patients reached by phone to determine receipt of test results, 114 (93%) confirmed SMS receipt. SMS-based delivery of Xpert results was verified for 114/233 (49%) patients overall. In contrast, phone calls to health centers confirmed that health centers received messages for 222/233 (95%) patients.
Conclusion: Reporting Xpert results via automated SMS is technically feasible and results in approximately half of patients receiving their test results immediately. Additional research should be done to address process inefficiencies in order to maximize impact of this technology and link its successful utilization to improved patient outcomes.

1. Background

There are significant gaps in the cascade of care for TB diagnostic evaluation [1], which are likely the most important contributors to the nearly 4 million TB patients who go missing worldwide each year [2]. Pre-treatment losses to follow-up are a particular concern, especially in the Xpert era where patient samples must be referred and transported to offsite locations [1,3]. Among confirmed cases, a recent systematic

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* Corresponding author at: Zuckerberg San Francisco General Hospital 5K1, 1001 Potrero Avenue, San Francisco, CA 94110, USA.
  E-mail address: Priya.Shete@ucsf.edu (P.B. Shete).
[1] Authors contributed equally to this work.

review of published studies found that up to 38% of sputum smear-positive patients in Africa and 28% in Asia are lost to follow-up prior to treatment initiation [4]. In Uganda, we have shown previously that the cumulative probability of a patient with TB being referred for testing, completing diagnostic testing, and initiating treatment within 14 days of diagnosis was only 35% [5]. These data highlight the need for rapid testing and communication of test results to patients to facilitate linkage to treatment.

Digital and mobile health (mHealth) technologies are increasingly being considered as a way to improve public health measures by improving communication and linkage to care, including for TB [6–9]. mHealth technologies have become widespread with the growing use of cellular phone services in even the most remote parts of the world. Uganda, for example, has approximately 22.8 million subscribers to cellular services, representing up to 55% of the population [10]. In HIV studies, mHealth technologies have been used to test whether mobile phone text-messaging is efficacious in enhancing adherence to ART among persons living with HIV (PLWH) and also used to assess the effects of mobile phone messaging interventions as a mode of delivery for preventive health care, on health status and health behavioural outcomes [11]. However, the use of SMS has not been well studied in TB prevention and care programs [12].

We sought to assess the feasibility of utilizing SMS technology to deliver TB test results during routine TB diagnostic evaluation in Uganda by establishing a "cascade" of SMS delivery. We describe process metrics to assess the ability of the testing platform and network to send an SMS message. We also surveyed patients to establish whether each message was received, read and understood.

2. Methods

2.1. Study setting

Uganda is one of the world's 22 countries with the highest burden of TB and HIV, and the treatment coverage rate most recently reported to WHO was only 53% [2]. The Uganda National Tuberculosis and Leprosy Program (NTLP) offers diagnostic and treatment services in the public sector without charge and recently has been scaling-up GeneXpert (Cepheid, USA) testing services. A 'hub-and-spoke' model is used where sputum samples are collected from patients presenting to peripheral microscopy centers (spokes) and transported 1–2 times per week by motorbike to district-level Xpert testing facilities (hubs). Results are sent back to microscopy centers the next time samples are collected. A digital platform, GxAlert (SystemOne, USA), facilitates country-level surveillance of results transmitted to a central server hosted at the NTRL. The study was conducted at four peripheral microscopy centers in rural and peri-urban communities in Uganda that referred sputum samples to an Xpert testing hub. At the time of the study, Uganda NTLP guidelines recommended Xpert as a first-line test for PLWH, patients with a prior history of TB, children under 15, prisoners, and health care workers.

2.2. Study design and population

We conducted a single arm interventional pilot study of SMS-based reporting of Xpert results at four community health centers in rural and peri-urban Uganda. These level IV health centers (HC IV) represent one of the lowest levels of the health system where TB diagnostic services are available. Health centers were included if they use standard (multi-day) sputum smear microscopy for TB diagnosis and had the ability to refer collected sputum samples to referral laboratory facilities for Xpert testing if needed. Sites were excluded if they 1) did not agree to participation; 2) performed sputum smear examination on <150 patients per year; or 3) diagnosed <15 smear-positive TB cases per year (based on 2015 data, NTLP personal communication).

We included consecutive adults with presumptive TB who had

sputum referred for Xpert testing between December 2015 and March 2016. Patients were included if they were considered "presumptive" if they were triaged with chronic cough (>2 weeks) and/or submitted sputum samples for TB diagnostic evaluation at the health center and had their sputum referred for Xpert testing. Patients were excluded if they 1) had sputum collected for monitoring of response to anti-TB therapy; 2) had sputum collected as part of active, community-based case finding (*e.g.,* contact tracing, community outreach campaign); 3) had a documented prior history of TB treatment (*e.g.,* reason for Xpert testing or TB treatment marked as treatment failure, relapse, or treatment after loss to follow-up); 4) were referred to a study health center for TB treatment after a diagnosis was established elsewhere; 5) started on treatment for presumed extra-pulmonary TB only; 6) were less than 18 years old or 7) did not agree to receiving an SMS regarding test results at the phone number they provided. Records of eligible patients including phone numbers were obtained from facility based TB registers including Xpert referral forms. All decisions to refer sputum samples for Xpert testing were made by microscopy center staff.

2.3. Study procedures and outcomes

For this study, we partnered with Yo! Uganda, a local information technology solutions company, to establish an SMS platform to transmit Xpert test results from the national GxAlert server to a designated phone at peripheral microscopy centers and to patient phones via the mobile phone network. By standard NTLP protocol, Xpert test results were flagged for transmission to a national server housed at the NTRL after entry of data into specific GxAlert fields in the electronic Xpert form at the testing site. Once linked to GxAlert, test results were sent to the central server automatically using a setting that was configured daily into the local Xpert software. The messages were scheduled by the platform to be sent immediately to the patient's phone number and the phone number of the referring health facility once the results were submitted to the server.

Patients received messages to phone number they provided to laboratory and clinical staff at the time of symptom evaluation and TB diagnostic testing. Patients were asked at the time of testing whether they would be comfortable with test results being sent to the phone numbers listed. Messages were sent in both English and Luganda. Patients with Xpert test positive for *M. tuberculosis* (MTB) were sent an SMS that read: "[Patient's ID] test shows TB, please come to [referring microscopy center] for TB treatment if you have not already." For patients with a negative Xpert test, the following message was sent: "[Patient ID 's] tests do not show TB, but if not better come back to the Health Centre. Tests can miss TB if done too early." Messages to the referring microscopy center for gave the patient's ID and test result for both MTB positive and MTB negative results.

To evaluate the feasibility of reporting Xpert results via SMS, we activated the SMS platform only for patients with samples referred from the four microscopy centers included in the study. We worked with NTRL staff to train laboratory staff at the four participating microscopy centers on completing Xpert referral forms, and also trained laboratory staff at the four Xpert testing sites on entering patient and microscopy center information captured by GeneXpert into the GxAlert software. GxAlert training took four to six hours of training for the laboratory staff over two sessions. Entered data were reviewed daily throughout the survey and feedback on quality given on weekly intervals to participating microscopy centers.

We extracted data from the GxAlert server and the SMS platform to assess the following steps in the SMS delivery cascade: 1) inclusion of patient phone number on Xpert referral form; 2) phone numbers correctly formatted upon entry into Xpert software; 3) transmission of SMS message by the GxAlert server to the local SMS service provider (Yo! Uganda); 4) transmission of the SMS message by the local SMS service provider to the mobile phone network; 5) confirmation of receipt of the SMS message by the patient on his or her handset. We also assessed SMS

delivery cascade to microscopy centers, which was identical to that for SMS delivery to the patient until the last step which tracked SMS messages sent by the mobile phone network directly to a designated phone number at the referring microscopy center. To confirm receipt of SMS messages, we called patients and microscopy centers daily for up to three days after Xpert testing was completed. Patients who confirmed receiving an SMS with their test result were asked to summarize the message content to allow us to assess their comprehension. Patients still had the option to receive their TB results from the microscopy centers even if participating in our study. If patients were unable to be contacted after three days, we alerted referring microscopy centers and encouraged them to follow up per their standard protocols, which varied by health center and included continuing to contact patients by phone, utilizing community health workers to find patients in their village/parish, or waiting for patients to return to the health center. Finally, using data from TB registers at the study clinics, we assessed TB status for participating patients.

2.4. Statistical analysis

We summarized patient characteristics and completion of each step of the SMS delivery cascade using medians with interquartile ranges (IQR) or proportions with 95% confidence intervals (CI). We compared proportions using Fischer's exact test. All analyses were performed in STATA 12 (Stata Corp, USA).

3. Results

3.1. Patient characteristics

From December 2015 to March 2016, 233 patients from the four microscopy centers had sputum referred for Xpert testing. Median age was 38 years (IQR 27–50), and 119 participants (51%, 95% CI 45–58) were women. 230 (99%) patients had HIV status recorded, of whom 121 (53%, 95% CI 46–59) were PLWH. 232 (99.6%) patients had indications for Xpert referral recorded: being a PLWH (41, 17.7%), smear-negative microscopy (109, 47%), young child (6, 2.6%), and possible drug resistance (71, 30.6%).

3.2. SMS delivery to patients

Of 161 (69%, 95% CI 63–79) patients who had a phone number recorded on their Xpert referral form, 152 (94%, 95% CI 92–97) had the phone number entered correctly (Fig. 1). An automated SMS was generated and sent to the local SMS service provider for 151/152 (99%, 95% CI 98–100) patients by the GxAlert server. Of these messages, 145/151 (96%, 95% CI 91–99) reached the mobile phone network. Phone outreach was completed for 123/145 (85%) patients, and of those contacted, 114/123 (93%, 95% CI 88–97) confirmed SMS receipt on their mobile phone handsets. All patients who confirmed receiving the message with their test result could accurately relay the content of the message. Overall, SMS-based delivery of Xpert results was known to be successful for 114/233 (49%, 95% 43–55) patients. There were no differences in the proportions of men (46% vs. 51%, $p = 0.05$) or PLWH (53% vs. 52%, $p = 0.01$) between patients who did and not confirm receipt of test results via SMS. Median age was also similar (37 vs. 40 years, $p = 0.05$).

3.3. Variation in SMS delivery to patients across sites

At the four participating health centers, the median number of patients referred for Xpert testing during the course of the study was 117 (IQR 59–175). The proportion of patients who had phone numbers that were recorded correctly varied between 38–75%. Among patients for whom an SMS reached the mobile phone network, the proportion who confirmed SMS receipt varied between 60–89%.

3.4. SMS delivery to health centers

Contact phone numbers for the referring microscopy centers were pre-recorded in the GxAlert software. The GxAlert server generated an automated SMS to the health center for 230/233 (99%, 95% CI 97–100) patients (Fig. 2). All 230 reached the mobile phone network and health center staff confirmed receipt of 222/230 (97%, 95% CI 94–99) messages. Thus, health center staff received an SMS with Xpert results for 222/233 (95%, 95% CI 93–98) patients.

4. Discussion

To our knowledge, this is the first study of its kind to present the steps of the SMS delivery cascade in its entirety as a way to assess feasibility of SMS-based delivery of Xpert results to patients and to referring health centers. We found that automated reporting of Xpert results via SMS is technically feasible, with health center staff confirming receipt of results for 95% of patients tested and 49% of patients confirming receipt of results when an SMS was generated and delivered to the mobile phone network. However, nearly one-third of patients did not have a mobile phone or were unwilling to share their mobile phone numbers, hampering the impact of SMS as a tool for delivering TB test results. When combined with small losses at other steps in the SMS delivery cascade, ultimately, half of patients tested did not receive results. While we did not systematically collect data on reasons for those losses, inability to receive SMS results to the patient's handset was often attributed to lack of stable infrastructure to keep the handset charged, lack of airtime, or the phone not being in the patient's possession. These results are in keeping with results of other similar studies on the use of mHealth tools for TB prevention and care [12] and point to limitations for SMS based interventions.

Despite the widespread use of mobile technologies for health and non-health applications in both urban and rural settings in Uganda, the feasibility and effectiveness of mobile technologies to improve TB care delivery and adherence to the cascade of care has been equivocal [12]. Studies of the patterns of mHealth use for delivery of TB care demonstrate significant variability in patient preferences for the type of message (test result given or request to return to clinic) and mode of delivery itself (SMS versus voice call) [12]. Data to inform feasibility and scale-up of SMS technologies, such as fidelity of mHealth intervention implementation, have not been widely collected. The few studies done to evaluate the effectiveness of SMS interventions for TB specific outcomes have mostly focused on treatment adherence rather than diagnostic evaluation and linkage to care, although one study attempted to do this by improving health worker performance. This gap in the literature is unfortunate, since diagnostic evaluation is the point of the TB cascade of care with highest patient attrition in many high burden settings [6,7,11,13]. Our study demonstrates potentially significant implementation challenges for SMS interventions focused on TB diagnostic evaluation, many of which are noted challenges for the use of SMS in TB treatment adherence [6,7,11,13].

In addition to documenting the SMS delivery cascade in its entirety, a major strength of this study was the thorough follow up made to confirm delivery of SMS messages to both patients and health centers as well as to establish their level of comprehension of the message itself. In addition, we adapted the platform to a novel application, for sending messages to patients and health centers via network providers, and tracked the SMS at each node in its delivery from GxAlert platform to cellular network to individual patient handsets as well as referring microscopy centers. Tracking these steps allowed us to identify the specific point in the SMS delivery cascade to target for future quality improvement efforts to maximize the potential of utilizing SMS technology to deliver Xpert results.

The study also had several limitations. First, although our study documented some gaps in the patient cascade of SMS delivery, and in particular identified problems related to mobile phone access or phone
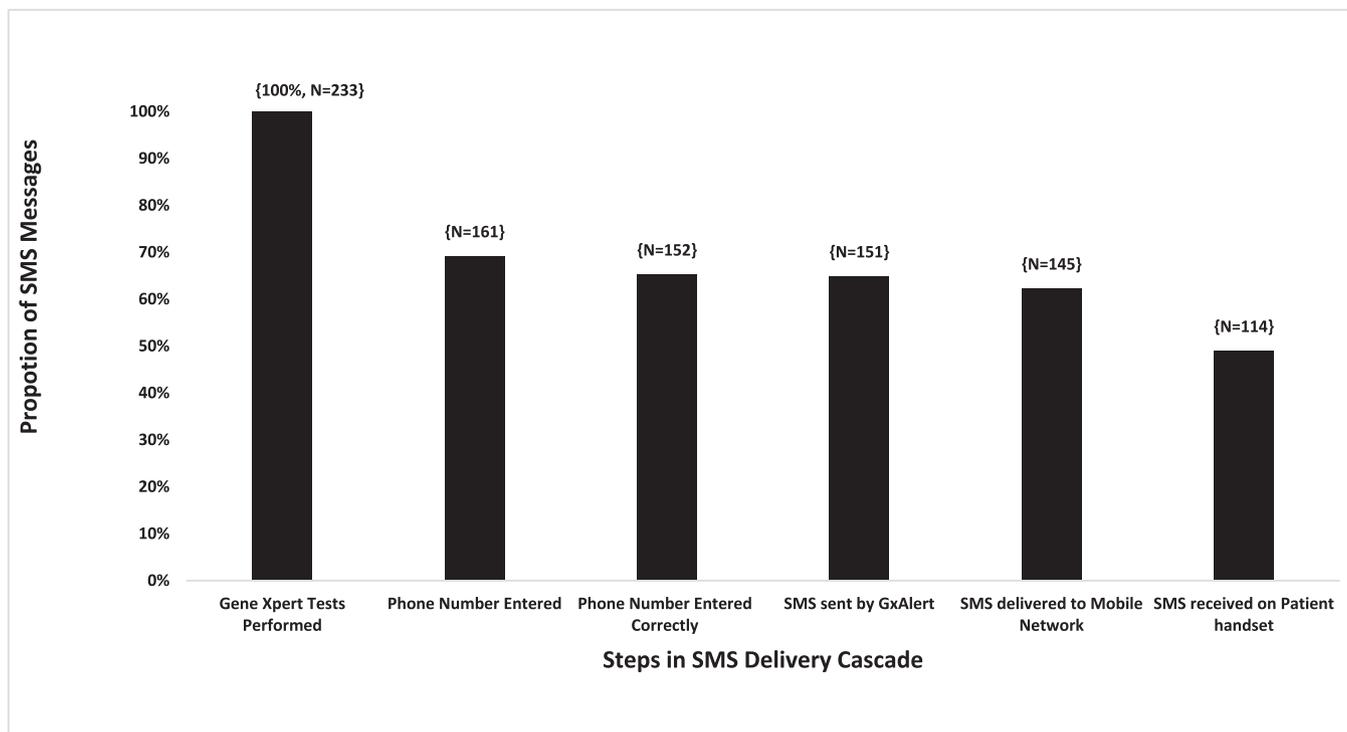
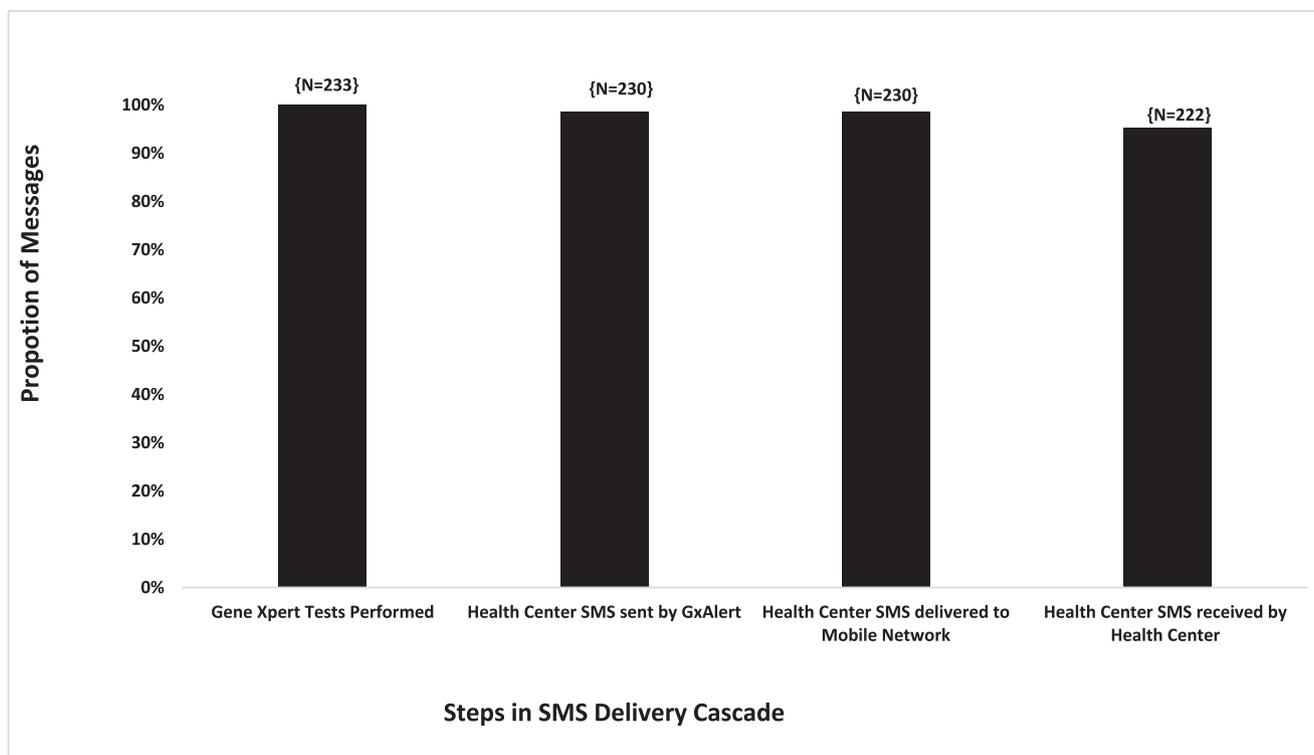**Fig. 1.** Patient SMS delivery cascade for Xpert MTB/RIF results.

Fig. 2. Health center SMS delivery cascade for Xpert MTB/RIF results.

number entry, we are not able to explain why these gaps occur. A recent study by our team described that while TB patients have an overall positive perception of receiving health messages by SMS, they felt that such messages could not replace a call from a health worker [12,14]. There was significant variability, however, in comfort with use of SMS and mobile technologies, use of handset, and types of messages that prompted patient action. Second, although we were able to link completion of the TB delivery cascade to completion of TB diagnostic evaluation, the small sample size of this pilot does not allow us to draw statistical conclusions about the potential impact of impaired SMS delivery on TB treatment initiation.

The results of our study describe a process for evaluating feasibility of SMS based mHealth tools in facilitating TB diagnostic evaluation for patients in high burden, low resourced settings. Such feasibility studies

are a necessary before the scale up of mHealth interventions that leverage SMS platforms. By testing the delivery of test results to both health care facilities and patients through a national platform, we were able to demonstrate the high fidelity of test result delivery via SMS to health facilities and the limited, more variable implementation of SMS based test result delivery directly to patients. These findings make the case for the need for context-specific formative research to improve SMS intervention delivery when used for TB prevention and care in order to maximize the potential impact of these mHealth technologies.

Steps in the cascade of SMS delivery of GeneXpert test results to the patient is presented on the Y-axis starting from testing itself through phone number entry, SMS being sent by the server, delivery to the mobile network and receipt on the patient's handset. The proportion of SMS messages successfully reaching each step is shown on the Y-axis. The number of patients for whom each SMS step was completed is noted in parenthesis. The largest attrition of SMS messages occurs because of lack of a recorded patient phone number.

Steps in the cascade of SMS delivery of GeneXpert test results to the referring health center is presented on the X-axis starting from testing itself SMS being sent by the server, delivery to the mobile network and receipt by the health center handset. The proportion of SMS messages successfully reaching each step is shown on the Y-axis. The number of patients for whom the SMS step was successfully completed is noted in parenthesis. The majority of SMS results were successfully delivered and received by the health center.

Ethics approval and consent to participate

The study was approved by the School of Medicine Research Ethics Committee at Makerere University, the Uganda National Council for Science and Technology, and the University of California San Francisco Committee on Human Research. Participants provided verbal consent prior to participation in study and phone interviews.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Data for reference

Data is available from the authors upon request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jctube.2019.100110.

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