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Remote monitoring of Xpert® MTB/RIF testing in Mozambique: results of programmatic implementation of GxAlert

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SUMMARY

SETTING: Electronic diagnostic tests, such as the Xpert® MTB/RIF assay, are being implemented in low- and middle-income countries (LMICs). However, timely information from these tests available via remote monitoring is underutilized. The failure to transmit real-time, actionable data to key individuals such as clinicians, patients, and national monitoring and evaluation teams may negatively impact patient care.

OBJECTIVE: To describe recently developed applications that allow for real-time, remote monitoring of Xpert results, and initial implementation of one of these products in central Mozambique.

DESIGN: In partnership with the Mozambican National Tuberculosis Program, we compared three different remote monitoring tools for Xpert and selected one, GxAlert, to pilot and evaluate at five public health centers in Mozambique.

RESULTS: GxAlert software was successfully installed on all five Xpert computers, and test results are now uploaded daily via a USB internet modem to a secure online database. A password-protected web-based interface allows real-time analysis of test results, and 1200 positive tests for tuberculosis generated 8000 SMS result notifications to key individuals.

CONCLUSION: Remote monitoring of diagnostic platforms is feasible in LMICs. While promising, this effort needs to address issues around patient data ownership, confidentiality, interoperability, unique patient identifiers, and data security.

KEY WORDS: tuberculosis; monitoring and evaluation; linkage to care; mHealth; eHealth; Xpert

OVER THE LAST DECADE, two major information and communication revolutions have begun that have the potential to transform how we deliver health care, particularly in low- and middle-income countries (LMICs). The first is the rapid spread of cell phone and data transmission networks around the world, and especially in LMICs.[1] The second revolution is the advent of affordable server- or Cloud-based databases and sophisticated big data analysis. These developments have spurred a growing interest in mHealth, which is defined as using mobile devices, such as mobile phones, personal digital assistants and other wireless devices to improve health care delivery.[2] Several studies have shown that specific mHealth technologies are able to improve health programs and outcomes in LMICs.[3–6] For example, mHealth programs have shown modest effects in improving tuberculosis (TB) screening, linkage to care, treatment initiation, medication adherence, and follow-up clinic appointments.[7–13] Although TB is a priority disease, as prompt treatment of pulmonary cases is necessary to prevent transmission, in most LMICs laboratory and treatment results are recorded in a paper registry and compiled on a monthly or quarterly basis.

TB disease management is one of the many health care delivery lines that could benefit from improved Information and Communication Technologies (ICTs). One of the most promising advances in TB care is the recent advent of molecular diagnostic tools for *Mycobacterium tuberculosis* and for drug resistance. The Xpert® MTB/RIF assay (Cepheid, Sunnyvale, CA, USA) is a highly sensitive, rapid, fully automated molecular test that uses real-time polymerase chain reaction on sputum specimens to simultaneously detect *M. tuberculosis* and to screen for rifampin (RMP) resistance, a strong marker for multidrug-resistant TB (MDR-TB).[14,15] Xpert was first recommended by the World Health Organization (WHO) in 2010, and has been widely deployed in LMICs.[16–18]

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Diagnostics, TB REACH and several for-profit diagnostic companies are investing in mHealth connectivity solutions for Xpert in LMICs that lack well-developed Laboratory Information Systems (LIS) or Electronic Medical Records (EMR). Within the past 3 years, three new remote monitoring solutions have been developed that use Cloud-based technologies to disseminate real-time Xpert test results. These innovative solutions include RemoteXpert (Cepheid), GxAlert (SystemOne, Boston, MA, USA), and XpertSMS (Interactive Health Solutions, Karachi, Pakistan). These technologies have the potential to improve patient treatment, such as linkage to care in the TB care cascade, programmatic monitoring and evaluation of test results and key indicators, and logistics management of Xpert cartridges and machine performance/maintenance. This paper compares these three remote monitoring platforms and describes in detail our experience implementing GxAlert in Mozambique.

SETTING

Disease context

In 2013, an estimated 9 million people developed active TB and 1.5 million died; however, only 6.1 million received a diagnosis, started appropriate treatment and were reported to National TB Programs (NTPs).[19] Of the new TB cases diagnosed each year, a growing number, approximately 480 000, are thought to have MDR-TB, which is a much more challenging disease to diagnose, treat, and cure. In 2013, 137 000 patients were diagnosed with MDR-TB, yet only 87 000 started treatment and just 40 000 were cured.[19] These statistics highlight the major leakage points within the TB and MDR-TB care cascade.

Country context

Mozambique is one of the world's 22 high TB burden countries. The WHO estimated the TB incidence rate in Mozambique at 552 per 100 000 population in 2013, i.e., about 140 000 cases.[20] However, only 37% of these estimated cases are diagnosed and notified; 56% of TB patients in Mozambique are co-infected with the human immunodeficiency virus (HIV).[20] In 2013, an estimated 3.5% ($n = 4900$) of the 140 000 new TB cases in Mozambique had MDR-TB; however, only 313 patients (~6.4%) with MDR-TB started treatment.[21] Given the increasing prevalence of MDR-TB and the global threat of this disease, improved MDR-TB diagnostics and access to treatment are a priority for the Mozambican NTP and the global health community. Xpert testing pilot projects began in 2011 in Mozambique, and currently an estimated 35 Xpert machines have been implemented throughout the country, including five in central Mozambique.[21]

Mozambique has a well-established NTP. Laboratory results for TB testing are kept in handwritten registries at each health center, compiled by hand and reported on a quarterly basis to provincial and national level. Mozambique does not currently have an electronic register for cough, laboratory results (for smear microscopy or Xpert), or patient records. As a result, the first GeneXpert machines installed in Sofala and Manica did not have internet connections, and were not networked. Despite being on a computer, Xpert results were extracted manually from each site, compiled, and reported quarterly. This impeded real-time, effective oversight of the Xpert testing program on a national level, and hindered effective management of the expensive cartridge inventory. Furthermore, MDR-TB provincial leaders were frequently not notified about RMP-resistant patients in a timely manner, and almost half of these patients were not started on appropriate treatment for MDR-TB.[21]

MATERIALS AND METHODS

The NTP sought to develop a remote monitoring system for the growing GeneXpert network in Mozambique, much like the online system used by the Mozambican HIV program to monitor testing with the Alere PIMA™ CD4 machines (Waltham, MA, USA). The NTP, with support from Health Alliance International (HAI; Seattle, WA, USA), an implementing partner, deployed five Xpert machines, each with four modules, at the principal district ($n = 2$) and urban ($n = 3$) public hospitals in Sofala and Manica Provinces, beginning in February 2012. Details of this process, the testing algorithm, and monitoring are described elsewhere.[21] The NTP worked with HAI to develop a target product profile in late 2013 for a remote monitoring platform and to research and evaluate three connectivity solutions to pilot for the growing GeneXpert network in Mozambique with support from a TB REACH grant.

We evaluated three remote monitoring platforms for GeneXpert: Cepheid RemoteXpert, XpertSMS, and GxAlert (Table 1). Cepheid plans to release RemoteXpert in 2015.[22] Overall, we determined that GxAlert was the best fit for Mozambique. GxAlert was originally designed to create an Xpert network in countries where EMR or LIS are not widely available. Unlike XpertSMS, GxAlert incorporates a user-friendly interface that does not require EMRs or an LIS to analyze data. The GxAlert platform extracts information from Xpert and sends it to a secure Cloud-based or in-country server. We also wanted a product that would allow for the transmission of patient health information, which is particularly important for local ministries so that they can generate reports and ensure that patients who test positive for *M. tuberculosis*, and especially for RMP

Table 1 Comparison of three remote monitoring tools for Xpert® MTB/RIF

Features	Cepheid remote Xpert monitoring tool*	XpertSMS	GxAlert
Secure data transmission and storage	Yes	Yes	Yes
Location of data server	Cepheid secure Cloud	Secure Cloud or in-country server	Secure Cloud or in-country server
Ability to transmit patient identifying data†	No	Yes	Yes
Uploads data automatically once connected to the internet	Yes	Yes	Yes
Compatible with OpenMRS® EMR	No	Yes	Easily connectible‡
Supports automated SMS to health care providers	No	Yes, used with OpenMRS® or other EMR	Yes
Allows uploading of data from different diagnostic companies	No	Yes	Yes
Can be configured to generate automatic reports	Yes	Yes if used with OpenMRS, GxAlert or other EMR	Yes
Availability	March 2015	Now	Now
Estimated cost	Free to low-income countries but only for GeneXpert machines that have an active service and warranty package	Software is open source and free, additional fees for formal technical support if desired	Software is open-source and free, additional fees for formal technical support if desired
Developed by a third party relative to Cepheid	No	Yes	Yes
Requires internet connection	Yes, may require wired ethernet	No§	Yes
Xpert cartridge inventory management tool	Possibly¶	No¶	Yes
Allows downloading of all patient and test results into Excel or csv file	No	Yes	Yes

* Not available at time of submission. Data regarding Cepheid remote monitoring tool based on e-mails and personal communication with platform developer and Cepheid data management team.
† Allows for upload of data from Patient ID, Sample ID or Notes field. Patient ID could be entered in this field, but not always (one can use a unique patient identifying number).
‡ One can develop a system for GxAlert to communicate with electronic medical records with existing or easily modifiable APIs. An API was recently released to create interoperability between XpertSMS, GxAlert, and GenXChange.
§ XpertSMS allows results to be sent to the server either from SMS or internet.
¶ But inventory management could also be done outside the system, or in GxAlert.
SMS = short message service; EMR = Electronic Medical Records; API = application programming interface.

resistance, are treated appropriately—this was reportedly not going to be possible using Cepheid's RemoteXpert system. As a third party platform, GxAlert was attractive because it offered the possibility of uploading results from other diagnostic platforms not made by Cepheid, such as Alere PIMA, *M. tuberculosis* culture, etc.

The Mozambican Ministry of Health (MOH) approved Xpert for general use and the NTP approved this pilot and subsequent expanded implementation of GxAlert. As this implementation project was not a formal research study, the University of Washington (Seattle, WA, USA) institutional review board (IRB) declined to provide a full review of the proposal.

RESULTS

GxAlert installation on Xpert computers

We first used commercially available USB internet modems to confirm that each GeneXpert computer could connect to the internet. We then performed a one-time installation of OpenVPN (OpenVPN Technologies, Pleasanton, CA, USA) on each GeneXpert computer, and entered a unique data encryption key. This process allows Xpert results to be encrypted during transmission via Cepheid's LIS connector to a secure, HIPAA (Health Insurance Portability and Accountability Act) compliant, Cloud-based database.[23] Xpert software 'Host Communication' settings were then changed to make sure that the Xpert results were directed to the appropriate internet protocol address associated with the secure GxAlert database and to automatically upload all recent test results every time the Xpert diagnostic software detected a viable internet connection.[23]

Establishing the GxAlert web-based interface

We worked with SystemOne to develop a unique, password protected, web-based portal for the Mozambique GxAlert pilot project. In partnership with the NTP, we identified a list of users —the Mozambican provincial and national level MOH laboratory and NTP staff— who were given a secure login and password to review summary and individual Xpert results, and defined the scope of their access — district, provincial or national level data —and if they could see patient-identifying information. We also created a database of 'contacts', primarily laboratory technicians and TB treatment nurses at each facility,

Table 2 Xpert results by health facility

Xpert site	Total tests *n*	*M. tuberculosis* *n* (%)	MTB+/ RIF− *n*	MTB+/ RIF− %	MTB+/RIF− indeterminate *n* (%)	MTB+/RIF+ *n*, % of all TB tests	Invalid *n*	Errors *n*	Test invalid/ error %
Gaza: Xai Xai	454	310 (68)	99	22	1 (0.2)	18 (15)	6	20	6
Gaza: Chokwe	239	189 (79)	28	12	0 (0)	4 (13)	10	8	8
Gaza: Manjacaze	533	407 (76)	84	16	3 (0.5)	13 (13)	19	7	5
Manica: Ed Mondlane	4729	3820 (80)	556	12	45 (0.1)	34 (6)	104	170	6
Manica: Gondola	3404	2646 (78)	384	11	27 (0.7)	23 (6)	53	271	10
P Maputo: Boane	389	282 (72)	56	14	10 (3)	17 (23)	1	23	6
P Maputo: Machava 2	662	435 (66)	162	24	10 (1.5)	34 (17)	5	16	3
Sofala: Ponta Gea	4574	3464 (76)	688	15	33 (0.7)	39 (5)	85	265	8
Sofala: HC Beira	9078	7065 (78)	1281	14	76 (0.8)	141 (10)	150	365	6
Sofala: Nhamantanda	5185	4221 (81)	501	10	28 (0.5)	75 (13)	127	233	7
Total	2947	22 839	3839		233	398	560	1378	7

MTB = *M. tuberculosis*; RIF+ = rifampin resistance; RIF− = rifampin-susceptible.

and entered their cellphone and e-mail addresses, but did not provide them with access to the online database. Finally, we developed key tabs within GxAlert so that users could 1) review a summary page; 2) review the performance of each device (error rates, kinds of errors, numbers of tests run per time period, summary of positive and negative test results); 3) access individual test results; 4) access the cartridge management tool; 5) develop and edit automated SMS and e-mail notifications; and 6) add, delete or edit contacts and users (see Results for examples).

Development of automated SMS and e-mail messages

We developed four specific automatic SMS messages (without patient identifying information) with the Mozambican NTP and SystemOne, which were triggered by the following events: 1) an SMS message to local laboratory technicians and TB nurses when an *M. tuberculosis*-positive, RMP-susceptible patient result was uploaded to GxAlert; 2) an SMS message to local laboratory technicians and TB nurses when an *M. tuberculosis*-positive, RMP-indeterminate patient result was uploaded; 3) an SMS message to local laboratory technicians, local TB nurses, the provincial MDR-TB point person, and the national MDR-TB point person when an *M. tuberculosis*-positive, RMP-resistant patient result was uploaded; 4) and finally, an SMS message to local laboratory technicians when they had not connected the GeneXpert machine to the internet and sent results to GxAlert for more than 3 days. Examples of these messages can be seen in Appendix Figure A.1.*

We also created a monthly and quarterly summary Excel file with the following indicators: 1) the total number of Xpert tests performed at each site; 2) the average number of tests run per day; 3) the total number and percentage of *M. tuberculosis*-positive Xpert tests by RMP resistance status at each site; 4) the total number and percentage of failed tests at each site; 5) the types of error results at each site; 6) the estimated number of Xpert cartridges remaining at each site; and 7) based on actual Xpert usage rates, the predicted date at which each site will run out of cartridges to aid in replenishing stock and to avoid expiry of unused cartridges.

GxAlert results

GxAlert software was successfully installed on all five GeneXpert machines in June 2014. To date, more than 29 000 Xpert test results have been uploaded to GxAlert (see Table 2), including five additional Xpert testing sites recently connected in Southern Mozambique and linked to GxAlert. Since July 2014, 13 000 new test results have been uploaded in GxAlert, more than 2000 of which were *M. tuberculosis*-positive. These have resulted in more than 8000 SMS notifications to key personnel, including laboratory staff, TB nurses, and NTP managers, notifying them about patients who tested positive for *M. tuberculosis*, and the results of RMP resistance testing (Appendix Figure A.2): 44 individuals were entered as users, and 45 as contacts, 35 of whom have logged into GxAlert and 15 of whom logged in during the 30 days before 18 March 2015. Several important challenges noted during this process are described in Table 3.

GxAlert interface

Overall, the preliminary anecdotal reports of the GxAlert online interface were positive, but have not been systematically collected or analyzed. Initially, GxAlert was only available in English, but it has recently been translated into Portuguese, the official language of Mozambique. It was relatively simple to work with the product developers to change the online interface, modify SMS alerts, manage users/ contacts, and to generate automated monthly and quarterly e-mail reports. Appendix Figures A.3 and A.4 provide representative images from the online GxAlert platform.

* The appendix is available in the online version of this article, at http://www.ingentaconnect.com/content/iuatld/ijtld/2016/00000020/00000003/art00012.

Table 3 Responses to technical and logistical challenges encountered when implementing GxAlert for remote monitoring of Xpert® MTB/RIF in Mozambique

Challenge	Reason	Response
Software installation	Complex, multistep process requiring moderate to sophisticated computer skills	Provide additional training to HAI and NTP staff, step-by-step job aids SystemOne has developed a simplified one-click installation software package called GxConnect (Itec, Gauteng, South Africa) that transmits results to GxAlert with a secure API, eliminating the need to install and use the OpenVPN software
Internet connectivity	One site did not have adequate USB modem signal strength Variable internet signal strength with different cell phone companies	We were able to utilize a local cable modem internet connection used by another project Trial USB modems with different cell phone companies and use the one with the best and most consistent signal
GxAlert online access and utilization	Some MOH staff lost the website address, login and password	Continue to send reminders to review Xpert data We are developing a tracking tool within GxAlert to see which MOH staff are logging into the system and how frequently, and will provide targeted feedback and outreach to those that are underutilizing the program
Lusophone staff struggling with English software	Software was initially only available in English	We created automatically generated SMS and e-mail reports in Portuguese We worked with GxAlert to translate the web-based interface into Portuguese
GxAlert only uploads results from Xpert	Other diagnostic platforms are not currently designed for remote monitoring	We are exploring the ability of other platforms such as the Alere PIMA™ system, MIDGET TB culture and others to upload results into GxAlert
Paying for internet connectivity	Commercial modems allow laboratory technicians not only to upload Xpert results to GxAlert, but also to access the internet	We are exploring ways to lock the modems, uninstall web browsers, and to effectively monitor appropriate utilization of Xpert computers and internet connections
Daily internet connection	Internet cell phone networks are frequently overwhelmed during business hours, or inaccessible	Connect to the internet early or late in the day when there is less traffic, allowing for rapid result uploads Develop systems that will allow Xpert to be connected constantly to the internet via a USB modem, allowing for real-time transmission of results instead of requiring an individual to connect to a modem each day
Underreporting of failed Xpert tests	It appears that Cepheid does not currently allow the transmission of 'incomplete' Xpert tests via the LIS—this category of results appears to primarily include those tests that were not completed due to electrical outages, a not infrequent problem at our sites	Further study this problem, and work with Cepheid to allow for the transmission of these 'incomplete' test results via the LIS SystemOne's new software package, GxConnect, overcomes the Cepheid LIS software obstacle and allows the transmission of these 'incomplete' test results
Managing digital database	Limited resources of MOH to manage and oversee digital information	Provide training and resources for MOH officials to manage this system and digital information

HAI = Health Alliance International; NTP = National Tuberculosis Program; API = application programming interface; MOH = Mozambican Ministry of Health; LIS = Laboratory Information Systems.

DISCUSSION

Overall, the installation of GxAlert was moderately complex, but ultimately successful at all of our sites. To simplify the installation process and to ensure that 'incomplete' test results (those that were terminated due to electrical outages, but which Cepheid does not currently allow to be sent via the LIS) were transmitted, SystemOne recently created a simpler one-click installation package. This product overcomes the Cepheid LIS connector limitation and transmits all results (including those that are incomplete), and uses a secure application programming interface to encrypt transmission of data to the online server, eliminating the need to install Open VPN. This new product requires additional testing, but should further improve the reliability and security of the Xpert network in Mozambique.

As noted in Table 3, we experienced a variety of internet connectivity challenges that our team and internet providers need to address to take full advantage of this platform. Furthermore, we would like to create a system where GeneXpert computers are constantly connected to the internet and the results are uploaded immediately and automatically, thereby removing the need for laboratory technicians to actively connect each day. We are currently in the process of developing and piloting several solutions to these issues in Mozambique. With the exception of HIV patients, Mozambique does not currently have unique patient identifiers, which makes trying to reconcile TB testing data to TB treatment data challenging, especially if the patients are diagnosed at one site and treated at another.

In 2015, Cepheid released version 4.6a of the

GeneXpert DX software that is used on GeneXpert machines. While this software update included many improvements, it blocked a few important data fields utilized by GxAlert and other LIS connectors. Some programmatic monitoring and evaluation (M&E) efforts were therefore interrupted. After receiving feedback from programs and partners, Cepheid pledged to reinstate the blocked fields with their next software release.[24] This episode highlights the importance of having new diagnostics that are increasingly connected, but that are designed in partnership with the programs to align with public health standards of data publication/transmission and best practice. If done well, it can foster a closer relationship between device makers and users both to drive consumption and to best serve patients.

This project helped to highlight the need for LMICs to develop comprehensive patient data management strategies, and to determine how they want to consume mHealth data. In particular, LMICs need to address issues such as data security, data transmission, data storage, data ownership, interoperability between different databases and systems, the need for unique patient identifiers, and the growing need to provide internet access at health care facilities to facilitate real-time communication of test results. Failure to address these challenges may lead to significant fragmentation and may impede efficient patient care and hinder effective M&E.

As products offer different advantages and disadvantages, it may be useful to use two or more products in parallel instead of one. For example, GxAlert is easier to use for monitoring and evaluating patient information, MOH supply chain and logistics, and external quality assurance programs, while RemoteXpert provides better technical support, as the GeneXpert machines can be monitored by their manufacturer. This field continues to change rapidly, and it is also possible that Cepheid may decide to allow the transmission of patient health information, which would make their product more attractive.

While this was not a formal research project, there is a need to evaluate the impact of these remote monitoring tools on patient care (appropriate treatment initiation rates, time to treatment initiation), and M&E efforts, and to understand how front-line and national TB health care workers currently use and want to use this platform. We are in the process of undertaking a formal IRB-approved evaluation of GxAlert in Mozambique to see if it has any impact on patient care.

In conclusion, remote monitoring of electronic diagnostic platforms is feasible in LMICs and has the potential to be part of the ICT backbone for the next generation of TB control strategies.

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Conflicts of interest: none declared.

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APPENDIX

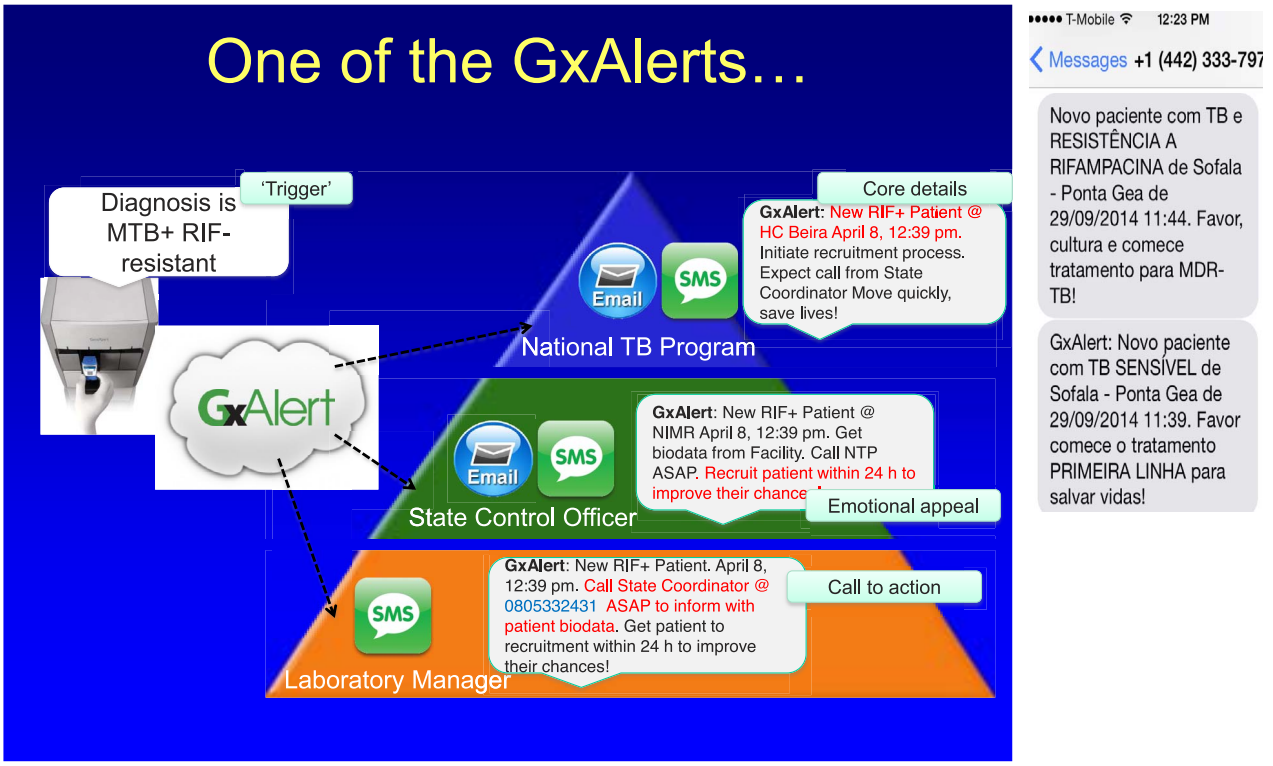

Figure A.1 GxAlert SMS notifications. NIMR = National Institute for Medical Research; NTP = National Tuberculosis Program; ASAP = as soon as possible; SMS = short message service.

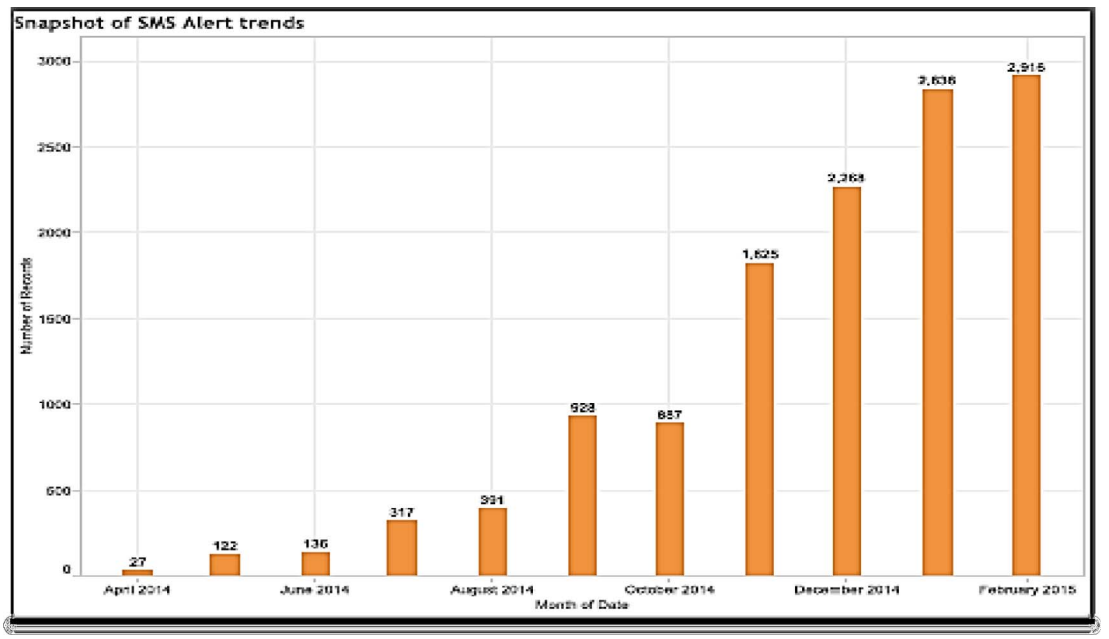

Figure A.2 SMS alert trends for GxAlert in Mozambique. SMS = short message service.

Figure A.3 GxAlert dashboard for all Xpert testing.

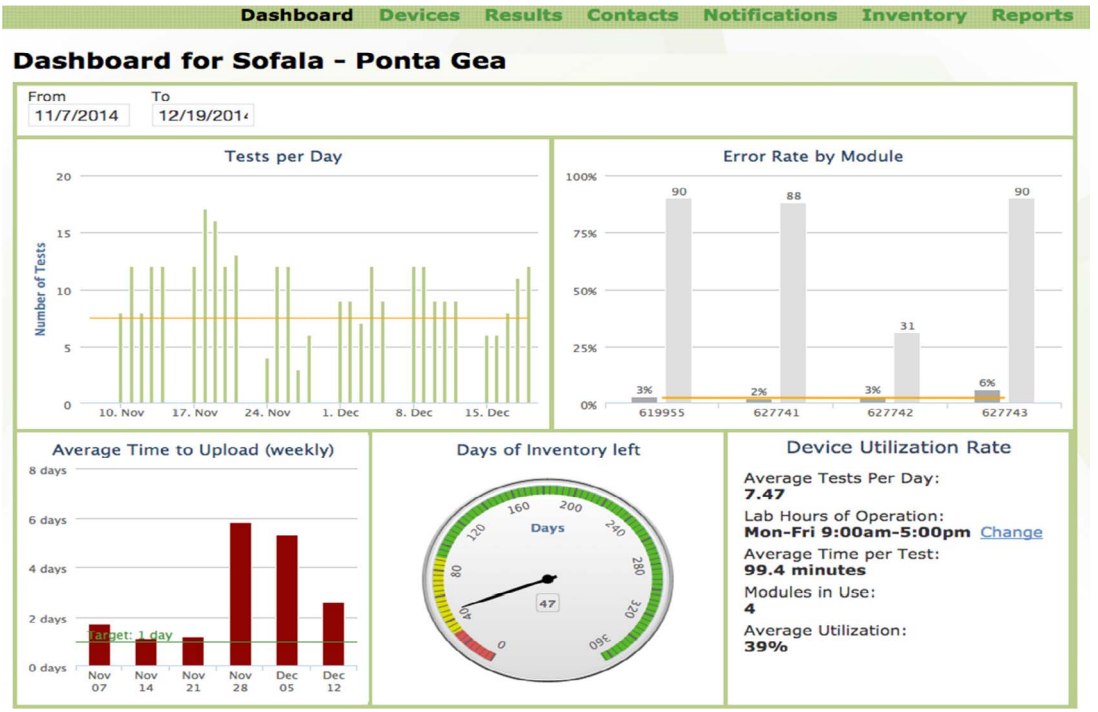

Figure A.4 Dashboard for individual Xpert machine.

RESUME

CONTEXTE : Les tests de diagnostic électronique, comme Xpert® MTB/RIF, sont en cours de mis en œuvre dans les pays à revenu faible et moyen (LMIC). Cependant, les résultats rapides qui pourraient être obtenus par un suivi à distance sont sous-utilisés. Le fait de ne pas transmettre en temps réel des données décisionnelles aux personnes clés comme les cliniciens, les patients et les équipes nationales de suivi et d'évaluation peut avoir un impact négatif sur la prise en charge des patients.

OBJECTIF : Décrire les applications récemment développées qui permettent un suivi en temps réel à distance des résultats de l'Xpert et la mise en œuvre initiale de l'un de ces produits au centre du Mozambique.

SCHÉMA : En partenariat avec le Programme National de lutte contre la Tuberculose du Mozambique, nous avons comparé trois outils différents de suivi à distance de l'Xpert et nous en avons sélectionné un, le GxAlert, pour le piloter et l'évaluer dans cinq centres de santé publics du Mozambique.

RÉSULTATS : Le logiciel GxAlert a été installé avec succès dans les cinq ordinateurs Xpert et les résultats des tests sont maintenant téléchargés tous les jours grâce à un modem USB vers une base de données sûre en ligne. Une interface web protégée par un mot de passe permet une analyse en temps réel des résultats des tests et 1200 tests positifs pour la tuberculose ont généré 8000 notifications de résultats par SMS aux personnes concernées.

CONCLUSION : Le suivi à distance des plateformes de diagnostic est faisable dans les LMIC. Même s'il est prometteur, cet effort doit aborder les questions relatives à la propriété des données par le patient, à la confidentialité, à l'interopérabilité, aux identifiants uniques pour chaque patient et à la sécurité des données.

RESUMEN

MARCO DE REFERENCIA: Las técnicas informatizadas de diagnóstico de la tuberculosis (TB), como la prueba Xpert® MTB/RIF, se han introducido en los países con bajos y medianos recursos (LMIC). Sin embargo, aún se subutiliza la información oportuna que podrían aportar gracias a la supervisión a distancia. El omitir la trasmisión inmediata de la información con utilidad clínica a los principales interesados como los médicos, los pacientes y los equipos nacionales de evaluación y seguimiento puede tener consecuencias negativas en la atención a los pacientes.

OBJETIVO: Describir las aplicaciones desarrolladas recientemente que hacen posible un seguimiento inmediato y a distancia de los resultados de la prueba Xpert y evaluar la introducción de uno de estos dispositivos en la zona central de Mozambique.

MÉTODOS: En colaboración con el Programa Nacional contra la Tuberculosis de Mozambique, se compararon tres dispositivos diferentes de seguimiento a distancia de la prueba Xpert y se escogió el programa GxAlert, con el fin de realizar un estudio preliminar y evaluar cinco establecimientos públicos en el país.

RESULTADOS: El programa GxAlert se instaló adecuadamente en los cinco computadores dedicados a la prueba Xpert y ahora es posible colgar los resultados de la prueba a una base de datos segura en línea, por conducto de un módem USB. En la web, una interfaz protegida por contraseña permitió analizar de manera inmediata los resultados de la prueba y los 1200 resultados positivos para TB generaron 8000 SMS de notificación de los resultados a los principales interesados.

CONCLUSIÓN: El seguimiento a distancia de las plataformas diagnósticas es factible en los LMIC. Esta iniciativa es promisoria, pero quedan por solucionar aspectos relacionados con la propiedad de los datos del paciente, la confidencialidad, la interoperabilidad, los identificadores únicos de los pacientes y la seguridad de los datos.