SmartTB: An Innovative Digital Data-Driven Platform for Enhancing Tuberculosis Treatment Monitoring in Tanzania

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Abstract

Tuberculosis is known to be a killer disease in Tanzania. Despite this, deaths can be reduced if patients are diagnosed early and receive treatment. The treatment duration is extended, and patients are required to visit healthcare clinics regularly for medication procedures. Ensuring proper observation of treatment procedures is essential for successful outcomes. In Tanzania, TB treatment is provided free of charge to curb transmission and prevent drug resistance. However, many TB patients discontinue treatment due to forgetting clinic visits on scheduled dates. To address this challenge, an innovative digital data-driven TB treatment monitoring platform called SmartTB has been developed. SmartTB serves as a reminder for patients' treatment schedules and offers real-time reporting. This study utilized the agile methodology to gather requirements from three Tanzanian hospitals and develop the system. User acceptance testing validated the system's performance, demonstrating its capability to support TB patients' treatment monitoring and data management. Nevertheless, SmartTB has not been launched for operational use, necessitating effective cooperation from stakeholders, including healthcare providers and policymakers, to ensure its integration into the country's healthcare system

Keywords: Data management, TB, Medication, Non-adherence, Healthcare.

Introduction

The evidence indicates that many people in Tanzania die due to tuberculosis (TB). However, the deaths can be reduced with proper treatment. A plan for successful TB treatment involves taking a number of different antibiotics for several months (World Health Organization, 2017). In this conception, TB treatment lasts for a long period of time, and a patient is required to visit a healthcare clinic for medication procedures. It is invaluable for TB patients to observe the treatment procedures for a successful outcome, and the government of Tanzania has made some efforts, including the provision of free TB treatment (Nahid *et al.,* 2019). However, TB patients frequently stop treatment because they forget to go to the clinic for medication on the scheduled dates (Mpagama *et al.,* 2020). Furthermore, Directly Observed Treatment (DOT) nurses face challenges in accurately recognizing the number of TB patients who miss doses, which results in poor reporting.

The consequences of the non-adherence of the TB patients to the treatment include drug resistance, treatment failure, and relapse (Ruru *et al.,* 2018). The patients are required to attend clinics every one week when in the initial phase and every two weeks for those in the continuation phase (Sumari-de Boer *et al.,* 2019). A DOT nurse must make sure that TB patients adhere to the specified course of treatment in order to reduce the transmission of the disease. Non-adherence to treatment is a major problem in TB control, and thus TB treatment and monitoring in Tanzania face a mounting task (Verma *et al.,* 2019).

Tanzania is one of the countries that uses digital adherence technologies (DATs) to monitor tuberculosis medication adherence. The DATs used in Tanzania include a District Health Information Software 2 tracker (DHIS2 tracker), which is a web-based application that supports data collection and analysis of transactional

or disaggregated data (Successful TB reach Report, 2020). The DATs are a patient-centric approach and have shown great importance in TB health care delivery services and messaging (Awad *et al.,* 2021). To improve the DATs, there must be a digital system that can capture the entire continuum of care to promote adherence to treatment among people living with TB in Tanzania (USAID, 2019).

Among the available TB patient tracking systems are digital healthcare technologies such as eHealth that encompass a wide range of wearable devices and systems such as the Electronic Health Records System (EHRS), Mobile Health (M-Health) System, Telehealth Platform, and an online eLearning Platform (Lupton, 2014; UNITED REPUBLIC OF TANZANIA, Ministry of Health, Community Development, Gender, Elderly and Children, 2019). Despite the adoption of digital healthcare technologies in Tanzania, there is no system that can monitor TB patients to improve adherence to TB medication. The World Health Organization's End TB Strategy suggests a necessity for the development of patient-centric digital systems that support collaboration between patients and healthcare professionals and reduce TB deaths (World Health Organization, 2017). Hence, there is a need to implement a digital platform that can monitor TB treatment in Tanzania (USAID, 2019). Therefore, the aim of this paper is to develop an innovative digital data-driven TB treatment monitoring platform called SmartTB that reminds patients of their treatment schedules.

Materials and Methods
SmartTB development

This study used an agile methodology to develop a SmartTB system. The motive behind this methodology is the ability to engage healthcare professionals in any phase of system development to meet user requirements. Furthermore, it supports effective collaboration between developers and users of the system. The SmartTB system developed in this study has four main functions, as shown in Figure 1. This is because monitoring of patient treatment is preceded by the normal processes of the hospital, such as registration, diagnosis, and laboratory testing.

Requirements analysis

The requirements analysis was conducted at three hospitals to identify the needs and challenges faced by the hospitals in monitoring the treatment of tuberculosis patients. Actually, the user requirements were gathered through organized workshops in three different hospitals. The members of the workshops were healthcare professionals from Mazimbu (10), Morogoro Regional Referral (15), and Sekou Toure (20) hospitals, as shown in Table 1. The selection criteria for the members were dependent on the availability of the healthcare workers. It is important to mention that the requirements were gathered before system development and during user acceptance tests. As per the sample size, it is worth noting that in each hospital, at least one user of the system was involved in requirement analysis and system testing. The users of the system are a medical doctor (MD), laboratory technologist (LT), DOT nurse (DN), radiologist, and pharmacist. The other respondents reported in Table 1 include district medical officers, district and regional tuberculosis coordinators, district and regional HIV coordinators, matron, and ICT officers.

Development of the front and back ends

The SmartTB system was developed using open-source technologies such as UNIX to

Table 1: Healthcare professionals' respondents from three hospitals; MRRP, Morogoro Regional Referral Hospital

SN	Hospital	Healthcare Professionals (Respondents)						Total respondents
		MD	LT	DN	Radiologist	Pharmacist	Other	
1	Mazimbu	1	1	1	1	1	5	10
2	MRRP	3	3	3	2	1	3	15
3	Sekou Toure	4	4	5	2	2	3	20

optimize interoperability and integration with other systems. Furthermore, Livewire Version 2 was used to develop the front end, while the back end was developed using Laravel Version 8. These are the most used popular PHP frameworks that support the management of system configuration (Latif *et al.,* 2018).

Development of databases and SMS reminders

This study used MySQL to develop the database of the system to allow scalability and handling of large amounts of data and multiple users. Additionally, a bulk SMS Application Platform Interface (API) was used for Swahili SMS reminders and notifications to TB patients and DOT nurses, respectively. The patients can receive normal real-time SMS one day before a clinic day to remind them of their medication appointments. Furthermore, a DOT nurse can receive an SMS one day after the clinic day. These SMS are stored in the SMS database to enhance easy access and the management of data.

SmartTB testing

After development, system developers performed unit testing to verify whether each section of code was working to perform the detailed specifications. The system developers confirmed that the data validation, input and output, and controls are working correctly. Following this, the test team conducted system testing to check that the system performs the required functions and that the expected requirements have been met. Normally, system testing checks that end-to-end processing completes with the correct results and ensures that the integrated system meets the specified requirements.

Thereafter, a user acceptance test was performed as the final stage of testing the SmartTB. The main purpose of acceptance testing was to validate that the system corresponds with the needs of users and is ready to be released for operational use. System developers conducted user acceptance testing at different times through test definition workshops in all three hospitals. During workshops, healthcare professionals had the opportunity to test the system while engaging in interactive discussions to understand how it works.

Results and Discussion
Architecture of an innovative digital data-driven platform for enhancing tuberculosis treatment monitoring in Tanzania

Figure 1 shows the architecture of the digital TB treatment monitoring platform, SmartTB, which encompasses four main functions as follows: Diagnosis (the medical doctor registers patient information related to TB after prescription, and the laboratory technician conducts TB testing following the medical doctor's recommendations), Treatment (the medical doctor and DOT nurse provide and administer medication adherence to TB patients until the end of the TB treatment), Monitoring (a DOT nurse monitors TB patients medication intake by receiving a normal real-time SMS one day after a patient misses clinics and a normal real-time SMS one day before a clinic day), Service performance and quality assurance (the SmartTB tool significantly generates medication and patient reports to the District TB Coordinator (DTC), District Medical Officer (DMO), Regional TB Coordinator (RTC), and Regional Medical Officer (RMO).
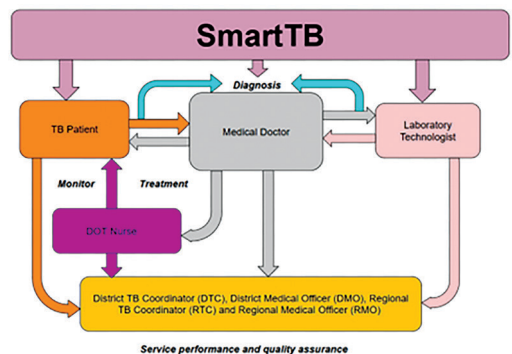

Figure 1: The figure shows the architecture of an innovative digital data-driven platform for enhancing tuberculosis treatment monitoring in Tanzania

User acceptance test results

The acceptance test was used as the final step to test the performance of SmartTB, aiming to determine that the developed system meets the requirements of the users. This test ensured

that healthcare stakeholders were involved in the acceptance testing process to avoid any misunderstandings or misinterpretations of requirements. Therefore, the given user acceptance test results in Table 2 reveal that SmartTB will support monitoring the adherence to treatment of TB patients (Seethamraju *et al.,* 2018).

cut-off problems, a DOT nurse can contact a support person when following up with the TB patient. Generally, the feedback was favorable and brought attention to the advantages of using technology to enhance healthcare outcomes, as shown in Table 2. Despite the fact that the SmartTB is not yet launched, healthcare professionals from Mazimbu, Morogoro

Table 2: User Acceptance test results from healthcare professionals at three hospitals

SN	Acceptance Requirement	Critical		Test Result		Comments (Total respondents in %)
		Yes	No	Accept	Reject	
1	The system must allow a DOT nurse to assign dose to TB patient		√	√		Ready for operational use (95%)
2	The last date of treatment must be correct based on the day when course was initiated	√		√		Good (90%)
3	The system must allow DOT nurse to request patient's referral	√		√		Recommend to use (92%)
4	DOT nurse can track the progress of the referred patient's treatment	√		√		Good (93%)
5	The system must ensure that patient receives a normal real-time SMS one day before a clinic day	√		√		This module can help to reduce the number of drop outs (90%)
6	DOT nurse receives a normal real-time SMS one day after a clinic	√		√		DOT nurse will be able to track the progress of patients who miss treatment (95%)

During user testing and acceptance of the system, 95% of stakeholders were content with the system and thought it was acceptable to get SMS reminders to take and monitor treatment. 3% of stakeholders, however, expressed privacy concerns and were concerned that receiving the SMS might make others aware of their TB status. The other concern of 2% of healthcare professionals was about the cost-effectiveness of the system, and finding more affordable alternatives was suggested. The SmartTB can register a support person for a TB patient, so in case a patient either does not own a mobile phone or is experiencing network and power

Regional Referral, and Sekou Toure hospitals validated it to confirm if it meets user needs during the user acceptance testing phase. Therefore, they were satisfied with the system results as reported in Table 2 and Figure 5 and recommended that the SmarTB be released for operational use. However, the study has not used any real data from tuberculosis patients.

Administering medication adherence to tuberculosis patients
In Figure 1 a DOT nurse can assign doses and view the treatment status of patients. The system generates alerts and notifications to

remind the nurse of the missed dose in the pharmacy store, ensuring prompt and accurate medication administration (Boone *et al.,* 2022). Furthermore, Figure 2 and Figure 3 show that a DOT nurse can request and process a patient's referral. This feature ensures that patients receive timely and appropriate care, and it also promotes continuity of care between different healthcare facilities. Additionally, the DOT nurse can track the progress of the referred patient's treatment and provide necessary follow-up care. Figure 4 shows status of a received patients' referral request.

Figure 2: The figure shows the patient-managed dose page

Figure 3: The figure shows a patients' referral request

Figure 4: The figure shows status of a received patients' referral request

Monitoring of treatment adherence in tuberculosis patients

This study has shown that SmartTB is an innovative strategy that may improve adherence to TB treatment (Sumari-de Boer *et al.,* 2019). A patient can be reminded through text message on the scheduled day to visit the health facility to take medication (Garfein & Doshi, 2019). Furthermore, real-time messages received by the DOT nurse about patients who missed clinics allow the DOT nurse to make follow-ups through either SMS messaging or phone calls. As a result, the DOT nurse has more time to devote to other tasks. This is comparable to the study that showed how automatic appointment reminders improved clinics' capacity to treat more patients (Boone *et al.,* 2022). Additionally, it is the responsibility of the TB healthcare facility to cover the SMS and phone call expenses. SMS reminders can help with TB treatment monitoring and stop the spread of the disease (Sumari-de Boer *et al.,* 2019). It is suggested that better health outcomes can be enhanced if tuberculosis patients follow the treatment procedures properly with the support of SMS reminders (Awad *et al.,* 2021). A DOT nurse can track patient progress and spot potential problems early on with the aid of SMS reminders. It is important to mention that tuberculosis patients are not obliged to pay for the SMS; the DOT centre that uses a SmartTB will be responsible for it.

Monitoring the treatment of TB patients enables healthcare providers to track the progress of patients using real-time SMS. This function might ensure that both patients and DOT nurses are adhering to their treatment plans (Sumari-de Boer *et al.,* 2019). The SMS sent to both TB patients and the DOT nurse is stored in the database to help healthcare workers monitor and manage TB patients through text message reminders and updates. It was also suggested that a monitoring system be used to observe how patients progress with treatment (Rodriguez *et al.,* 2022). As a result, DOT nurses may provide guidance to patients who face challenges following treatment procedures (Liu *et al.,* 2015). Treatment of TB patients is a collective approach; thus, DOT nurses are supposed to ensure that TB patients receive the
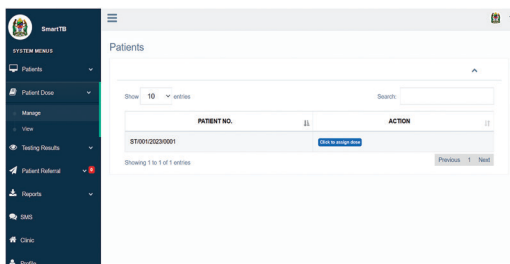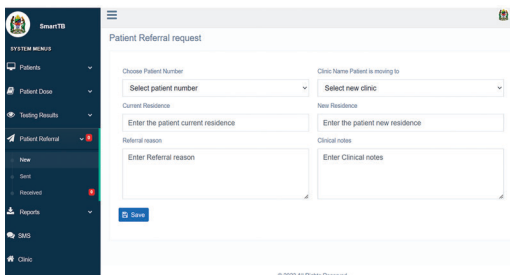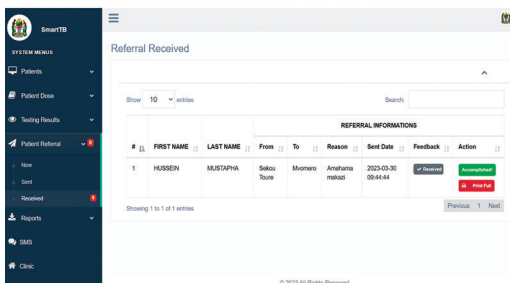
necessary treatment and care (Iribarren *et al.,* 2022). The SmartTB system can assist DOT nurses in identifying TB patients who miss clinics by sending real-time messages to the nurse one day after the clinic appointment as reported in Figure 5. In addition, DOT nurses can use these messages to make follow-up calls to TB patients through either SMS messaging or phone calls, ultimately monitoring patient progress and adjusting treatment plans (Seethamraju *et al.,* 2018). This is similar to the study that showed how automatic appointment reminders improved clinics' capacity to treat more patients (Boone *et al.,* 2022).
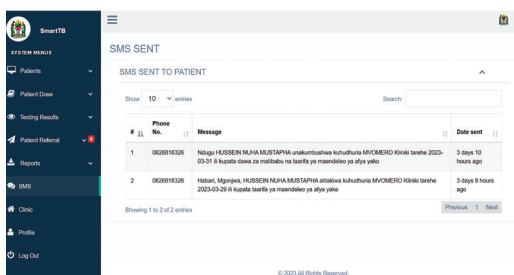
Figure 5: The figure shows SMS sent to patient and DOT nurse

Conclusion

Tuberculosis is one of the major killer diseases and needs immediate solutions to reduce deaths. This study has revealed that SmartTB can support monitoring of TB patients' treatment and data management. Moreover, it can improve the efficiency of TB management and decrease the burden on healthcare workers. The implementation of SmartTB requires the effective cooperation of stakeholders, including healthcare providers and policymakers, to ensure that the system is utilized and integrated into the country's healthcare system. However, the future plan is to pilot the SmartTB system in DOT centres in Tanzania, ultimately scaling up the SmartTB technology. Future studies could incorporate real data captured by SmartTB from DOT centres to measure the effectiveness of monitoring the treatment of TB patients in Tanzania. SmartTB will enable the eradication of tuberculosis in Tanzania by ensuring effective communication between patients and healthcare workers. Therefore, the SmartTB will provide

real-time reporting to healthcare professionals and thus reduce poor reporting and ensure proper decision-making.

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