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Original Article

Evaluation of Queue Management System (QMS) Use in Chest X-Ray for Tuberculosis Screening: A Case Study

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Abstract

Background Tuberculosis (TB) remains a threat to public health globally and is one of the top infectious killer diseases in Africa and Asia. The government and international partners have strategically intervened by cascading chest radiography (CXR) to identify, manage, and monitor treatments outcomes. However, patient have reportedly been dissatisfied with the quality of CXR screening services provided, raising complains that spans across quality of care, waiting times, communication levels, staff attitudes, and treatment outcomes.

Aim, Settings, and Design Coming at this present time when the major focus in health care is on improving patients' care and experience, this study aims to ascertain the performance of queue management system (QMS) use for CXR-TB screening in Nigeria as well as its acceptability; adopting quantitative research design.

Materials and Methods Questionnaires were administered face-to-face to the three categories of respondents (radiographers, radiology assistants, and patients) who meet the specific set of inclusion criteria, following a brief explanation about the research aim. Consent was gotten by way of a signed consent form and ethical approval obtained. A Likert 5-point scale was utilized in analyzing the responses, undergoing descriptive statistics using SPSS (version 25) software.

Results QMS is extremely useful in workflow, accuracy, communication, combatting work stress, and maintaining privacy, but with accompanying occasional technical challenges. A remarkable preference for QMS to manual in CXR-TB screening was noted among all research subjects, with strong level of agreement (close mean values of 4.06, 3.81, 3.91; standard deviation of 0.70, 0.73, 0.60).

Conclusion Findings from this study uncover the vital role the QMS plays in improving the quality of CXR-TB screening services, demonstrating great acceptability.

Keywords

- queue management system
- chest X-ray
- tuberculosis screening
- queueing systems

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Introduction

Tuberculosis (TB), a highly contagious airborne disease, is ravaging lives globally, growing at a proportionate rate alongside Nigerian population of over 213 million.[1] Currently, Nigeria ranks first in Africa and sixth in the world, accounting for approximately 4.6% of the global TB burden. To worsen matters, the country has been plagued with a high triple burden of TB, drug-resistant TB, and human immunodeficiency virus-associated TB. Nigeria is reportedly among 1 of the 10 countries accounting for 77% of the global gap in TB case detection and notification, and contributing to about 8% of the 4.3 million TB cases missed globally.[2,3]

TB is caused by the *Mycobacterium tuberculosis* bacteria that majorly affects the lungs but can attack any part of the body.[4] Early detection is vital to interrupting transmission and optimizing treatment outcomes.[5] Chest radiography (CXR) remains the oldest tool for pulmonary TB screening and diagnosis and has played a key role in TB control programs in high burden populations.[6] It is an easy, cost-effective, fast, and sensitive screening test performed by radiographers in large populations. Images generated during this process are usually sent to a radiologist for interpretation (to rule out presence or absence of TB) so further confirmatory testing (sputum) can be done on those screened positive.[7]

However, lately several complaints have been raised regarding the quality of care rendered to patients during these radiological procedures.[8] While 56.4% of complaints gathered during a 9-year interval relates to the clinical domain, it is interesting to observe a significant 23.4 and 20.0% complaints stemming from relationship and management domains, respectively: quality of care, treatment, staff attitudes, communication breakdown, and delays constituting vital subcategories.[9] In a recently conducted regression analysis, three components, namely, waiting environment, waiting time, and service quality, were identified as determinants of patient satisfaction.[10]

Thus, in this era of patient-centered care, it is vital that care meet the health care goals determined by the preferences and values of those receiving it; translating to patients' right to receive care in a nondiscriminatory and confidential manner.[11,12] This involves space and privacy duly accorded to patients during CXR procedures requiring undressing or exposing part of the body.[8] In addition, establishing good patient and TB health team relationship to enable exchange of information, as the level of interaction can positively or adversely affect the quality of care rendered, treatment-related decisions, and clinical outcomes.[13] Nevertheless, this appears very challenging in TB management, owing to the highly infectious and spread nature of the disease.[14] The emergence of coronavirus disease 2019 further raised consciousness on the need to avoid crowded settings in the hospital, viewed also as a wakeup call in TB care and treatment.

Queue management system (QMS) has the potential to respond to these demands and in a timely fashion, but lack of empirical evidence on its use in health care sector exists, with emphasis on TB screening services.[15] Therefore, this study aims to assess the performance and acceptability of QMS software use in CXR screening for TB. In evaluating the radiographer and imaging assistants' perception as well as patients' experience in the use of QMS, health care service providers can gain insights on strategies to improving the quality and clinical outcomes of CXR-TB screening services.

Materials and Methods

Study Setting and Design

This research was conducted at exactly 3 months following QMS installation in a top health facility in Nigeria, comprising the complete medical team (doctors, nurses, imaging, laboratory scientist, and pharmacist) and offering TB screening/diagnosis/treatment services for migration purposes, active case finding, preemployment, and routine medical checks. The study is quantitative in design, utilizing a questionnaire that comprised of closed-ended questions.

Software and Design

The name of the software was Q-SYS QMS, developed by Riana Group. This proposed QMS was built as a centralized control queue system (not as a standalone queue system for one service counter operation), with the ability to support many departments, and in which each department can have many service counters. This model, is network compactible, all units in the building involved in TB management connected via local area network (LAN) or Internet, permitting monitoring in real time. This model utilizes computations and algorithms that work on a first come first serve basis, serving tickets in order of increasing registration complete time.

Participants

Three categories of respondents were actively involved in this study—radiographers, radiology assistants, and patients. Radiographers were saddled with the task of taking quality chest X-rays images of high diagnostic value in line with the ALARA principle (as low as reasonably achievable), using a Siemens direct digital X-ray machine. Radiology assistants on the other hand managed the workflow of patients within the X-ray waiting area, responding to departmental queries and offering overall assistance to patients while navigating the radiology unit. Inclusion criteria varied for each study respondent as follows: radiographers and radiology assistants should have a cumulative work experience of not less than 3 years, with an experience of at least 2 years in the current facility of research. This would automatically translate to knowledge and expertise gained in both the use of the previous manual system as well as the 3 months using the QMS software. Only patients 18 years and above who have previously visited the facility for CXR in the last 3 months or more will be qualified to participate in this research. This includes remedical cases, follow-up cases, or routine 6 months/1 year checks. In order to obtain meaningful results, a sample size of approximately 200 was adopted (distributed in the ratio of 50:50:100 for radiographers,

radiology assistants, and patients, respectively) as per the guidelines of Ganesh.[16]

Procedure/Data Collection

A brief explanation of the research aim, goal of the questionnaire, and the need to give truthful responses was done by a team of researchers for each category of research subject, and consent obtained via a signed consent form. Thereafter, questionnaires were administered face-to-face to only those who met the inclusion criteria. Three different questionnaires were prepared for the three groups of respondents, questions carefully structured per targeted set of respondents, who should be in a better position to provide accurate responses. For each respondent category, questions were framed to address the research aim/objectives, written in clear terms, of great depth, and in a sequential order (►**Table 1**).

Ethical Consideration

Ethical approval was obtained from the Health Research Ethics Committees in Nigeria (HREC).

Measurements and Outcomes

A Likert 5-point scale rating system was employed to allow for adequate range of responses, designed to measure the attitude, opinions, and perceptions for each set of respondents to a variety of questions. Responses typically include "strongly agree," "agree," "neutral," "disagree," and "strongly disagree," coded numerically (►**Table 1**).

Statistical Analysis

All completed forms were duly checked for appropriateness before entering the data into SPSS software (version 25) for descriptive and inferential statistical analysis. For each category of respondent, responses for each question were assembled and grouped together to arrive at an average score, also expressed in percentage. An overall mean score of all questions per respondent category was calculated (►**Table 1**), including computing the variance and standard deviation (SD) to describe how dispersed the data is (►**Table 2**). This is imperative in assessing the level of satisfaction, agreement, acceptability, and concerns.

Table 1 Analysis of mean score and percentage of all responses obtained for each question per category of study respondent

Radiographers								
Questions	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**	**Total scores (50)**	**Mean score**	**%**
Software is easily accessible on the system at all times following installation		2	4	12	32	50	4.48	**89.6**
All applicants attended to have their respective tickets		13	18	1	18	50	3.48	**69.6**
Missing tickets It happens often			4 4	41 41	5 5	50 50	4.02 4.02	**80.4** **80.4**
Ease to transfer tickets to nurses, lab, or doctors				3	47	50	4.94	**98.8**
QMS use promotes accuracy, minimizes errors due to incorrect applicant identification, and aids tracking throughout stay in the facility		4	1	4	41	50	4.64	**92.8**
QMS use improves work speed	3	27	20			50	2.34	**46.8**
QMS use reduces work stress of walking about and lowers fatigue level			2	3	45	50	4.86	**97.2**
All tickets are accounted for at the end of the entire screening exercise				22	28	50	4.56	**91.2**
QMS use eases communication with team members			1	19	30	50	4.58	**91.6**
QMS use aids in the overall discharge of your duties	1	3	22	24		50	3.38	**67.6**
Other encountered technical issue (s) with the software use It occurs often			17 17	28 28	5 5	50 50	3.76 3.76	**75.2** **75.2**
QMS be adopted for use in chest X-ray screening of tuberculosis		9	2	18	21	50	4.02	**80.4**
Mean: 56.84/14 = **4.06**; Variance: 6.3896/13 = 0.4915; SD: **0.70.**								

(*Continued*)

Table 1 (*Continued*)

Radiographers								
Questions	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**	**Total scores (50)**	**Mean score**	**%**
Radiology assistants								
Questions	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**	**Total scores (50)**	**Mean score**	**%**
Software easily accessible on the system at all times following installation			10	4	36	50	4.52	**90.4**
Tickets properly arranged in increasing order of waiting time	17		7	6	20	50	3.24	**64.8**
Missing tickets. It happens often			15 15	22 22	13 13	50 50	3.96 3.96	**79.2** **79.2**
QMS speakers at the waiting area sound whenever the radiographer calls each ticket		5	9	19	17	50	3.96	**79.2**
There a corresponding display of called tickets on the screen at the waiting area			5	12	33	50	4.56	**91.2**
Applicants are attentive, listening to when their tickets will be called or displayed on the screen		34	16			50	2.32	**46.4**
Personal guidance or assistance usually rendered to applicants to know when their tickets are either called or displayed on the screen				2	48	50	4.96	**99.2**
Other encountered technical issue (s) with the software use It occurs often			23	27		50	3.54	**70.8**
QMS use promotes work orderliness			14	4	32	50	4.36	**87.2**
QMS use improves time management		14	22	7	7	50	3.00	**60**
QMS use eases communication		9	25	12	4	50	3.22	**64.4**
QMS be adopted for use in chest X-ray screening of tuberculosis			6	39	5	50	3.98	**79.6**
Mean: 49.58/13 = **3.81**; Variance: 6.4101/12 = 0.5342; SD: **0.73**.								
Patients								
Questions	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**	**Total scores (100)**	**Mean score**	**%**
Ease in hearing when tickets are called		11	28	40	21	100	3.71	**74.2**
No difficulty in the display of tickets on the screen?			12	71	17	100	4.05	**81**
Tickets displayed/called based on a first come first serve basis		33	41	26		100	2.93	**58.6**
Privacy and respect are accorded throughout the chest X-ray procedure with QMS use			9	39	52	100	4.43	**88.6**
Confidentiality is maintained with QMS use		2	13	36	49	100	4.32	**86.4**

Table 1 (*Continued*)

Radiographers								
Questions	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**	**Total scores (50)**	**Mean score**	**%**
Significant difference in time management with QMS use compared to manual	4	16	61	19		100	2.95	**73.8**
QMS use makes the entire screening process seamless		3	12	38	47	100	4.29	**85.8**
Great level of satisfaction with service			8	39	53	100	4.45	**89**
QMS preferred to manual and be adopted for use in chest X-ray screening of tuberculosis		4	14	54	28	100	4.06	**81.2**

Abbreviations: QMS, queue management system; SD, standard deviation.
Mean: 35.19/9 = **3.91**; Variance: 2.8386 /8 = 0.3548; SD: **0.60**.
Note: Significance of the bold values is to highlight them.

Results

This section shows a summary of all responses obtained from the questionnaire (►**Table 1**), descriptive statistics done (►**Table 2**) and graphical representation of the data (►**Figures 1**–**5**).

Discussion

Radiographers

An in-depth look at the responses from radiographers (►**Fig. 1**) reveals with a high degree of certainty (89.6%) the easily accessible nature of the just installed QMS software on the X-ray system, allowing for a nearly perfect (98.8%) transfer of patient tickets to other units involved in TB management such as nurses, laboratory, doctors, and pharmacist. Thus, almost all tickets (91.2%) accounted for at the end of the entire CXR-TB screening exercise. In line with a previously proposed QMS in 2016 that enabled customers receive a token number upon acknowledgment of receipt and displaying token number and counter service, this software was found to be very useful in overall customer flow management.[17] Similar system that provides token generation for multiple interfaces (registration, pharmacy, laboratory, report collection, and bill payment) was observed in the study of Sumit et al.[18]

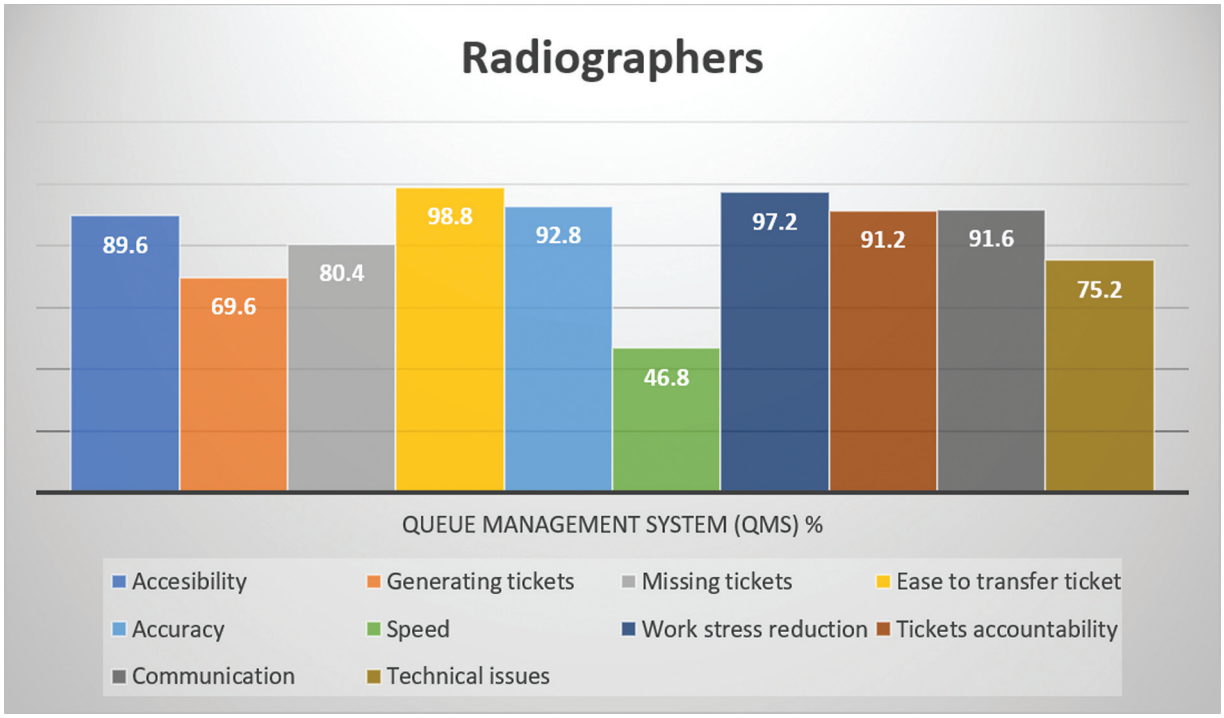

Fig. 1 Overall responses obtained from radiographers expressed as percentage. Most notably is the fact that while all assessed parameters surpassed 50% pass mark, speed recorded 46.8%.

Nevertheless, a high occurrence of missing tickets was reported (80.4%) because not all patients had a corresponding ticket. Australia's leading technology provider asserted that a typical QMS enables customers to take a ticket and wait (queue) for their turn to be served.[19] Elsewhere, a comprehensive queuing management system designed for hospital use employed an electronic queue (combining smartphone application usage, cloud-base database, and information sharing over the Internet) in which all patients were given pertinent ticket queuing information.[20] Hence, possible reasons for missing tickets in this study could be attributed to several factors, namely, forgetfulness to send tickets to the X-ray unit, sending tickets to the wrong unit, or software malfunction since it was established that front desk officers have been trained to generate tickets for each applicant at the point of registration. To manage this problem, it is recommended that hospital management and staff members organize/attend routine trainings (both internally and externally) to improve user performance and operationalize compliance.[10,21]

It is intriguing to see that QMS use reduces work stress/fatigue levels (97.2%), promotes work accuracy (92.8%), and ease communication with team members (91.6%). These findings seem to fit into effective work–rest strategies, limiting physical contact between health professionals and patients, geared at improved operational performance among workers without hampering communication levels.[22–25] Work-related fatigue is becoming a global and costly problem in many operational systems, affecting performance.[26] Consequently, a proactive approach on eliminating fatigue problems before it appears remain the gold standard to increase productivity and health outcomes in a clinical setting.[27]

Nonetheless, QMS use does not improve work speed (46.8%). This is not surprising because patients are attended to on a one-to-one basis and not in groups. The health facility is a very busy one, with an average of about 120 CXR cases per day (comprising of booked and walk-ins), speed often required. This challenge together with significant forms of technical issues (75.2%) encountered (although occasionally) seems to constitute the main reason for the decrease in overall impact of QMS in the radiographers' duties (67.6%). In addressing these issues, one of the measures is the regulation of booking, since staff strength and number of patients booked are factors that determines the queueing system performance optimization.[28] QMS use as demonstrated in many studies seem to be the perfect solution for a controlled environment, as queues must be fair and managed systematically to avoid chaotic situations.[17] Furthermore, periodic maintenance and software updates is very necessary in QMS use to eliminate/minimize technical concerns, owing to its many hardware and software components.[29] Hence, the need to opt for regular maintenance contract agreement with the service engineers during software purchase as seen in the findings of Abdulrahman et al.[30]

Radiology Assistants

As seen in responses obtained from radiology assistants (►**Fig. 2**), the freely accessible nature of this newly installed software (90.4%) as well as the high incidence of missing tickets (79.2%) were manifest; a similar position held by radiographers. Most notably, here is a fair agreement (64.8%) in tickets arrangement according to the increasing order of waiting times. QMS software gathers real-time data about the service, wait times, and customers in populating queue.[31] Wherefore, delay

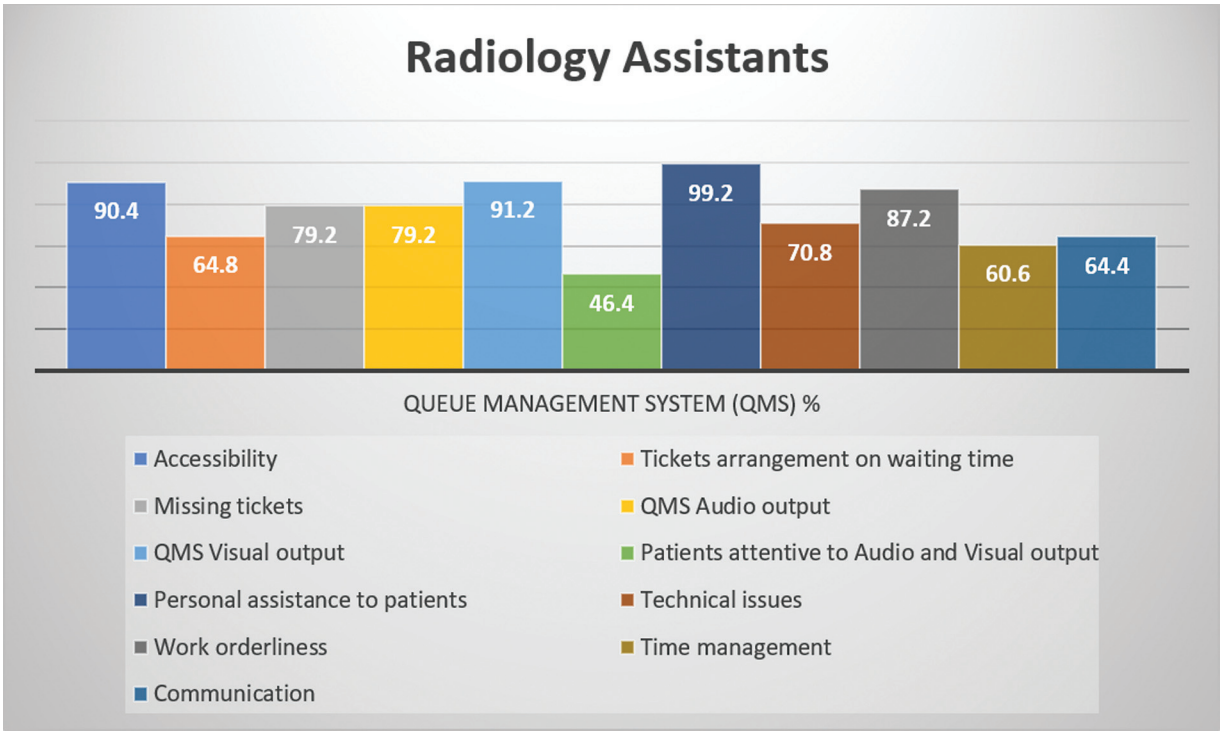

Fig. 2 Overall responses obtained from radiology assistants expressed as percentage. The takeaway point is that patient's level of attentiveness to audio and visual output fell below the 50% pass mark.

in sending tickets for queueing or generation of priority tickets at point of registration may have possibly given rise to this. To handle this shortcoming, appropriate communication both with the ticketing team and health professional is required.

Furthermore, the sound performance of the QMS speakers stationed at the waiting area was remarkable (79.2%), although an even higher performance in its display of called tickets on the monitor was noted (91.2%). Voice call systems via output directional speakers been strategically placed can guide people toward designated queueing areas, serving as a very effective and modern alternative approach to traditional physical barriers for queue management.[32] Nevertheless, it is worrying to see that only 46.4% of applicants were attentive to the call from the speakers, reason for a higher ranking on tickets' visuality than audibility, and its limited role in communication (64.4%). Lack of attentiveness could be attributed to the low education levels and poor psychological state of patients, which resulted in heavy reliance on radiology assistants for assistance (99.2%). Successful implementation of technology-driven models necessitates public enlightenment, owing to a positive existing association between education and patient satisfaction. According to the technology acceptance model, perceived ease of use and perceived usefulness, highly influenced by education levels, are two key factors determining an individual's intention to use a technology. Therefore, intensified efforts should be channeled into public education and awareness to bridge this gap.[33–35]

Moreover, the software, designed to efficiently handle queues via the token system, was instrumental in promoting work orderliness (87.2%) and a bit of time management (60%). This agrees with previously conducted research in which queuing systems improved orderliness and ensured an equitable customer's experience.[36]

Patients

Feedbacks gotten from patients (►**Fig. 3**) show that they agreed to the ease in hearing (74.2%) and display of tickets (81%), assenting to radiology assistants' stand on the sound condition of the QMS speakers and monitor. Installation of monitors provides visible evidence for the fairness of the queuing system.[36] As was the case with radiology assistants, only a proportion of patients (58.6%) admitted to the sequential arrangement of tickets. This was majorly due to the generation of priority tickets as already highlighted above, the adopted queuing system in the current study been FIFO (First-In, First-Out) to guarantee fair processing of lines.[37] It is important to point out that lack of information on the number of existing customers on the queue, as is obtainable in a ticket queue system, could result in naive customer abandonment perception when not the case.[38] To tackle this, appropriate communication at all levels is necessary to build a strong sense of ticket management strategy among service users.

Interestingly, QMS offered privacy and respect (88.6%), while ensuring confidentiality (86.4%).[39] Patients feel more valued and respected in the hospital using a queuing system due to the convenience and comfort that comes with its use. Again, QMS made the entire TB screening process seamless (85.8%) and improved time management (waiting time) (73.8%); thus, an excellent level of satisfaction (89%) with the service recorded. During an experimentation in 2017, application of a queueing theory was found to decrease outpatients' waiting time in the range of 44 and 78%.[40] Similar findings were seen in a randomized controlled trial, QMS use recording significant less mean waiting time and higher level of satisfaction among patients in the intervention group than those of the control group.[41] Elsewhere, customers expressed support and satisfaction with QMS

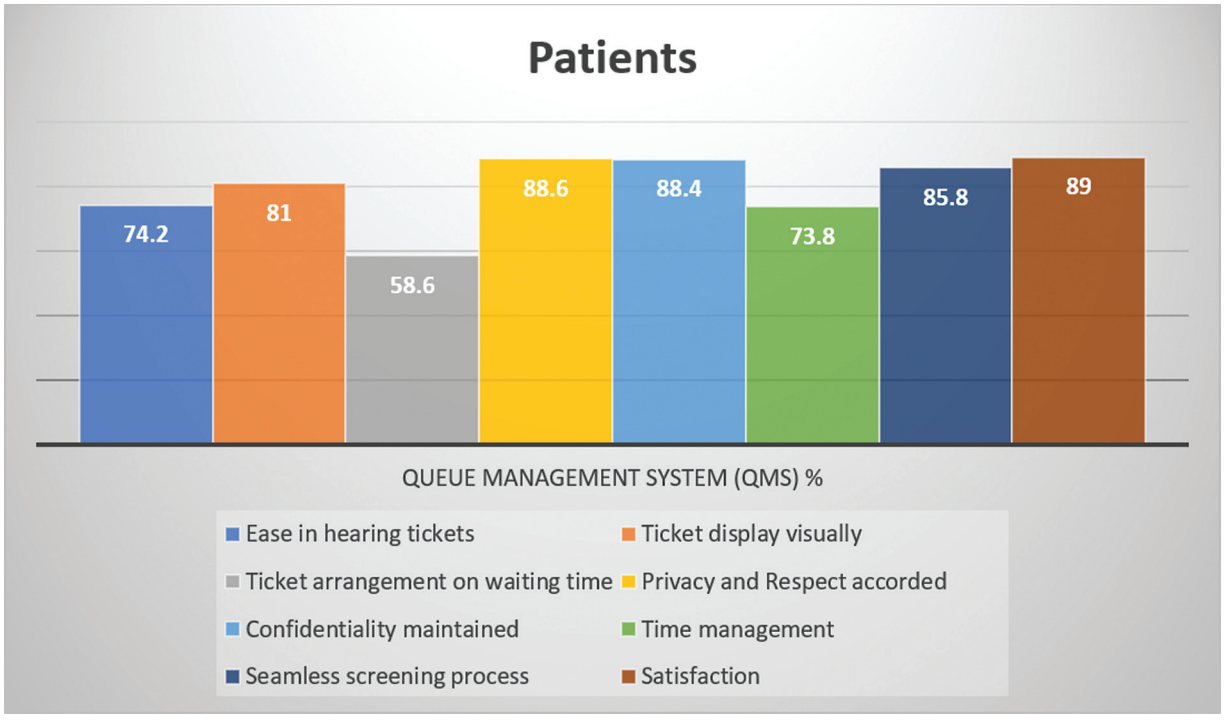

Fig. 3 Overall responses obtained from patients expressed as percentage. All assessed parameters exceeded the 50% pass mark.

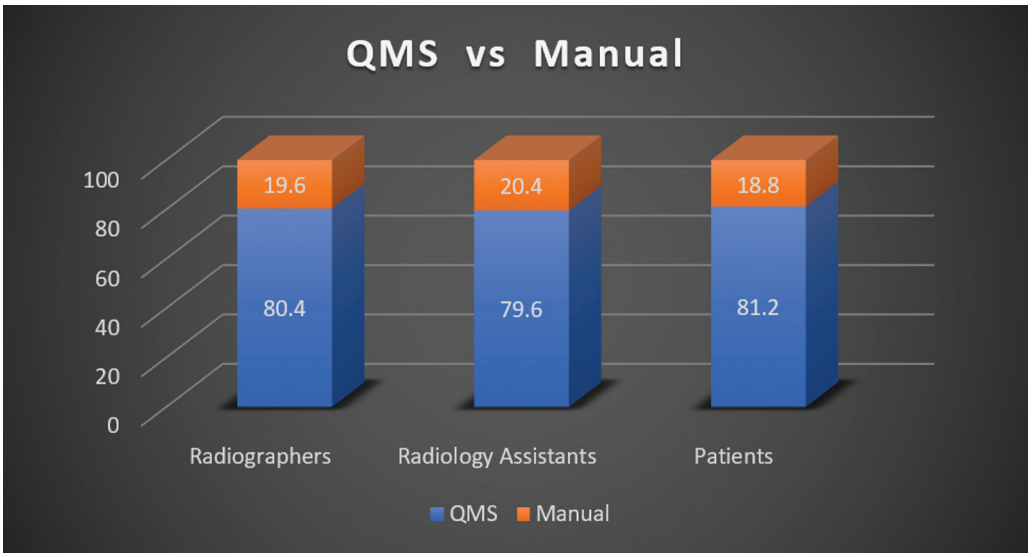

Fig. 4 Comparison between queue management system (QMS) use and manual in chest radiography-tuberculosis (CXR-TB) screening among radiographers, radiology assistants, and patients, expressed in percentage. A strong level of agreement for QMS preference is recorded.

technology, evaluating their queueing experience as effortless, easy, and quick.[36]

Waiting for service is the most unpleasant experiences in everyday life, a significant positive relationship existing between waiting line management technique and customer satisfaction.[42,43] Hence, to better time management (recorded values of 60 and 73.8% for radiology assistants and patients, respectively), publishing available capacity and time slots for the public to choose a token will avert unwanted queues and reduce waiting time for the public as seen in the recent study of Smruthi et al.[44]

This study thoroughly assessed the performance of QMS in improving quality of CXR-TB screening services across clinical, relationship, and management domains. Overall, impressive statistics supporting QMS use (80.4% radiographers with mean and SD values of 4.06 and 0.7, respectively; 79.6% radiology assistants with mean and SD values of 3.81 and 0.73, respectively; 81.2% patients with mean and SD values of 3.91 and 0.60, respectively) and an almost equal size of data representation across each study respondent were well demonstrated (►**Figs. 4** and **5** and ►**Table 2**). However, this research focused mainly on QMS use in the radiology unit. It

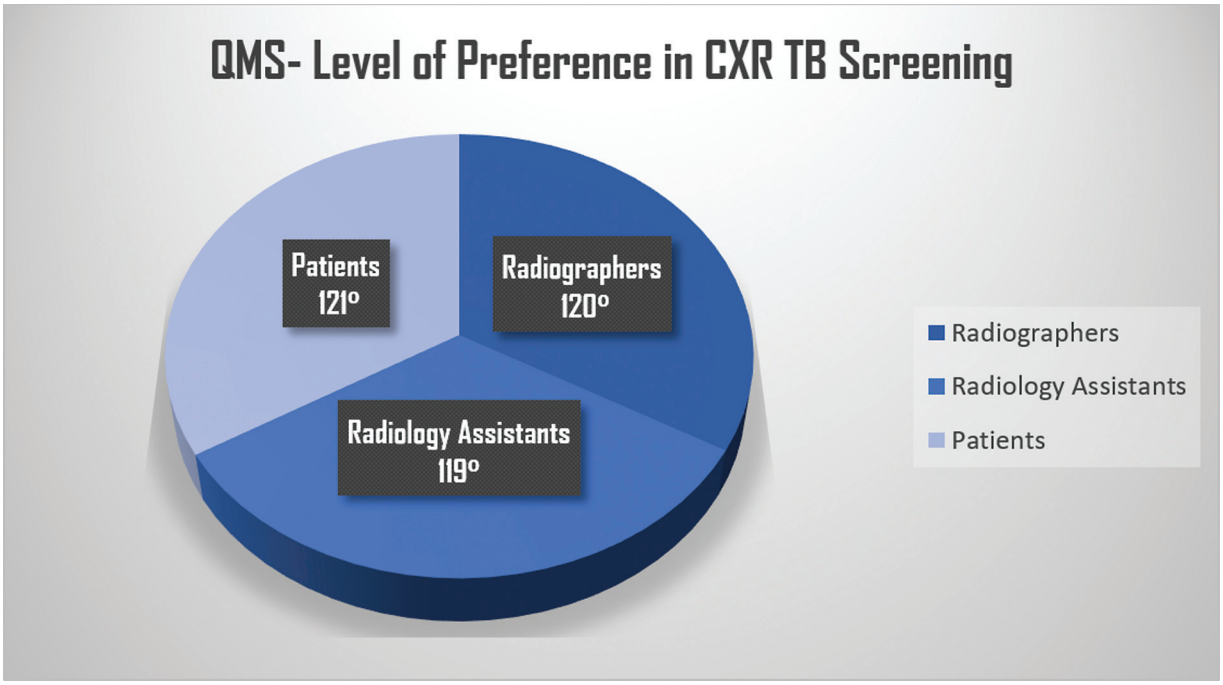

Fig. 5 Queue management system (QMS) level of preference in chest radiography-tuberculosis (CXR-TB) screening: Pie chart depicting numerical proportion on QMS preference among radiographers, radiology assistants, and patients. An almost equal size of data representation for each respondent category.

Table 2 Cumulative mean, variance, and standard deviation of all responses obtained for radiographers, radiology assistants, and patients

Respondent	Mean	Variance	Standard deviation
Radiographers	4.06	0.4915	0.70
Radiology assistants	3.81	0.5342	0.73
Patients	3.91	0.3548	0.60

Note: Close main values, with low dispersion noted.

is recommended that further studies explore its applicability across other units involved in TB management.

Conclusion

Achieving patient-centered care is a particular challenge in TB diagnosis and management. Findings from this study show the central role QMS plays in improving quality of TB services, with a remarkable preference for QMS use over the manual counterpart in CXR screening. A strong level of agreement in this preference is noted among all three research subjects (radiographers, radiology assistants, and patients) with low spread of data points.

Conflict of Interest
None declared.

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