Journal of Health Informatics in Africa

Official Journal of the Pan African Health Informatics Association (HELINA)
published by Koegni-eHealth Innovation for Development
HELINA is the Africa Region of the International Medical Informatics Association (IMIA)

Volume 9 (2022) Issue 1

Eds: Nicky Mostert, Ulrich Kemloh

ISSN: 2197-6902
DOI: 10.12856/JHIA-2022-v9-i1

JHIA : www.jhia-online.org
HELINA : www.helina-online.org
IMIA : www.imia-medinfo.org

Published in the Journal of Health Informatics in Africa
Volume 9 (2022) Issue 1

ISSN: 2197-6902
ISSN/NLM abbreviation: J Health Inform Afr
DOI: http://dx.doi.org/10.12856/JHIA-2022-v9-i1

Publisher
Koegni eHealth, Innovation for Development e.V. Germany
Postfach 652166
D-22372 Hamburg, Germany
www.koegni-ehealth.org
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Editorial to JHIA Vol. 9 (2022) Issue 1

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The Journal of Health Informatics in Africa is the official journal of the Pan African Health Informatics Association (HELINA) and publishes the proceedings of the HELINA conferences, as well as open-call issues. This issue is the first open-call issue for 2022 comprising of two research papers submitted directly to the journal. These papers have been double blind peer-reviewed before being accepted for publication. Although papers written in French are also published by the journal, both papers in this issue was written in English.

The paper by Walusimbi and Wamema proposes a collaborative mobile application architecture to improve collaboration among healthcare providers at the point of care.

Mkayula, Mbise, and Mahundi investigated the challenges associated with Electronic Medical Record (EMR) interoperability between hospitals and make recommendations to improve interoperability.

I would like to make use of this opportunity to urge authors to ensure that only original, unpublished manuscripts are submitted to JHIA for review. All submissions are checked and if evidence of plagiarism or previous publication is found such a submission is immediately rejected.

I wish to thank the dedicated peer-reviewers that took time out of their busy schedules to assist with the review process. Also a word of thanks to the editorial team and authors who made this issue of JHIA possible. Your dedication is very much noted and appreciated.

Nicky Mostert
19.12.2022

Journal of Health Informatics in Africa

Approaches Towards Interoperability of Electronic Medical Records Systems: A Case of Selected Referral Hospitals in Tanzania

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Background and Purpose: Electronic Medical Record (EMR) systems are different among hospitals and they often come from different vendors. As a result, it is difficult to share patient information across them. The ability to exchange patient information, also known as interoperability, has become a challenge both within the hospital and across hospitals. This study, therefore, investigated the interoperability of EMR systems in hospitals and sought to explore approaches to achieve interoperability between EMR systems in health facilities.
Methods: The study employed a qualitative design, which involved two parts, narrative literature review and semi-structured interviews. The literature review was used for identification of factors influencing the interoperability of EMRs. Thereafter, data were collected through semi-structured interviews with 14 key personnel in the ICT department from 4 Regional Referral Hospitals (RRH) and the Muhimbili National Hospital (MNH). The qualitative data from the interviews were analysed using the content analysis method.
Results: The initiatives related to EMRs interoperability among hospitals should start with the Ministry responsible for health. Establishment of hospital ICT policy to support interoperability of EMR systems within the hospital. Hospitals should invest in interoperability technologies such as REST API and HL7 FHIR to achieve interoperability of EMR systems.
Conclusions: Interoperability of EMR systems require enough budget to be allocated both within the hospital and between hospitals. Also, adherence to the Tanzania health enterprise architecture which provides the framework towards achieving interoperability of digital health systems.

Keywords: *Interoperability, EMR, standards, hospitals*

1 Introduction

Health information is information related to the health of a person including medical history, symptoms, laboratory results, diagnoses, and outcomes. Thus, health information is generated upon the encounter with the healthcare systems [1]. Health Information Systems (HIS) is the interaction between people, processes, and technology to support information operations and management of health information. The intention being the availability of information to improve the quality of healthcare services [2] [3] [4]. HIS manages administrative, clinical, and financial issues in hospitals [5]. In hospitals, health information is managed through Electronic Medical Record systems (EMR) which are dedicated to creating, storing, and retrieving clinical information [6]. The effectiveness of healthcare service delivery is determined by the availability of real-time health information [7].

The National eHealth Strategy 2013–2018 p.2-1 in Tanzania aimed to "enable the health sector to operate more effectively as connected systems, overcoming fragmentation and duplication of service delivery" [8]. Also, improving multi-way communication and sharing of information within the health sectors [8]. Moreover, the common goal for the Tanzania Digital Health Strategy of 2019 – 2024, Tanzania Development Vision 2025, and the Health Sector Strategic Plan 2021–2026, is to emphasize the provision of high-quality healthcare to all households. The application of digital health technologies has great potential for making the health system more responsive to health needs and improving individual health outcomes [9]. Likewise, there are ongoing initiatives for interoperable HIS such as Health Information Mediator (HIM), Health Data Repository (HDR), and Health Data Collaborative (HDC) by the Ministry of

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 J Health Inform Afr. 2022;9(1):1-13. DOI: 10.12856/JHIA-2022-v9-i1-303

Health, Community Development, Gender, Elderly and Children (MOHCDEC) and digital health stakeholders. These initiatives are focused to improve the availability, quality, and use of data for decision-making[10][11].

Despite these achievements, several challenges affected the successful implementation of the Digital Health Strategy of 2019 – 2024 [9]. One of the challenges is the existence of multiple, fragmented electronic health information systems that were not interoperable and/or not well aligned with the workflow in the health sector [10]. The current situational analysis indicates the existence of multiple digital health systems which include EMR across the health sector such as hospitals operating in silos [9][12].

The health system in Tanzania has different levels, from community to national level. Specialized healthcare services are provided by regional referral hospitals, while zonal and national hospitals provide advanced healthcare services and also serve as teaching hospitals [13]. Therefore, lack of interoperability of these EMR systems in different levels of health system leads to inadequate information flow and incapable of interaction among them [14]. Due to the existence of different EMR systems, the study proposes approaches towards achieving interoperability of EMR systems in hospitals.

2 Materials and methods

2.1 Literature search

To investigate what influences interoperability of EMR in hospitals, a literature search was carried out from August to November 2020. The search was performed from the following electronic databases: Google Scholar, PubMed, Jstor, Science Direct, and IEEE. These electronic databases were chosen because they provide health informatics databases including EMR systems, and offer a set of search options for enhancing reference retrieval. The search used the terms ("electronic medical records" OR "electronic health records" OR "patient health records" OR "Hospital Information System" OR "Health Information System") AND (interoperability OR interoperable) and advanced search was such that the article title should include the term/keyword ("Interoperability"). The initial search yielded 22609 articles from the database search. The statistics of the search from the databases was based on the search criteria used. However, these results needed to be screened to remove all articles that were not relevant to the study. By applying advanced search criteria, a total of 565 articles were retrieved from databases. Out of those, 368 articles were excluded by the title criterion, while 115 articles were excluded by the abstract criterion. The remaining 82 articles were considered for the study, and 9 articles were added from other sources, hence making a total of 91 articles. From the 91 articles, 5 articles were theses/dissertations, 4 articles were editorials/opinions/perspective/peer review, and 3 articles had no method defined; 11 articles were duplicates and 51 articles were found not to be relevant to the study. Thus, 17 articles were included in the analysis. Factors that influence interoperability from the identified articles are presented in Table 1.

Table 1: Factors influencing interoperability from literature reviewed

ARTICLE NAME	FACTORS FACILITATING OR HINDERING INTEROPERABILITY
1. Atalag et al. (2010)	Contextual factors such as:- 1. Business drivers and leadership 2. Organisational and legal aspects 3. Social and political influence 4. The use of standards
2. Sachdeva & Bhalla (2012)	1. The use of message or interface standards (e.g. HL7) 2. The use of content-oriented standards (e.g. ICD 10) 3. The use of Hybrid standards (openEHR) 4. The existence of Data types and messaging formats (e.g. XML, ASCII, integer, string) and shared codings 5. Adherence to medical Terminologies
3. Barbarito et al. (2012)	1. The use of medical standards 2. Political and guidelines

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	3. Technological infrastructure for data sharing 4. Organisation policies and law
4. Soceanu et al. (2013)	1. The use of medical standards 2. Political context and strong government 3. Policy and regulations
5. Botts et al. (2014)	1. Policies and organization 2. The use of medical terminologies 3. The use of communication standards
6. Hammami et al. (2014)	1. Existence of many terminologies 2. Lack of uniform data standards
7. Edmunds et al. (2016)	1. Technical factors 2. Legal aspects, and organisational 3. Financial and cultural factors
8. Janaswamy & Kent (2016)	1. The use of standards 2. Differences in formats, data types, programs, and DBMS
9. Ojeda-Carreño et al. (2017)	1. The use of medical standards (HL7 and DICOM) 2. Adherence to medical terminologies and controlled vocabularies (ICDx)
10. Beštek & Stanimirović (2017)	1. The use of Standards (FHIR and OpenEHR) 2. The use of medical terminologies (ICD10) 3. Political, and regulatory supremacy
11. Frisse (2017)	1. The use of conformed standardised communication protocols (e.g. HTTP, SOAP, REST)
12. Hammond (2018)	1. The adherence to medical terminologies and controlled vocabularies (ICD, SNOMED-CT) 2. The use of medical standards (HL7, SMART® on FHIR) 3. Organisational, and policies 4. The existing governance rules
13. Naveed et al. (2018)	1. The use of medical Terminologies 2. The adherence to interoperability standards
14. Souza et al. (2019)	1. The use of interoperability architecture 2. The development of Interoperability standards
15. Adel et al. (2019a)	1. The use of communication protocol 2. The adherence to medical terminologies and controlled vocabularies
16. Adel et al. (2019b)	1. Differences in standards, programs, and DBMS
17. Kobusinge (2020)	1. The use of interoperability standards 2. Contextual factors (Policy and Resources).

From the seventeen articles, the study identified eight (8) factors in the category of technical and non-technical factors as per summarized in Table 2. These factors are: adherence to medical standards, the existence of medical terminologies and controlled vocabularies, the use of standardised data types, adherence to communication channels or protocols, political contexts, the existence of diverse social backgrounds, legal aspects (law, policy, rules, and regulations) and availability of resources.

Table 2: Categorized factors that influence interoperability from literature reviewed

CATEGORY	FACTORS
Technical	1. Adherence to medical standards 2. The use of medical terminologies and controlled vocabularies 3. The use of standardised data types 4. Adherence to communication channels or protocols

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Non-Technical	1. The influence of political supremacy 2. Existence of diverse social backgrounds (customs, constructs, beliefs, desires, and practices among people) 3. Legal aspects (Law, Policy, Rules, and Regulations) 4. Availability of resources (money, time, and labour)

2.2 Methodology

A case study approach was used to help to investigate the interoperability of EMR systems in hospitals. One advantage of a case study is used when a researcher has a place that can inform a problem similarly for the case of EMR systems at MNH and regional referral hospitals [16]. Therefore, the study employed a Qualitative research design. It started with literature review to identify the factors influencing efforts towards interoperability. This was then followed by semi-structured interviews where respondents were asked questions framed around the factors obtained in the narrative literature review. The semi-structured interview was conducted to examine how factors identified in literature review influence EMR systems interoperability between MNH and selected regional referral hospitals. One advantage to the choice of qualitative method is to offer an effective way of developing a rich, detailed description of a case as stated by[15]. Therefore, qualitative data were collected from system administrators at MNH and selected regional referral hospitals. Table 3 presents the number of interviews conducted with the key personnel from hospitals and President's Office – Regional Administration and Local Government (PO-RALG).

Table 3: Number of interviews conducted and the main EMRs they are managing

Organization	EMR used	Number of interviewees
Amana RRH	eHMS	2
Mwananyamala RRH	GoTHoMIS	2
Temeke RRH	GoTHoMIS	2
Tumbi RRH	GoTHoMIS	2
Muhimbili National Hospital	Jeeva	3
PO-RALG	GoTHoMIS	3
Total		14

Data collection in this study was conducted in Dar es Salaam and Pwani regions in Tanzania. The study involved selected referral hospitals. Referral hospitals were chosen because they have all adopted the use of electronic medical record systems. Due to the time of the study, only five (5) referral hospitals participated in the study. Data were collected from only two regions which are Dar es Salaam and Pwani in Tanzania. Preferably, it would have been better to collect data from other RRH to increase the scope of the study findings and the sample size. Dar es Salaam region was chosen because of the national hospital and three regional referral hospitals. Pwani region was chosen because of Tumbi RRH and to increase the scope of the study. Referral hospitals involved in the study were Amana RRH, Mwananyamala RRH, Temeke RRH, Tumbi RRH, and MNH.

Hence, results obtained from the interview were analysed using qualitative data analysis techniques. Analysis and interpretation of qualitative data started from the research field and it was a continuous process. Both manifest and latent content analysis was used to analyse the transcribed data collected from the one-on-one interview. Content analysis is an analytical method of coding and classifying non-numerical data. It is a suitable method for analysing verbal, visual, or written material for systematic reduction, abstraction, and simplification of recorded information, and to set off categories for adopted inferences and descriptions [17]. The purpose of content analysis is to organize and produce meaning from the collected data to draw realistic conclusions [18]. These results were interpreted and explained to provide the final results. According to [18] [19] the following steps were achieved in the content analysis after transcribing the interview: - 1)To become familiar with the data by re-reading the interview several times and putting it into smaller units that have the same meaning this process is also known as condensation. 2) Developing

codes or labels which describe the meaning of the condensed units. 3) Grouping of the codes or labels which belong together. 4) Formulation of themes which is the underlying meaning.

Moreover, the study observed all ethical considerations to ensure University and National research policies comply. In doing so, the study was conducted after obtaining a research clearance permit from the University of Dar es salaam Research and Publications Committee on behalf of Tanzania Commission for Science and Technology (COSTECH). Also, the study obtained ethical clearance for conducting the study which was also obtained from the University of Dar es Salaam Research and Publications Committee. During the research, the target participants were contacted to obtain appointments for the interview under their consent. The purpose of the interview was explained to each participant before the interview. Verbal consent was sought from participants to conduct interviews and written consent when the referral hospital requested it. Confidentiality has been maintained throughout the study as no names have been disclosed.

3 Results

3.1 Investigation of Interoperability of EMR Systems in the Selected Referral Hospitals

Analysis of EMR interoperability was based on the technical and non-technical factors obtained from the narrative literature review. The study identified eight (8) factors and categorized them into technical and non-technical factors. Technical factors identified were; i) Adherence to medical standards, ii) The existence of medical terminologies and controlled vocabularies, iii) The use of standardised data types, and iv) Adherence to communication channels or protocols. Non-technical factors identified were i) The influence of political supremacy, ii) The existence of diverse social backgrounds, iii) Legal aspects (law, policy, rules, and regulations), and iv) The availability of resources.

Investigation of EMR interoperability in hospitals helped to understand the current EMR systems implemented in the referral hospitals and if they are interoperable among hospital sections, and between hospitals. Also, it assisted to understand the mode of sharing patient information, imaging information, tools that are currently in use, and the contents taken in sharing patient information. Under this section, all case hospitals visited were Temeke RRH, Mwananyamala RRH, Amana RRH, Tumbi RRH, and MNH. Table 4 shows the summary of the results of technical factors and Table 5 shows the summary of the results of non-technical factors in the cases visited.

Table 4: Results of technical factors which influence interoperability found in the referral hospitals

TECHNICAL FACTORS	TEMEKE RRH	MWANANYAMALA RRH	AMANA RRH	TUMBI RRH	MNH
MAIN EMR SYSTEMS IN USE	GoTHoMIS	GoTHoMIS	eHMS	GoTHoMIS	Jeeva
OTHER EMR SYSTEMS	X-rays/ Ultrasound	Labnet X-rays/ Radiology	X-rays/ Radiology	Labnet/ CTC2/ X-rays	CTC2/ PACS

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Medical standards	HL7 v2	HL7 V2	HL 7	HL7 V2	No Medical standards for Jeeva
Imaging standard	DICOM	DICOM	DICOM	DICOM	DICOM
Medical terminologies	ICD 10	ICD 9 & ICD 10	ICD 10	ICD 10	ICD 10
Data types	XML	XML	XML	XML	XML HL7
	OOP using java for backend front end angular HTML	OOP using java for backend front end angular HTML	PHP ASCII	OOP using java for backend front end angular HTML	Visual Basic
	MySQL	MySQL	MySQL	PostgreSQL	DB2
Communication standards	API pull standards	API pull standards	API pull standards	API pull standards	API JSON API XML REST API

For non-technical factors, Table 5 indicates the summary of the results on how each non-technical factor investigated in the selected hospitals' influences the interoperability of EMR systems in the hospitals. The results indicate that the interoperability of EMR systems can be attributed with the influence of political supremacy, legal aspects (law, policy, and regulations), and the availability of resources while the existence of diverse social backgrounds (beliefs, desires, and practices among people) cannot be attributed to the interoperability of EMR systems. Therefore, in Table 5 "YES" means that the factor can contribute to the interoperability of EMR systems, and "NO" means that the factor cannot contribute to the interoperability of EMR systems

Table 5: Results of non-technical factors which influence interoperability found in the referral hospitals

NON-TECHNICAL FACTOR	TEMEKE RRH	MWANANYAMALA RRH	AMANA RRH	TUMBI RRH	MNH
The influence of political supremacy	YES	YES	YES	YES	YES
Existence of diverse social background	NO	NO	NO	NO	NO
Legal aspects (Law, Policy, and Regulations)	YES	YES	YES	YES	YES
Availability of resources	YES	YES	YES	YES	YES

- **Temeke Regional Referral Hospital**

Temeke RRH hospital uses Government of Tanzania - Hospital Management Information System (GoTHoMIS) system to store patient information, Government Electronic Payment Gateway (GePG) installed with the hospital's billing system for a payment system, Digital Imaging and Communications in Medicine (DICOM) for communication, and clear canvas used in imaging. The payment system is integrated with the GoTHoMIS system so that once the payment has been made, the doctor can attend to the patient. Imaging systems and GoTHoMIS are not interoperable and are recognized as standalone

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systems. Sharing of patient information between hospital sections is through the systems and contents that become shared are the only ones that a doctor or nurse should see. The patient at the hospital is identified by a medical registration number which is auto-generated by the system. Patient information with other hospitals is shared through referral forms.

Temeke's GoTHoMIS system is designed with Health Level 7 (HL7) V2 medical standards and for imaging systems the standard used is DICOM. In terms of medical terminologies, the system uses the International Statistical Classification of Diseases and Related Health Problems (ICD 10). The type of message format deployed in the system is Extensible Markup Language (XML). The results show they neither import and export data nor do any data processing. The system has been developed by Object-Oriented Programming (OOP) using java for backend front end angular Hypertext Markup Language (HTML) and deployed Relational Database Management System (DBMS). Most of the systems are standalone but GePG and GoTHoMIS systems are integrated with Application Programming Interface (API) pull standards. Protocols for data transmission include Transmission Control Protocol / Internet Protocol (TCP/IP) and Hypertext Transfer Protocol (HTTP).

Non-technical factors results indicate the influence of political supremacy has an impact in making agreements and procedures on the content of patient information to be shared since patient information is privacy. On the other hand, the social aspects such as beliefs have no impact on interoperability where this procedure is in the medical system. *"As long as you are in the treatment process your beliefs should stay away" (Respondent, personal interview, November 03, 2020).* Thus, it implies that customs and beliefs among people cannot hinder sharing of information in the process to achieve continuity of care through the interoperability of EMR systems. Moreover, the study indicates a lack of hospital ICT policy but is currently in the process and lack of ICT budget for interoperability of EMR. Resources to support EMR interoperability may include funds for interoperability and experts of both EMR systems. Also, the study indicates the great demand for EMR systems interoperability between hospitals which will support the sharing of patient information from one hospital to another.

> *The need occurs where you can find the patient arriving at the hospital and being treated and reach a point where he needs extra service or treatment which are currently not available here for example MRI test we, therefore, request it to another hospital to take the test. These request normally occurs when the case needs higher capacity and we lack specialist doctors for that case, or we do not have the equipment to perform that test (Respondent, personal interview, November 03, 2020).*

- **Mwananyamala Regional Referral Hospital**

Mwananyamala RRH uses GoTHoMIS to store patient information, GePG for a payment system, and a laboratory system called Labnet. Only the payment system is connected to the GoTHoMIS system. Other systems are standalone they are not interoperable and even the GoTHoMIS patient information system is not working properly because of existing system bugs and they are expecting to move to Afyacare system. Sharing of patient information within a hospital is mainly using forms and we use referral forms when sharing patient information with other hospitals. The patient who uses NHIF may use NHIF portal for referrals. In terms of imaging, they use digital x-rays and access through shared folders within the hospital and with other hospitals, patients get his / her softcopy. Patients are identified by their medical records number auto-generated by the system.

Mwananyamala's GoTHoMIS system is designed with HL7 V2 standards and in the imaging systems such as radiology, and x-ray the standard used is DICOM. In the case of medical terminologies, the system uses ICD 9 and ICD 10. The type of message format deployed in the system is XML. The results show they do not import data but export data through pdf format. In addition to that, they do not do any data processing. The system is developed by OOP using java for backend front end angular HTML and has deployed Relational DBMS MySQL. Most of the systems are standalone but in terms of the GePG and GoTHoMIS system, they are integrated with API pull standards. Protocols for data transmission include TCP/IP and HTTP.

Non-technical factors results indicate that political aspects and their leadership have an impact on planning and making an agreement for the interoperability of EMR systems. Social aspects such as beliefs and mores have no impact on interoperability and it is in great demand on the side of doctors to improve the health outcome of patients. Also, the study indicates lack of hospital ICT policy has an impact even with GoTHoMIS and LABNET to communicate. *"Because if these systems could communicate without*

any problem even the work would become very smooth" (Respondent, personal interview, November 05, 2020). Moreover, the study indicates a lack of ICT budget allocated for EMR interoperability and the expectation of another system called Afyacare. Resources to support interoperability include funds for interoperability and experts of both EMR systems.

- **Amana Regional Referral Hospital**

In the case of Amana RRH, the system used to store patient information is Electronic Hospital Management Systems (eHMS), imaging systems such as radiology and x-ray. They also have a GePG government payment system, the GePG system is integrated with the eHMS. EMRs are interoperable, and sharing of patient information within the hospital unit is through the system while sharing with other hospitals is through referral forms. Contents and information took to be shared depending on what you are supposed to view. In terms of imaging systems, they are accessed through shared and the patient may request for his/her softcopy. Patients are identified through their medical record numbers auto-generated by the system.

Amana RRH eHMS system is developed with HL7 standards and in the image format, the standard used is DICOM. In terms of medical terminologies, the system uses ICD. The type of message format deployed in the system is XML. The results show they can export and import data in excel and pdf, they can also process data in excel, pdf, and notepad. The system has been developed by Hypertext Preprocessor (PHP) ASCII and they have deployed Relational DBMS MySQL. Most of the systems are standalone, but the GePG system and eHMS system are integrated with API pull standards. Protocols for data transmission include Hypertext Transfer Protocol Secure (HTTPS).

Non-technical factors studies indicate that political aspects such as leadership have an impact on operations and the improvement of health information systems. On the other hand, social aspects such as beliefs and mores have no impact on interoperability since we follow the procedure and patients believe in doctors. Also, it is in great demand on the side of doctors because technology brings motivation and simplifies their work. The study indicates a lack of hospital ICT policy and the use of ICT policy from the Ministry responsible for health. The policy has an impact to give directions and guidelines on what to do. *"If there is policy, people will abide, without policy people will do anyhow" (Respondent, personal interview, November 06, 2020).* Moreover, the study indicates the existence of an ICT budget that does not include a budget for EMR system interoperability. Resources to support interoperability are reliable internet, technology, and expertise.

- **Tumbi Regional Referral Hospital**

In the case of Tumbi RRH, they use GoTHoMIS to store patient information, Labnet system on the laboratory side, CTC2 on the Care side and Treatment Clinic. Patient information is shared within the hospital through the system but mainly we use forms. These systems are standalone, they are not interoperable and they use referral forms to share patient information with other hospitals. Contents to be shared are the ones you should view and the imaging systems are provided with film. Patients are being identified by names and by unique medical record numbers.

Tumbi's GoTHoMIS system is designed with HL7 V2 standards and the imaging system standard used is DICOM. In the case of medical terminologies, the system uses ICD 10. The type of message format deployed in the system is XML. The results show they do not import and export any data but they process pdf data format. The system is designed by OOP using Java for backend front end angular HTML and deployed Relational DBMS PostgreSQL. Most of the systems are standalone, but the GePG and GoTHoMIS systems are integrated with API pull standards. Protocols for data transmission include HTTP.

Non-technical factors studies indicate that political aspects have an impact on HIS and the interoperability of systems. A good example is between PO-RALG and the Ministry responsible for health. They are speaking different languages whereby one is speaking of GoTHoMIS and another speaking of Afyacare. Also, culture and beliefs have minimal impact since it is difficult to cope with new technology but later society copes. *"They have an impact, people react differently, and it is nature. People are very difficult on receiving new things and then later on they accept" (Respondent, personal interview, November 10, 2020).* EMR system interoperability is in great demand to improve the health outcomes of patients. Moreover, the study indicates a lack of hospital ICT policy and the use of the ICT policy from the Ministry responsible for health. The policy has the impact to give directions and guidance to prevent entering into problems by giving directions and guidelines on what to do.

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> *The Policy has an impact on system interoperability initiatives because policy, as it is in a normal state, will direct you on what to do like do this and not this and you have to follow that policy otherwise you could get into trouble. (Respondent, personal interview, November 10, 2020)*

Also, the study indicates the existence of an ICT budget that does not include a budget for EMR system interoperability. Resources for EMR interoperability includes Reliable internet and computer infrastructure. *"It's just investing in ICT infrastructure both within and outside" (Respondent, personal interview, November 10, 2020).*

- **Muhimbili National Hospital**

Jeeva is a system used to store patient information at MNH. Jeeva is a module-wise system and is used with all units in MNH, each section containing its module. In terms of images, sharing is through the ClearCanvas PACS system and patients may request for Compact Disc (CD) softcopy. Contents to be shared are the ones you should see and the patient is identified by his or her medical record number auto-generated by the system.

Muhimbili's Jeeva system is designed without standards but MNH can create an interface to communicate with other systems which have standards and for the imaging system the standard used is DICOM.

> *It was not in the HL7 No formal specific standard but by using these communication standards, we are able to create a separate App that has the ability to communicate with someone who wants to send their information in HL7 format. For example, laboratory machines send in HL7 format so we have a separate APP, and its job is to translate the reading into those machines and bring us to the standard format. The system was developed in 2004-2006 and has no standards. (Respondent, personal interview, November 10, 2020)*

In the case of medical terminologies, the system uses ICD 10 and in terms of drug codes, they use custom codes and generic names. The type of message format deployed in the system is XML HL7 message format. The results show they do export Excel, XML, JavaScript Object Notation (JSON) is used in integration with District Health Information System 2 (DHIS2), Comma-separated values (CSV) with the health information mediator of the Ministry. On the other hand, they process Excel, XML, and JSON, while with Portable Document Format (PDF) they lack permits. Also, the system is designed with Visual basic. They have also deployed Relational DBMS DB2. Standards for communication API JSON or API XML the technology is Representational State Transfer (REST) API while protocols for data transmission include HTTPS, Secure File Transfer Protocol (SFTP), TCP/IP.

Non-technical factors studies indicate that political settings have an impact on the interoperability of EMR between hospitals, the Ministry responsible for health influences interoperability and not hospitals. *"Hospital has no influence for EMR interoperability between hospitals. The Ministry itself has plans and policies" (Respondent, personal interview, February 20, 2021).* On the other hand, social aspects such as beliefs and habits have no impact on interoperability because we are not very educated and we do follow health procedures. In addition to that, there is an ICT policy for the hospital but it does not address the issue of EMR system interoperability but there is a clause regarding ICT to deal with specifications of all imported systems should have standards to support interoperability and also policy considers all hospital systems specifications to be recommended by IT department. *"Without policy means you are not able to act on, no guidelines on what to do and not in your plans of what you are supposed to do" (Respondent, personal interview, March 03, 2021).* Moreover, we have governing bodies responsible including the Ministry responsible for health and E-Government Authority (e-GA). E-GA is mainly for policy and guidelines and the MOHCDGEC has the policy and strategic documents that support and emphasize the implementation of interoperable systems. For example, we give MTUHA reports based on the Ministry format to facilitate decision-making. Nonetheless, we have an ICT budget but not for EMR system interoperability when we consider resources for EMR interoperability are financial (funds), expertise (human resources), time, and technology on how to share.

- **Government of Tanzania Hospital Management Information System (GoTHoMIS) -PO-RALG**

The Government of Tanzania Hospital Management Information System (GoTHoMIS) is an electronic information system intended to collect and report facility-level clinical information (basic patient-level clinical dataset) and to support health facilities in service delivery management. GoTHoMIS is a full

hospital information system developed by the Government of Tanzania. The GoTHoMIS will provide functionalities that capture the complete and relevant patient information. The system also automates the patient administration functions to give a better and more efficient patient care process. The GoTHoMIS will answer all enquiries about the patient, which include admission, appointment scheduling, billing, and discharge details. The system is currently in use at Tumbi RRH, Temeke RRH, Mwananyamala RRH and extended to district hospitals countrywide.

GoTHoMIS operations are managed by the President's Office, Regional Administration, and Local Government (PO-RALG). The system uses *"HL7 V2 medical standards and supports the use of DICOM standard for imaging systems" (Respondent, personal interview, February 08, 2021).* Also, the disease codes system uses ICD10 and standard drug coding Government of Tanzania Medical Stores Department (GoT MSD) Catalogue. The system also supports JSON, XML message format and can process, import and export several data types including JSON, XML, XLS, PDF, RTF, CSV. Apart from that, the system is developed using OOP using Java for backend, Front end Angular, HTML, and work in Relational DBMS such as (PostgreSQL) using Java Persistence API (JPA) and MySQL. In addition to that the system use REST API, GraphQL, Advanced Messaging and Queuing Protocol (AMQP) standards for communication (communication standards) and support protocols such as HTTPS, Transport Layer Security / Secure Sockets Layer (TLS/SSL) as TCP/IP transport layer protocol for communication between client and server during data transmission. The patient identification used is a medical record number generated by the system. The system records patient information: a summary of medical history, demographic data, medication lists, allergy lists, vital signs, and laboratory test results.

4 Discussion on Results

4.1 Technical Factors

The results indicate the existence of different EMR systems among hospitals. These systems have similar medical standards, which is HL7, but with the exception of the Jeeva system of Muhimbili which was developed without standards. On the other hand, with the Jeeva system, they can develop an interface to communicate with any EMR system which contains medical standards. In all cases visited they have adopted the use of DICOM standard for imaging systems. The use of medical standards has also been discussed by some researchers [15] [5] as a factor that influences interoperability. However, in our case, the visited hospitals' EMR systems have medical standards and image standards, therefore, the availability of medical standards is an enabler for the interoperability of EMR systems.

Moreover, all visited hospitals have adapted the use of ICD 10, and drug codes are custom and generic names. This implies that they have to adhere to the interchange of medical information. Medical terminologies and control vocabularies, which include ICD 9 and ICD 10 play a role in facilitating sharing of medical information. According to the study done by [5] [20] [21], it was revealed that medical terminologies and controlled vocabularies play a major role in achieving interoperability of EMR systems. The study findings indicated that, in all the visited cases, the availability of medical terminologies, disease codes, and control vocabularies are enablers for the interoperability of EMR systems.

Nevertheless, the results indicate that EMR systems have deployed similar message formats like XML, and can export and import the same data type like excel, and XML. Also, the EMR systems can process data in excel, pdf, XML with exception of the Jeeva system where there is no permission to process pdf. On the other hand, these EMR systems have been built with different programming languages and they run under different relational database management systems. Jeeva is built on Visual basic, eHMS in PHP ASCII and GoTHoMIS system used OOP using Java for backend, front end angular, HTML. On the side of relational database management systems, includes MySQL, Db2, and PostgreSQL. Hence, EMR systems are designed as per hospital needs and they are different in data structure and format. Also, similar results on the existence of different EMR systems with different data structures and formats in Tanzania have been reported by [11][12]. Thus, the existence of different designs, data structures, and relational databases with different database schemas which include relations and attributes, is regarded as a factor that influences the interoperability of EMR systems.

Lastly, the results indicate the use of REST API technology for communication standards across EMR systems. Jeeva uses the same technology REST API standards for communication which can either be API

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JSON or API XML. GoTHoMIS uses Rest API GraphQL, Advanced Messaging and Queuing Protocol (AMQP). Protocols used during data transmission are the same including HTTP, HTTPS, and TCP/IP transport layer protocol for communication between client and server, and the addition of SFTP used by MNH. The study done by [22] [23] revealed communication channels and protocols have an impact on interoperability but for the case visited this is not regarded as a factor that can influence the interoperability of EMR across hospitals because in all cases they are using the similar communication standards and protocols during data transmission.

4.2 Non-technical Factors

The study indicates that lack of agreement among leaders and organizations responsible for health slows down interoperability initiatives. Interoperability across hospitals is not part of their plan at the hospital level but it is for the Ministry responsible for health. On the other hand, the Ministry responsible for health and PO-RALG speak a different language for example Afyacare and GoTHoMIS. Thus, it is difficult in making agreements and procedures on how to achieve interoperability across hospitals. Similar results were revealed by [24], the organization with authority is the driving force to HIS initiatives which include interoperability. Also, this political supremacy was revealed to have an impact on interoperability by [12]. Thus, the influence of political supremacy is one of the factors which influences interoperability.

Moreover, in all cases visited the study indicates social beliefs and practices do not influence the medical procedural system. Social customs have no impact on the interoperability of EMR systems when medical information is being shared across hospitals. Also, as technology grows it simplifies the performance of doctors in improving patient healthcare as information can be shared over time from one place to another. The results are not similar to [25] who revealed aspects of culture as a factor that hinder information sharing hence interoperability while in the cases visited it indicates social cultures, beliefs, and norms will not be able to resist EMR interoperability and sharing of patient information. Thus, the diversity of social backgrounds, customs, and beliefs is not regarded as an influencing factor towards the interoperability of EMR systems.

Nevertheless, the research indicates that some hospitals have an ICT policy of the hospital and others do not have it. Also, those with hospital ICT policy, do not address EMR systems interoperability. The existence of a policy facilitates a process that should be followed to ensure that the existing systems within the hospital can exchange information and that policy will support the recommendations of different hospital EMR systems to communicate as well. Similar results have also been revealed by [26] in Uganda where it was found that policy has an impact from system development, integration, information exchange, and interoperability executions within a country. Hence, policy is regarded as a factor that influences the interoperability of EMR systems. Policy instructs, gives direction, makes people abide, and supports interoperability of EMR systems.

Lastly, the results indicate lack of resources to achieve interoperability. In all cases visited there is lack of funds, infrastructure, and expertise. Resources that include funds, time, infrastructure such as reliable internet, and expertise of both systems have a great impact in influencing and achieving the interoperability of EMR systems. Similar results were revealed by [25] [26] resources such as financial to have an impact in the interoperability of EMR systems. Thus, in all cases visited resources are one of the factors which influence the interoperability of EMR systems.

5 Approaches towards achieving interoperability of EMR

From the empirical studies, for technical factors, the findings indicated EMR systems interoperability in hospitals can be attributed to the use of standardised data types. Also, for non-technical factors, the influence of political supremacy, availability of resources, and legal aspects which include policy and regulations can be accounted for the interoperability of EMR systems. Hence from these results, the study has recommended approaches towards achieving interoperability of EMR systems in Tanzania.

i. The initiatives of systems interoperability should not start at the hospital level but should start from the top. All initiatives related to EMR interoperability among hospitals should start with the Ministry responsible for health. Likewise, The Tanzania Digital Health Strategy and Health Policy provide policy statements and strategic initiatives to ensure EMR and other systems are interoperable. In all cases visited

the issue of interoperability was not a problem but they act and do according to the regulations provided to them.

ii. Establishment of hospital ICT policy to support interoperability of EMR systems within the hospital. The Tanzania Digital Health Strategy and Health Policy provide policy statements and strategic initiatives to ensure EMR and other systems are interoperable. There should be a way to manage and oversee if policies are being followed. Most of the systems have adapted similar medical standards, interoperability will only be achieved when there is policy or guidelines to give direction on how to achieve EMR systems interoperability and the law to enforce interoperability of EMR systems. Also, Hospitals that have a hospital ICT policy like Muhimbili, their policy should address the issue of interoperability of EMR systems.

iii. Adherence to the Tanzania health enterprise architecture provides the framework towards achieving interoperability of digital health systems. Sharing patient information improves health outcomes and it may also involve more than one organisation. Therefore, healthcare organisations that are the stakeholders of health should adhere to the framework to achieve interoperability of digital health systems.

iv. Hospitals should invest in technology which means investing in various interoperability technologies such as REST API and HL7 FHIR to achieve interoperability of EMR systems. The use of interoperability technologies will also support the interoperability of EMR systems within the hospital and between hospitals. For all the RRH visited this is not their priority since it is not in their work plan and no budget has been allocated for it.

v. There should be a reliable supply of internet to achieve technical interoperability. Also, we should perform proper maintenance of EMR systems, this is to ensure that system errors and bugs are fixed on time to ensure smooth operations. In one of the cases visited the usage of GoTHoMIS is low because of system bugs and hence it is difficult to think of sharing patient information and interoperability of EMR across sections. Thus, proper maintenance of EMR systems should be conducted and reliable internet service to ensure smooth operations of EMR systems.

vi. Enough budget should be allocated towards the interoperability of EMR systems both within the hospital and between hospitals. EMR interoperability should be able to handle budget restrictions. Budget should be allocated in hospitals to support the investment in interoperability technologies to achieve interoperability of EMR systems within the hospital section. For all cases visited no budget is allocated for interoperability of EMR systems within the hospital, hence it is difficult to achieve interoperability of EMR systems among hospital sections.

vii. The Ministry and other governing bodies should ensure that the established policies are being followed. The Tanzania Digital Health Strategy and Health Policy have established an interoperability policy to give directions and guidance in achieving interoperability between digital health systems.

Acknowledgements

None

Statement on conflicts of interest

No conflict of interest

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 J Health Inform Afr. 2022;9(1):1-13. DOI: 10.12856/JHIA-2022-v9-i1-303

Journal of Health Informatics in Africa

Improving Collaboration Among Healthcare providers in Resource Constrained Healthcare Facilities: An Enterprise Architecture Approach

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Background and Purpose: Application of an Information System that can provide a seamless flow of patient information and medical guidelines is highly desirable in the practice of Evidence Based Medicine (EBM). Information systems in Resource Constrained Health Facilities including Uganda have been found to be inadequate in supporting collaboration among healthcare providers. This study aimed at optimising collaboration and information sharing among healthcare providers by developing an architecture for a collaborative mobile application.
Methods: The study adopted a case study research design and qualitative data was collected from 32 informants using a series of data collection methods including; interviews, focus group discussions, observation and document reviews from the hospital's resource centre, published articles and online informatics journals.
Results: Findings from this study showed that there were various information and communication systems including computers, e-mails, internet access and suffice to note, telephone calls for both landline and mobile were still being used for collaboration. Collaboration challenges that were identified include system integration issues, infrastructure limitations, data quality issues, system usability and geographical dispersals of both healthcare providers and healthcare facilities among others. The study further established that current systems focus more on monitoring and evaluation, surveillance of chronic diseases and data capture; less is done towards optimisation of collaboration.
Conclusions: Healthcare providers ought to make decisions based on the most up-to-date, solid, reliable and scientific evidence, this study proposed a collaborative mobile application architecture to improve collaboration among healthcare providers at any point of care. The architecture was developed using enterprise architecture principles taking cognizance of its four crucial C's; connection, collaboration, communication and customer.

Keywords: Collaboration, Resource-Constrained Healthcare Facilities, Evidence-Based-Medicine, Architecture.

1 Introduction

Nations that have inadequate health systems are liable to experiencing poor economic growth since the productivity of the labour force is bound to be affected by poor health [1]. They have to deal with the expectations of their citizens to resolve the challenges in persistent inequities in accessing healthcare among different communities [2]. More interventions are desirable and also essential world over since health systems are increasingly facing tough and complex challenges that partly originate from new pressures such as the prevalence of chronic illnesses, fragile populations and the intensive use of expensive yet vital health technologies [3]. To overcome these challenges, various nations have taken substantial steps in developing Health Information Systems (HISs) that can enhance the provision of healthcare service delivery[4] [5]. HISs are capable of improving collaboration and healthcare service delivery [6] as systems enable communication between and among healthcare providers even in hard-to-reach areas; and enable them to get access to critical information for decision making [7].

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 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

With the influence of donor aid, Resource Constrained Healthcare Facilities (RCHFs) have implemented HISs to provide access to quality and equitable healthcare. Systems such as Electronic Patient Records (EPRs), Electronic Medical Record (EMR) [4], Electronic Health Record (EHR) [8], and District Health Information System (DHIS) [9]. These programs are influenced at the national level through various International donor funding such as WHO, USAID and DFID [10].

Whereas significant potential for HISs to positively influence optimal collaboration among healthcare providers exists, it is imperative to note that collaboration has been hindered by; individually operating entities, each generating its own silo of information and this makes interaction minimal [11] [12]. Healthcare systems in RCHFs greatly rely on donor funding in the pilot stages because of the huge costs involved,[4] and when there is need for scalability, institutions have to devise ways of getting funding yet this is costly. Donor systems are customized to target specific programs such as data collection and reporting on HIV/AIDS, malaria and tuberculosis, hence result in fragmented systems which hinder collaboration [13]. Focus is put on monitoring and evaluation, disease surveillance, chronicle diseases, patient registration, data capture and billing; very little is done towards optimization of collaboration [14]. These systems are a "cut and paste" solutions [15], though they are effective in mother countries, they are not in RCHFs; because of the design-reality gaps [16][17].

Those systems are further aggravated by other challenges common to most RCHFs [18] [19] including; financial and structural constraints; insufficient digital infrastructure due to high costs [20] unreliable electricity,[21]; low-quality and expensive Internet access,[22]; geographical proximity which hinders healthcare providers from getting to know each other and innovate together[23], a big number of the populace in rural areas which is aggravated by lopsided ICT implementations, inadequate information exchange mechanism across institutional boundaries, moreover they are hospital and departmental centred [24], and are inward facing to organizational units yet they should be outward facing to enhance collaboration [4], hardware acquisition [25], and lack of regional integration.

Amidst the prevalent adoption of ICTs, ICT systems that can execute a seamless flow of information through healthcare business processes are not widely used in healthcare environments [26]. It is common to find healthcare organizations still using manual systems, e-mails, telephones (landline and mobile handsets) as means of communication and collaboration [27]. This hinders collaborative prompt response to emergencies such as outbreak of diseases that lead to increased mortality and morbidity in RCHFs.[28].

Besides those challenges, it is worthy to note that, healthcare service delivery has two characteristics which make the deployment of HISs challenging as well as potentially highly helpful. First, healthcare is a key example of **collaborative work;** and this involves partnerships and shared decision making [29] secondly, contrary to other disciplines, healthcare work is often **non-routine**, which makes it difficult to pre-schedule clinical procedures and activities. Issues such as emergencies and exceptions are so common enough and impede standardization of clinical practices. These two characteristics call for dependency on communication and critical information sharing to achieve optimal collaboration but they also provide justification for deployment of seamless communication technologies to coordinate clinical workflow [30] [31]. Without workable architecture that can enhance collaboration and information sharing, the gap between empirical evidence and clinical workflow would continue to exist and this would have a negative impact on the quality of care [32] [33]. [34] specifically cites collaboration and communication limitations as the leading root cause for medical errors, delays in treatment, duplication of tests, wrong-site surgeries, or even unexpected death.

Despite the various interventions with different technologies, collaboration shortfalls as mentioned earlier still exist and a big portion of the HISs research had concentrated on initiatives relating to HIV/AIDS, tuberculosis, and malaria. Few studies had been carried out in information systems that focus on point-of-care collaborative architectures; so, this study aspired to explore existing healthcare information systems, the collaborative challenges that healthcare providers encounter in healthcare service delivery and the existing opportunities available that call for communication and collaborative technology architecture [35]. Thence, designing and developing a mobile tool architecture that would bridge the information gap and improve up-to-date information sharing on an anytime and anywhere basis was highly desirable.

Notably, the application of wireless networks and the wide implementation of mobile phone applications play a great role in overcoming these issues. According to [36] [37] [20]., the adoption of mobile phones is increasing year by year, this provides chances to implement systems that require minimal resources in

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innovative ways. For these reasons, the architecture could bridge the gaps that arise from such fragmented systems and inadequate ICT infrastructure, geographical dispersals of healthcare providers [38] [39] [40]; [41] [25] and the poor and remote rural communities with challenging healthcare access.

To accomplish the objective, this study sought to answer this research question: How can collaboration among healthcare providers in RCHFs be enhanced to improve healthcare service delivery. This question was broken down into sub-questions as follows:

a) How do the existing Health Information Systems enable the sharing patient information and medical knowledge with regards to healthcare?
b) What collaboration and information sharing challenges do healthcare providers in RCHFs face?
c) What ICT Systems requirements must be met to optimize collaboration among healthcare providers?
d) How can the existing architecture development methodologies be used to develop a collaborative mobile application architecture?

2 Research Methodology

Research Design. This study was based on a case study research design in order to have an in-depth understanding of phenomenon under investigation. The case study research is an intensive study of a single unit with an aim to generalize across a larger set of units[42]. The design was also motivated by its ability to allow the generalisation of data collected from a single source. It has been known to be relevant in situations where one seeks to understand the relationship between information technologies and organisational context [43].

Sampling Method used: The study utilized purposive sampling in determining both the case study and key informants. The decision to use purposive sampling was motivated by the fact that, it would enable the researchers to choose informants that were capable of responding to an area of interest [44]. Secondly, it was the appropriate method since there was a limited number of primary data sources that could contribute to the study.

Inclusion Criteria for the Study Site*:* Lubaga hospital was adopted because it is one the largest hospitals in Uganda and was easily accessible. It had also implemented e-health systems namely clinical master and DHS2 though limited in scope, these would provide insights on the collaborative challenges and the opportunities they offer for improvements. Secondly, the hospital has Community Health Workers (CHW) under a home care department called ACT who face a variety of collaboration challenges and information access barriers hence the need to explore the associated access challenges and opportunities. The informants for this study were selected from the administration and management department because these support strategic and administrative processes; the front-office area which supports the admission of inpatients, outpatients, emergency/first aid patients; the clinical area which supports the core healthcare processes (the processes through which healthcare organizations provide treatment to patients); the IT department because this handles the management of health information systems; the resource centre since this is responsible for acquisition , dissemination, and utilization of medical knowledge and patient information; the research department which grants permission for doing research and has the documentation of the hospital.

Data Collection Tools: The study adopted two sets of data collection including primary data and secondary data. To collect primary data, three common qualitative methods were used including, in-depth interviews because they focus directly on case study topic, and they are insightful since they provide and perceive causal interfaces and explanations. Secondly, they enable the researcher to understand the phenomena in depth of what the interviewee says. The interviewer also has the benefit of following up on incomplete or unclear responses by asking additional probing questions and it has a high response rate since most informants will agree to be interviewed [45] [46]. Focus groups, and participant observation were also used and the three types of data that were generated from the three methods were field notes, audio recordings and transcripts. Purposive sample sizes were used and determined basing on theoretical saturation which is

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an approach that is used to investigate empirically until no further themes emerge [47]. To collect secondary data, documentary analysis using the hospital's resource centre was used basing on internal annual reports, existing system documentation, and strategic plan.

Data Analysis: ATLAS.ti 9 (Windows) was used to code, analyse and clean up the data that was collected basing on themes that were derived from research questions. The researcher read the responses of each informant that participated in the study to gain in-depth understanding. Secondly, the statements were extracted that bore meaning to the research questions. To ensure data accuracy, direct quotations from the informants were used. During the analysis of the responses, the researcher articulated what the responses meant and recorded the emerging themes. Similar themes were categorized and grouped together. And audio recordings were replayed for verification. Several sub-themes were classified per every theme. A thematic framework basing on thematic analysis technique was developed by moving codes into their respective thematic headings.

Figure 1: Shows the thematic framework for the presentation of the results for both the existing systems and collaboration challenges.

Figure: 1 Thematic Framework Analysis of the existing healthcare information systems and the collaboration challenges

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2.1 Statement of Ethical Approvals

The purpose of the study was explained to the Lubaga hospital research department and a research proposal was shared with them as a requirement. Besides, an informed consent form was submitted together with a payment of a research fee. A letter of approval numbered **LHREC/2018/012** permitting the researcher to conduct the study was obtained.

3 Results

3.1 Characteristics of Informants

Table 1 below shows the characteristics of informants.

Data Collection Method	Informants	Department	Frequency
Interviews	Top Management	Administration	3
Interviews	IT Staff	IT Department	4
Interviews	Medical Doctors	Medicine, Surgical & Children's Wards	5
Interviews and Focus Group Discussions	Nurse/Midwife	Medicine, Surgical & Children's Wards	15
Interviews	Laboratory Chemist	Laboratory	1
Interviews	Radiologist	Radiology	1
Interviews	Information Scientists	Records Department	2
Documentary Review	Information Scientist	Research Department	1
	Total		32

3.2 Existing Healthcare information sharing systems

Almost all informants reported that there were various information and communication systems including computers, e-mail, internet access, although internet use is becoming increasingly essential, telephones for both landline and mobile were still being used in collaboration. Besides there was a largely used system called Clinic Master as shown in Figure 2 to capture patient information and generate reports (Figure 2) and clinical management across inpatient/outpatient, laboratory, surgical and radiology units. Illustrative responses on the use of clinic master appear below.

> *"The hospital's current information and communication infrastructure includes computers, e-mail, internet access, and, telephone for both landline and mobile. Besides there is a system called Clinic Master that is currently used and this is basically for clinical management but at the back there is a government system called DHS2 that is used in aggregating statistical data collection, validation and analysis". (Interview held with the HCSP-01 on 24th May, 2018).*

> *"I use Clinic Master System to do most of my work but some services are still done manually" We also use phones to communicate among ourselves and the doctors. (*Interview held with the HCSP-02 on 24th May, 2018).

> *"We capture Bio data of patients, patient's medical history and the doctors pick notes from patients and feed them into the system. As the doctor talks to the patient, that information is directly entered into system and after typing it into the system it is saved, reports can be generated and shared with support from the IT department" (*Interview held with HCSP-03 on 24th May, 2018)

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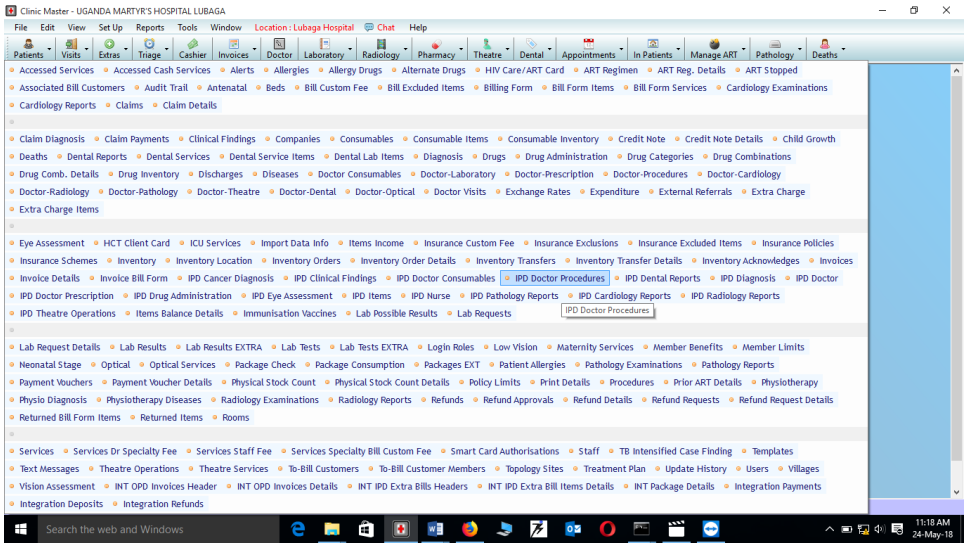

Figure 2: Showing Clinic Master System Generated Reports at Lubaga Hospital

3.3 Challenges faced in sharing of healthcare information

3.3.1 System Integration

Informants reported that there are system integration issues among the Catholic Church Founded Hospitals on one hand and the local internal systems of the hospital on the other. The illustrative example appears below:

> *"Kisubi and Nsambya hospitals do not have the Clinic Master System yet they are referral hospitals. In Kampala there is Lubaga which is using the system. There are also small units like Jinja Karoli they have a health center but they send patients to us but they do not have Clinic Master. So their bio data has to be captured from scratch when they are referred here. Nsambya Hospital is using a system called SAP, it is an ERP which is troublesome to customize. Kisubi is inquiring from us about the status of the integration of clinic master and Navision, then they will come onboard."* (Interview held with the HCSP-01 on 24th May, 2018, Lubaga Hospital).

When the informants were asked about how the current systems relate to each other and how they exchange information for collaboration, they noted that there are three systems i.e., Clinic Master, Navision and DHS2 systems within the hospital but are not connected to each other and so there is no seamless flow of information (Table 2). They indicated that they are detached; users pick data from clinical master and feed it manually into DHS2.

Category	**Patient Information sharing internally?**	**Patient Information sharing externally?**	**Medical knowledge sharing both internally and externally?**
Top Management	Yes but with limitations	Not possible	Not Applicable
Medical Doctors	Yes but with limitations	Not Applicable	Not Applicable
Nurse /midwives	Yes but with limitations	Not Applicable	Not Applicable
Computer Scientists	Yes	Not Applicable	Not Applicable
Information Scientists	Yes but with limitations	Not Applicable	Not Applicable

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Table 2: System Functionalities in the Provision of Healthcare Information

3.3.2 Data Quality Issues

Informants also noted that there are data quality issues characterised by information completeness gaps. They reasoned that this is related to inadequate documentation as it is usually done manually especially from other health units when a patient is referred. In addition, some Healthcare providers might not always provide some clinical information that might be significant to clinical research. When referrals are done the information provided is not always complete and this makes it a time-consuming process before one makes a decision about which care to offer. It is sometimes difficult for Healthcare providers to figure out things from the manual medical record since there is no inter- automatic transfer of information from one health unit to another. Below is an illustrative example.

> *"The challenge is that currently we cannot be sure that the information given in the medical record will match the post treatment for the patient. So it is a bit tricky to figure out what has been previously prescribed as there is no interface between information systems that can provide the history in its entirety"* (Interview held with a HCSP-04 on 25th May, 2018, Lubaga Hospital*).*

3.3.3 Infrastructure Limitations

Informants also reported that there are infrastructure limitations as there are not enough information delivery channels for healthcare providers to access the current system. Each ward has one computer that is shared and when it is being used others have to wait; an indication that the implementation of clinic master was still largely at a pilot stage, and needed to be scaled up. Subsequently, there is low utilization of the technology by the Healthcare providers. Below is an illustrative example:

> *"The system is available, usually online but can be accessed on only the computers where it is installed and within the environs of the hospital" (Interview held with HCSP-01 on 24th May, 2018, Lubaga Hospital).*

3.3.4 System Usability

To further examine the implementation of clinic master, this study assessed the system usability as it is one of the critical factors in the successful implementation of any technology. It was found out that some users found it easy to use and others didn't. For this reason, there was always a switch between the manual and the electronic system which becomes tedious and ultimately hinders communication and collaboration. Below is an illustrative example

> *"There are issues with customization of the clinic master. The system does not fulfil all the users' expectations. The levels of customization facilitate about 60% of what they want to do and this retards the workflow as one has to switch between the system and the paper; recording here and there. Clinicians who were used to the books; turning them to the system makes it difficult for them and they usually wonder that if they have recorded in the book is there a need to record in the system*". (Interview held with HCSP-05 on 25th May, 2018, Lubaga Hospital).

3.3.5 Proximity

The study found out that there were healthcare providers who were full time, and consultants that came as and when they had appointments, there were services that were referred to other health units, for instance imaging centres for radiology and laboratory services. There was also a home care program which was partly clinical because its activities were related to inpatients, Healthcare providers also go to outreach to help in trainings in good hygienic conditions, there was a home care department called ACT which

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physically picked patient's results from the laboratory moreover in a paper-based form. All these brought about a geographical dispersion of health services characterised by communication gaps.

4 Proposed Architecture for a Collaborative Mobile Application.

This section presents the architecture vision, goals and principles of development and implementation, strategic standards and objectives that guided the design of the architecture. It also includes the user requirements that are crucial in the design. The section also addresses the last objective of this study (How can the existing architecture development methodologies be used to develop a collaboration mobile application architecture?). The method used to resolve this research question was based on both the literature review and enterprise architecture framework and in particular the most commonly used which is TOGAF, Version 9.1, a standard of The Open Group Architecture. This has been contextualized to suite the RCHFs. It helps in developing architectures that are consistent and reflect the concerns of the key stakeholders [48] .

4.1 The Architecture vision:

To provide an information system architecture that is capable of optimizing collaboration and information sharing among healthcare providers.

4.2 Goals and Principles of the Architecture derived from The TOGAF Standard, Version 9.1

Business Principles

Name	Statement	Rationale	Implications
Primacy of principles	Architecture principles to apply to organizational units within healthcare facilities	Healthcare providers to abide by the main principals of the enterprise for its business, technology and information architectures. This will enable the organization to provide reliable and quality information for decision making.	The architecture should have provisions for ensuring collaboration, consistency and continued alignment to business without undermining the management of technology, information and business processes for both internal and external healthcare providers
Maximize benefits to healthcare facilities	Decisions are made to provide maximum benefits to healthcare facilities	Decisions made from an enterprise-wide perspective have greater long-term value than decisions made from any particular organizational perspective.	Application components should be shared across organizational boundaries
Common use applications	Solutions that can be applied across the organization are preferred	The architecture should be able to integrate various applications in the rapid integration of dynamic and diverse hardware.	The architecture should enable data transmission between various software products that are secured and connected through APIs and web services
Information Principles			
Information is a business asset	Information is an asset that has a value chain from creation to information that provides new insights	The architecture should have provisions for combining information with other sources to create new information that is critical in decision making.	The architecture should ensure compliance with confidentiality, integrity and availability and ensuring timely correct information flow and access.
Information is shared	Healthcare providers can access and share information that is required.	The architecture should have a single source of information and have it shared in response to business needs	The architecture should allow easy access to most accurate and timely information on an anywhere-anytime basis.

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Information security	Data is confidential and shared in harmony with legislation and data policies	The architecture should have measures for restricting information from unauthorized users	Provision of access to information as well as maintenance of its security should be taken care of at the information but not at the application layer
Application Principles			
Technology independence	Applications are not dependent on specific hardware and operating systems software.	The architecture should ensure that the application can run on various technology platforms.	The architecture should incorporate interfaces that will enable legacy applications to interoperate with other applications.
Ease of use	The technology should be simple, efficient, effective and easy to execution tasks	The architecture should enable collaboration within an integrated environment.	The architecture should have an interface that accelerates usability
Technology Principles			
Requirements-based change	Technology should be implemented in harmony with business needs	The architecture should be developed in accordance with healthcare providers' collaboration needs instead of having the business change in response to IT changes	Changes in implementation of the architecture must comply with full examination of the proposed changes using the enterprise architecture

Table 3: Showing principles of the Architecture- The TOGAF Standard Version 9.2

4.3 Business requirements (User Requirements) to optimise Collaboration

This section presents the business / user requirements; These requirements were identified basing on the challenges that healthcare providers faced. The challenges were identified from both the field findings and literature review and were used as a basis for determining the stakeholder's needs for the proposed system and entailed the institutional requirements in general.

The following is a summary of user requirements that were gathered for the target architecture. The architecture should be able to:

(i) Display a list of available business start-up resources from the database to the users according to their access rights and privileges. And for this study this entailed links to the patients' database, call for help (collaboration), user's profile, medical guidelines and logout.

(ii) Have user-friendly interfaces and user guides understandable by Healthcare providers with basic computer skills.

(iii) Provide access to healthcare information from multiple sources such as access to patient bio data, history database, medical guidelines and instant online consultations among healthcare providers

(iv) Evolve to meet changing requirements both in terms of functionality as well as operation and specification since policy in healthcare is subject to review and updates

(v) Be easy to maintain - Maintaining health information systems is prone to high rate of change over time. Modifications in software is inevitable after the product has been deployed and this includes, corrections, improvements or adaptation to changes in environment, requirements and functional specifications [49].

(vi) Work with existing approaches – as indicated in the literature review of this study, the proposed architect in this study was based on the Agile Enterprise Architecture where customer satisfaction is the highest priority; change in requirements is welcomed and is no longer an obstacle; and architect is modified regularly in consecutive releases.

These requirements were validated by 20 potential users of the collaborative tool and the results of the validation are presented in figure (3) below:

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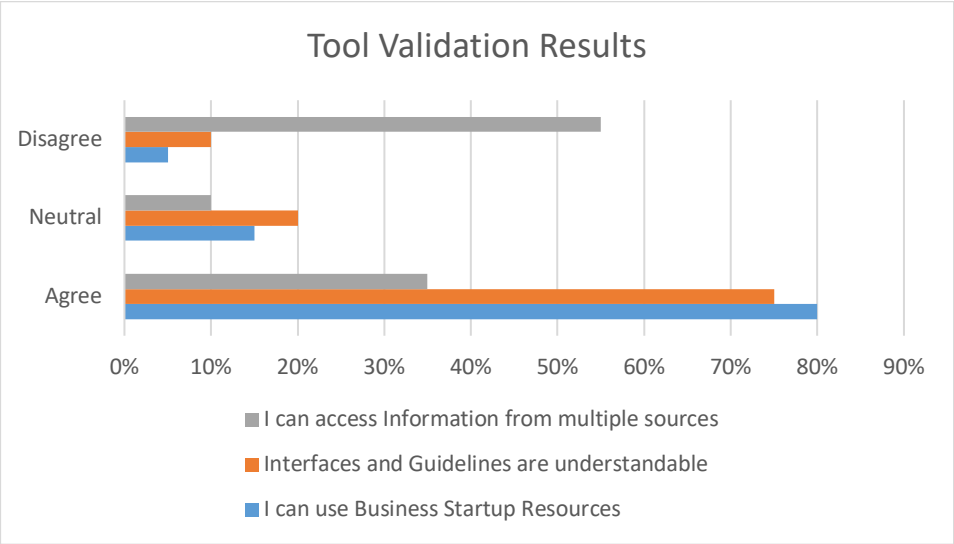

Figure 3: Shows the tool validation results

The validation of the tool indicates that 80% of the respondents strongly agreed that the tool provides start-up menus that are easy to use in their day-to- day work, 15% took a neutral position 5% disagreed. The 5% of the respondents may have been top management who do not use the tool frequently. All in all, the usability of business start-ups is highly acceptable. 75% of the respondents agree that the interfaces and guidelines are understandable, 20% took a neutral position and 10% present disagreed and these may have been ICT officers who do not use guidelines. 35% of the respondents can access information from multiple sources, 10% remained neutral and 55% disagreed and this is attributed to the fact that users needed more training on traversing through different menus to access information from multiple sources.

4.4 Proposed enterprise architecture for a mobile collaboration tool for Resource Constrained Healthcare Facilities

Below is a detailed model of the various architecture domains that make up the target Enterprise Architecture including the Business, Application, Data, and Technology that were constructed basing on the archmate language notations in figure (5).

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4.5 Complete Enterprise Architecture for Resource Constrained Health Facilities

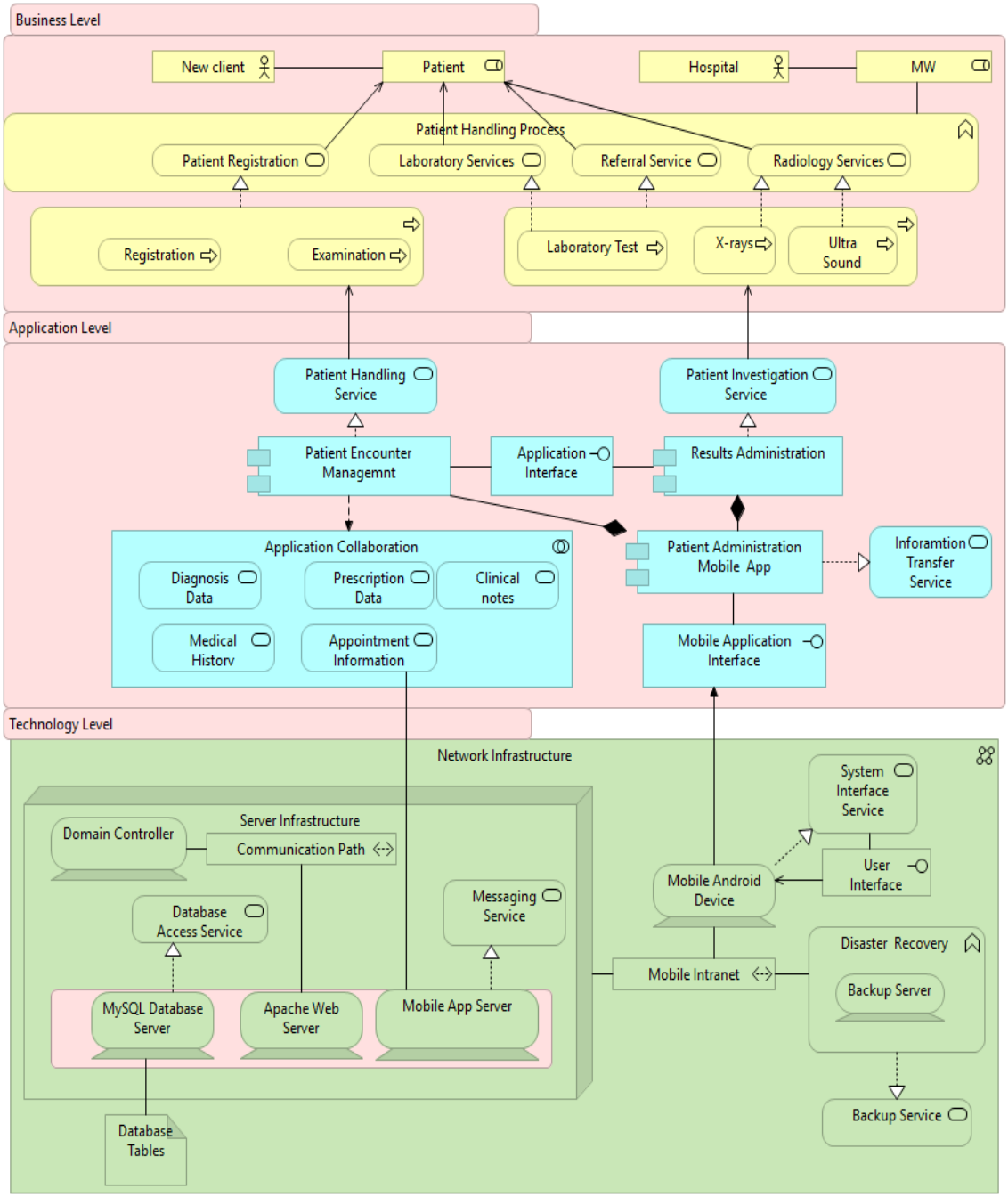

Figure 4: Enterprise Architecture Layers for Resource Constrained Health Facilities

Below is figure 5 that shows the archmate language notations that were used to develop the architecture in figure below:

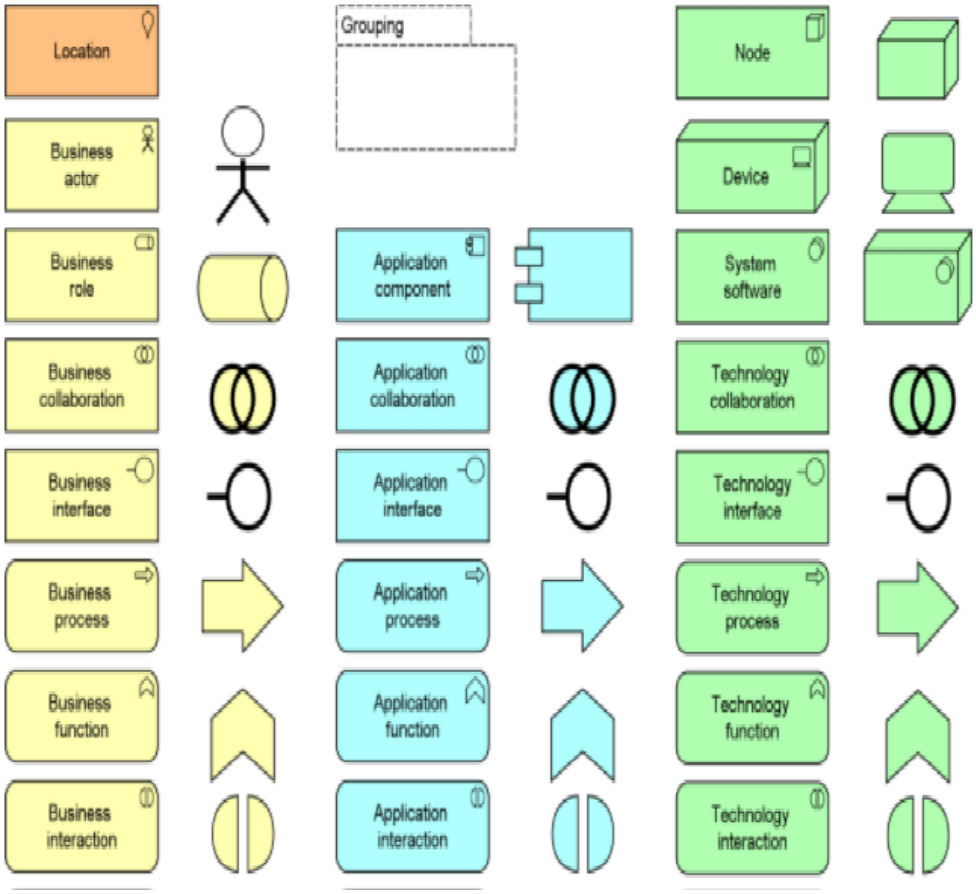

Figure 5: Showing Arch mate Annotations: Source: ArchiMate 3.0.1 Specification 2012-2017 The Open Group

The architecture comprises of the business level which encompasses the OPD, laboratory, referrals and radiology services. To reduce the length of stay, medical errors, duplication of tests and the associated problems with the existing method of patient handling, there was need to improve communication and collaboration among Healthcare providers.as illustrated in figure (4).

The application level was proposed in this study to primarily handle medical worker's interaction with the patients during the examination process. With this in place the patient's medical history is shared easily, diagnosis and treatment can be done in collaboration with other professionals and medical guidelines embedded in the patient administration application can be accessed online depending on a given condition.

The technology level architecture introduces the database server, apache web server and the mobile application servers to support collaboration. These servers are linked to the hospital network through the internet. These servers realize three services that are used in collaboration and these are the database access service, the messaging service and the backup service. This level emphasizes the need for technology that support the application and information sharing in the clinical workflows. This technology includes the servers, collaboration technologies, and storage and data recovery.

The inference drawn from the discussion of the findings were such that it is imperative to streamline certain processes as well as introducing new ones in some areas. A mobile tool architecture was of paramount importance as it can act as interface between the current technology and service delivery at any

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point-of-care. Therefore, an enterprise network architecture had to be done to streamline and align business processes to the overall objective.

5 Discussion

Basing on the results of the findings it was clearly evident that the development of an architecture that can support a mobile tool could resolve the mismatch between the actual and assumed information in clinical workflows thereby enhancing collaboration among Healthcare providers and ultimately improve healthcare service delivery in Resource Constrained Healthcare Facilities. To that effect it will enable Healthcare providers to work in agile collaborative manner as they will be able to innovate together and uncover new ways of service delivery in a way that reduces waste, patient-length-of-stay and missed handoffs which potentially lead to medical errors such as mistaken identity, improper diagnosis, and duplication of tests, wrong-site surgeries, inaccurate treatment and unexpected deaths.

During the study, a number of healthcare sharing information systems and the collaboration challenges that healthcare providers face were identified that are consistent with past research. The level of communication technology in the hospital and between hospitals was still at its infancy as the implementation of clinic master at the hospital was largely at experimental stage, with minimal collaborative features and therefore required to be scaled up. Subsequently, there was insufficient utilization of the communication technology by the Healthcare providers as there were still instances of manual information processing. These findings correspond with [40] [41] [25] as they point out that there is still lack of communication technology infrastructure in Resource Constrained Healthcare Facilities (RCHFs) and this has a great impact on data quality in regards to information completeness in clinical workflows. When referrals are done the information provided is not always complete and this makes it a time-consuming process before one makes a decision about which care to offer. It is sometimes difficult for healthcare providers to figure out things from the manual medical record since there is no inter- automatic transfer of information from one health unit to another. Secondly, there are issues with the outpatient clinical-information correctness. These findings correspond with [50] as she indicates that poor data quality caused by different issues such as lack of communication technology required in collecting the required data poses challenges to good data quality which ultimately affect decision making and quality service delivery.

More to that, the responses were in agreement with [51] who notes that there is no sub Saharan African country which has developed modern Health Information Technology that has improved online collaboration by providing timely health information. He further notes that with the influence of USAID DFID and WHO, there are emerging systems in RCHFs but these mainly focus on managing data collection and reports. Less is being done in improving online collaboration by providing patient information and medical guidelines in a concurrent and seamless manner at a point-of-care. Furthermore, the responses are indicative of [52] who note that, systems such as Electronic Patient Records (EPRs) are increasingly being considered to improve data storage, by storing and tracking medical data over the lifetime of a patient, typically across healthcare units. However various studies of such systems indicate that whereas the development and analysis of these western solutions is increasingly becoming important less is being done towards collaboration and innovations that are local in nature. This is principally true in RCHFs where IT infrastructure is still under-developed, as compared to developed countries. Many a time RCHFs look at developed ones for ICT solutions, yet local infrastructural issues can introduce drastic operational or performance challenges into the system. This is a clear manifest of a ‘design-reality’ gap [16]. There are cultural differences between the makers and the users of ICT technologies [48]. Factors of the real-world implementation differ from those considered in the design, leading to operational complications; this is a fact that is clearly manifested in the findings.

This study further revealed the user’s needs and these were elaborated in three scenarios; first, when a patient visits the hospital and when a patient is discharged from the hospital, secondly, when a facility is caring for a patient referred to them by another physician and thirdly, when they refer their patient to another physician. In that regard, this study revealed what type of information they want in the various care hand-

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offs or transitions, how they like to receive or access it, and how quickly. It was noted that across all the three situations as outlined above the medical lists, relevant laboratory results and relevant imaging results from radiology are very vital types of information to receive and use during transition of care. This collaborates with [9] as she proposes an online and real-time knowledge sharing approach that can support Healthcare providers in the process of service delivery. However, the flow of information in the above scenarios especially with the referrals was still largely characterized by paper work. For example, in case referrals to the hospitals, patients manually carry the referral forms to the consulting Healthcare providers. The existing system does not interface with other systems from other health units, if any anyway. Besides, when hospitals are also making referrals to other health units or consultants, the process is mainly paper based due to lack of system integration with other health units. These findings correspond with [16] who states that Healthcare providers and institutions lack the adequate systems functionalities to deliver strategic change yet there is a sense of urgency on their part to make use of information technology.

Looking at the case study for instance, this study found out that there are three systems including Clinic Master, Navision and DHS2 systems but they are not connected to each other and so there is no seamless flow of information. They are detached, users pick data from clinical master and feed it manually into DHS2. This collaborates with [53] as he notes that when having multiple information systems within an organization, integration of information may be required across various business units/departments. By effectively integrating systems, organizations can reap the benefits of increased efficiency and effectiveness in their processes whilst decreasing the disruption caused by having all their information in different locations.

To understand the issue of proximity or geographical dispersal, this study explored the degree to which healthcare providers are distributed and how they keep in touch with their respective units. It was found out that that there are Healthcare providers who are full time, there are consultants that come as and when they have appointments, and there are services that are referred to other health units, for instance imaging centres for radiology and laboratory services. All this brings about a geographical dispersion of health services that calls for collaborative and communication architecture. There are also home care programs which are partly clinical because their activities are related to inpatients and they also go to outreach to help in trainings in good hygienic conditions, in outreach, at Lubaga hospital for instance, there is a home care department called ACT which picks patient's results from the laboratory physically, this further reveals that there are limitations in information sharing as there are Healthcare providers that deal with outreach programs who because of lack of proximity do not have access to information unless they move physically to the hospital and pick it manually in a paper based form. This matches with [50] as he contends that rural areas experience distinct challenges in gaining access to health care. And he proposes the implementation of ICT infrastructure can support rural health in overcoming geographic and historical healthcare barriers.

The study confirmed that there are infrastructural limitations since the hospitals do not have enough information delivery channels for Healthcare providers to access the current system. Each ward has one computer that is shared and when it is being used others have to wait; an indication that the implementation of clinic master was still hindered by infrastructural limitations. Subsequently, there is low utilization of the technology by the Healthcare providers. These findings correspond with [25] indicate that the use of Technology-Based Interventions (TBI) for healthcare delivery is hampered by poor infrastructure as the major barriers to communication and collaboration among Healthcare providers.

Moreover, RCHFs have substantial operational shortfalls in their physical networks because of the high costs, geographic dispersals, and a big number of the populace in rural areas. Thence the use of wireless networks and implementation of a well-structured mobile architecture can help to overcome this issue. This is in agreement with [54] as he contends that the adoption of mobile phones is increasing year by year, and this provides chances to implement systems that require minimal resources in innovative ways. For these reasons, connected collaborative healthcare (architecture) can bridge the gaps that arise from lack of adequate ICT infrastructure.

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6 Conclusion

Healthcare is a key example of collaborative work and contrary to other disciplines, it is often non-routine, which makes it difficult to pre-schedule clinical procedures and activities. Issues such as emergencies and exceptions are so common enough and impede standardization of clinical practices. These two characteristics call for dependency on communication and critical information sharing to achieve optimal collaboration but they also provide justification for deployment of a seamless collaborative mobile application architecture to coordinate clinical workflow. Healthcare providers ought to work in an agile collaborative manner that empowers them to innovate together and uncover new ways of service delivery in a manner that reduces waste, missed handoffs, patient length-of-stay, medical errors such as improper diagnosis, wrong medication, mistaken identity duplication of tests, wrong-site surgeries, inaccurate treatment and unexpected deaths. To that effect, this study investigated the existing systems and associated collaboration challenges faced by healthcare providers and also analysed those that were derived from literature review. All in all, there was need to develop an architecture that would connect healthcare providers and enable them to work and innovate together. The development of the collaboration architecture was based on enterprise architecture taking cognizance of its four crucial C's; connection, collaboration, communication and customer. The solution was based on the alignment of the hospital's strategic vision with its information technology. It connects different business units for synergistic communication and collaboration, creating a more seamless end-user experience. Future research that focuses on sociotechnical aspects of information security and privacy requirements when designing and developing a mobile application for collaboration among medical workers is essential and timely.

Acknowledgements

The researchers would like to recognize all the administrators of Uganda Martyrs Hospital Lubaga and informants who played a significant role in providing data that informed this study.

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 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

Journal of Health Informatics in Africa

ISSN: 2197-6902
DOI: http://dx.doi.org/10.12856/JHIA-2022-v9-i1

Publisher
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