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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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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.

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Statement on conflicts of interest

No conflict of interest

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