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Interoperability of Electronic Health Record Systems in Rwandan Healthcare System

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Abstract

Background: The extensive use of ICT in healthcare delivery has become important globally. As a result, patient data in many countries, including Rwanda, are dispersed across different Electronic Health Record (EHR) systems. Often these systems exhibit a lack of interoperability among healthcare organizations, resulting in several silos of isolated patient data.

Methods: In this study, the research strategy employed was a survey, with data collection conducted through semi-structured interviews and an examination of documents. The gathered data were then analyzed thematically.

Results: The findings revealed that the existing policies at the national level do not explicitly promote health information exchange (HIE) in Rwanda. Moreover, there is a lack of a common data model supporting interoperability between healthcare facilities, and EHRs are not interoperable because there is no national HIE mediator. Therefore, the caregivers cannot access the transferred patients' complete medical history. Every healthcare facility has its specific EHR system for data storage and some of them also have frequent internet disturbances.

Conclusion: In this study, HIE challenges on different levels of interoperability in the Rwanda EHR systems have been identified. Several of these challenges can be addressed by the new guidelines and standards for HIE released by the African Union: these will greatly contribute to Rwanda and other African countries to address the challenges. Clear strategies for implementing interoperable EHR can supplement the existing HIE guidelines and standards.

Keywords: Electronic Health Record, Health Information Exchange, Health Information Systems interoperability, Refined eHealth European Interoperability Framework (ReEIF), Rwanda healthcare system

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1. Introduction

The practice of using Information and Communication Technologies (ICT) in healthcare, often called "eHealth", is becoming increasingly important globally [1],[2]. Through the incorporation of ICT, healthcare systems can efficiently manage patient data from diverse sources. [2]. However, in most national healthcare systems, data is dispersed across multiple data sources, resulting in a number of silos of isolated patient data [3].

An early attempt to address this issue was the development of Electronic Health Record (EHR) systems that collect and organize the majority of patient health information [3]. However, sharing health information between silos of EHRs from different organizations is still challenging [4], which has been reported in different countries worldwide [5], [6].

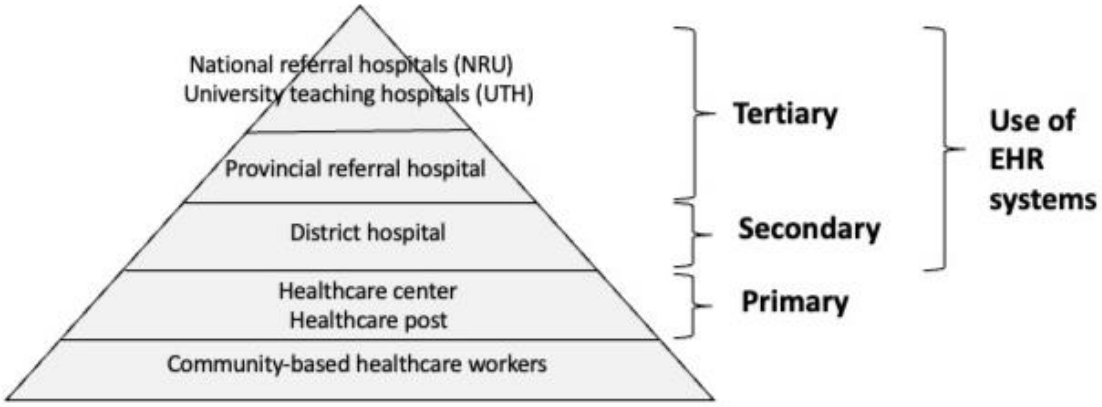

Figure (1) Healthcare levels of public healthcare facilities in Rwanda [7]

Figure (2) Healthcare levels of private healthcare facilities in Rwanda [8]

Similarly, Rwanda has silos of EHR used in private and public healthcare facilities. Notably, these facilities operate at various levels. That is, the public healthcare facilities are organized into levels ranging from health community workers, health posts, health centers, district hospitals, and provincial referral

hospitals up to the highest level of national referral hospitals and/or university teaching hospitals (NRH/UTH) as illustrated in Figure 1. Regarding private healthcare facilities, they are also organized into seven categories ranging from dispensary, medical practice, medical clinic, specialized clinic, polyclinic, hospital, up to specialized hospital (Figure 2).

EHR systems are used at the secondary and tertiary levels in public healthcare facilities, see Figure 1, and from medical clinics up to specialized hospitals in private facilities, see Figure 2. However, these EHR are not designed to exchange health data electronically between healthcare organizations. To address this situation, previous research from Rwanda [9], [10], has proposed an HIE mediator (i.e., a digital system supporting the exchange of messages between systems, also called EAI tool), and the use of ICD11 for health information exchange (HIE). HIE can be defined as "the sharing of clinical and administrative healthcare data among healthcare institutions, providers, and data repositories" [11]. A key factor for enabling HIE is interoperability, which can be defined as "the ability of two or more systems or components to exchange information and be able to use the exchanged information" [12]. The notion of interoperability was originally used for IT systems, but it can also apply to social and organizational systems.

This paper takes a broad perspective of interoperability by investigating the challenges of interoperability in Rwanda's healthcare system. Thus, the research question addressed in this study is: "What are the interoperability challenges of EHRs in the healthcare system of Rwanda?".

To categorize and describe these challenges, the Refined eHealth European Interoperability Framework (ReEIF) Model was used. It presents six levels of interoperability: (1) legal and regulatory, (2) policy, (3) care process, (4) information, (5) applications and (6) IT infrastructure as shown in Figure 3. In this context, the term "level" refers to a category of interoperability.

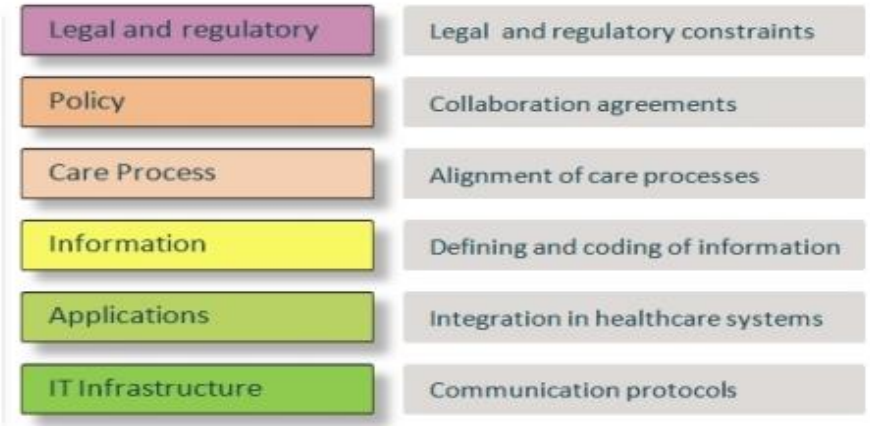

Figure (3) The ReEIF Model [13]

2. Subjects and Methods

In this study, we used the survey as a research strategy and collected data using semi-structured

interviews and a document study. The choice of semi-structured interviews ensured a high response rate as well as detailed and insightful answers from the participants [14], who were managers at healthcare facilities in Rwanda. An interview guide was used and mapped to the ReEIF model to receive insights on the different levels of interoperability. The interviews took place between September 24, 2021, and May 12, 2022. In addition, a document study was conducted to gain insight into the current laws, official policies, and strategies concerning personal data sharing in healthcare, the interoperability of EHRs, and HIE in Rwanda.

2.1 Sample selection for the semi-structured interviews:

For the semi-structured interviews, we used purposive sampling, which allowed us to target people with relevant and required knowledge on different healthcare interoperability levels [15], [13]. We aimed to interview participants from the secondary and tertiary levels of the public healthcare system, and from the medical clinics level and up in private facilities since only facilities on these levels use EHR systems. The participants contacted were the personnel employed by the healthcare facilities. They were chosen based on their managerial roles in the healthcare facilities, see Table 1. In the table, the roles have also been related to the roles in the ReEIF framework, see Figure 4 for the mapping of roles to the ReEIF levels. We interviewed 17 participants (Table 1).

Table (1) Roles of the respondents participating in the semi-structured interviews

Roles of the participants at the healthcare facility	Number of participants	Roles according to the ReEIF
Managing director	1	Directors
Human Resource director	1	Directors
Human Resource officer	1	Healthcare managers
Nursing and Midwifery Director	3	Healthcare managers
Clinical Director	1	Healthcare managers
ICT Director	2	System engineers
ICT Officer	6	Systems managers
Data Manager	2	Information analysts

2.2 Recruiting participants for semi-structured interviews

2.2.1 Process of recruitment

One of the researchers in the study went to the hospitals to recruit the participants. Our study was conducted in 9 healthcare facilities: 3 district hospitals in urban and semi-urban areas, 4 teaching hospitals and 2 private polyclinics in urban areas.

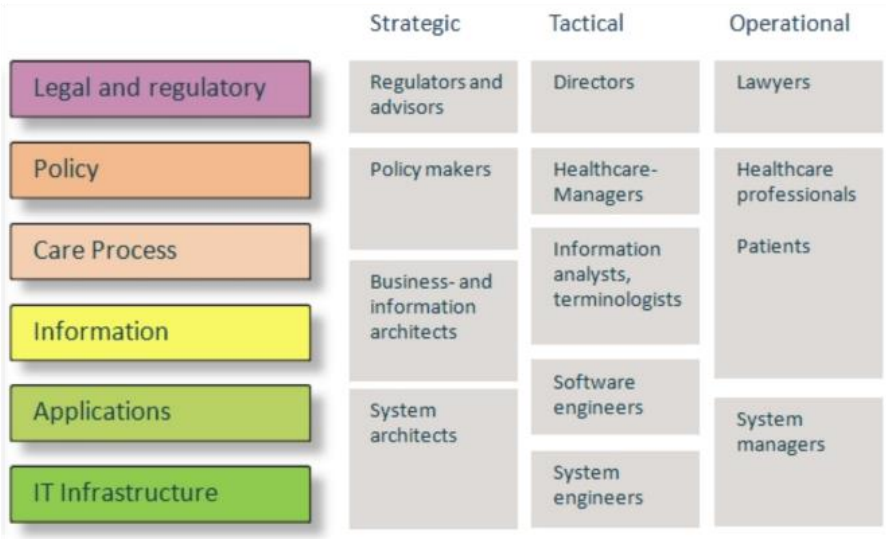

Figure (4) The ReEIF model with stakeholders [13]

2.3 Data analysis of the semi-structured interviews

The qualitative data used for analysis were audio-recorded interviews. One researcher translated the recorded interviews into English from Kinyarwanda. The translated transcripts were imported into MAXQDA, a software for qualitative analysis. Using deductive reasoning, the transcripts were analyzed using the levels of the ReEIF framework [16]. Moreover, inductive coding was used within each ReEIF level to identify more detailed interoperability challenges. This approach allowed us to point out different challenges mentioned by the participants.

2.4 The document study

The document study was performed to gather legal, policy and strategic documents from national government agencies of Rwanda and pan-African bodies impacting Rwanda related to personal data sharing in healthcare, interoperability of EHRs, and HIE. We performed a search into two steps: (1) using the phrases "health data sharing in Rwanda" and "interoperability of EHR in Rwanda", we searched Google for related documents (see Figure 5) and, (2) using the phrase "health information exchange", we searched the East African Community (EAC) repository (http://repository.eac.int) and the website (https://africacdc.org) of African Union Centre for Disease Control and Prevention (Africa CDC) (see Figure 6).

The study excluded:

- All documents on personal data sharing, interoperability of healthcare systems and HIE not written in English;
- All documents that are not related to personal data sharing, interoperability of healthcare systems, personal data sharing or HIE;

The study included:

- All Rwandan legal documents, and policy documents from national government agencies related to personal data sharing, interoperability of healthcare systems and HIE;
- All Rwandan strategic documents from national government agencies related to interoperability of healthcare systems and HIE;
- All guidelines, strategic and policy documents provided by pan-African bodies impacting Rwanda regarding personal data sharing, interoperability of healthcare systems and HIE.

Inductive coding was applied to the selected documents to identify what they stipulate on personal data sharing, interoperability of EHRs and/or HIE.

Eight documents, [17-24], were identified to be further analyzed.

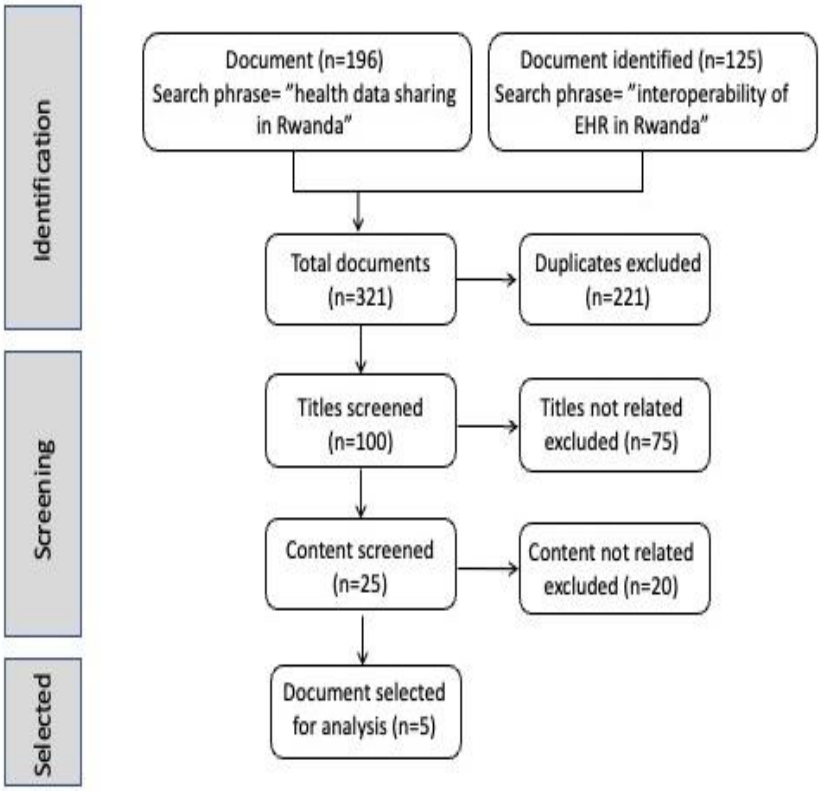

Figure (5) Search results from Google

3. Results

This section describes the result of the analysis of the semi-structured interviews and the document study.

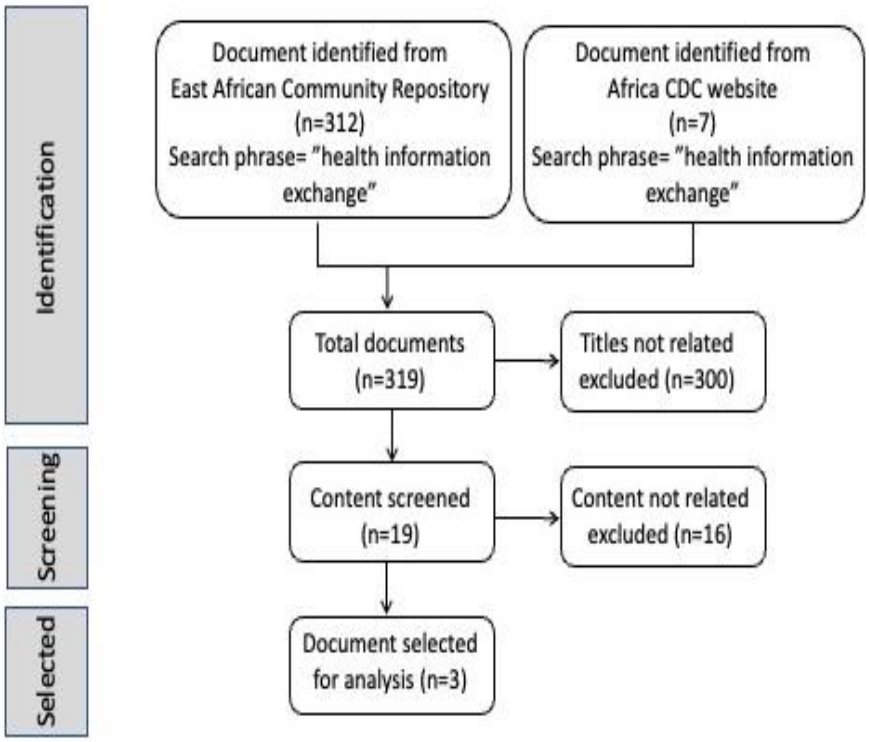

Figure (6) Search results from pan-African bodies websites

3.1 The result of the semi- structured interviews

The result of the analysis of the interviews and documents is organized into seven interoperability challenges.

3.1.1 Lack of articles in law specific to interoperability and HIE

The participants were asked about the existence of legal texts supporting interoperability and allowing the transfer of patients' health information between EHR systems (Table 2). The existing law mandates obtaining the prior consent of the subject data for any form of personal data sharing. However, the existing laws do not, according to some of the participants, include specific articles regarding the interoperability of systems in the Rwandan healthcare system and HIE. This could, according to the participants, be seen as a challenge, since it is unclear how the regulations address issues related to interoperability.

Table (2) Lack of articles in law specific to interoperability and HIE

Challenge	Description	Number of respondents	Examples of quotations
Lack of articles in law specific to interoperability and HIE	Articles in the existing legal framework do not address interoperability and HIE of healthcare systems	3	"I think our EHR systems are not interoperable because the existing law does not mention exchange of health data through electronic means." "The law mentions the consent of the subject, however does not provide guidelines for health information sharing."

3.1.2 Lack of governmental policies about interoperability

Concerning the different policies in force in healthcare facilities, the study investigated which ones guide the interoperability of EHR systems and the HIE. According to some of the respondents, there is not yet a specific policy with guidelines for systems interoperability and HIE, except the policy for health data management in healthcare facilities, which focuses on storage, access and reporting (Table 3).

Table (3) Lack of policies on HIE and interoperability

Challenge	Description	Number of respondents	Examples of quotations
Lack of governmental policies about interoperability	Governmental policies do not include guidelines on interoperability of EHR and HIE	3	"[...]interoperability does not work because it is not yet mentioned in the policy. I think it can work if they put a ruling policy, they can establish the requirements and do it and they should ensure the confidentiality and privacy of the patients." "We cannot start an initiative for interoperability of our EHR with another healthcare facility, because there is no policy that gives such guidelines. It has to be initiated by the MoH."

3.1.3 Discontinuation of patient´s information

Patients are required to present a referral note, when visiting district hospitals or referral/teaching hospitals, except in cases of emergency. For instance, when a community health worker detects an alarming symptom from a mother or child during a routine visit, the mother/child is referred to the nearest health center. If the mother/child needs to go to the next level, the transfer is done with a referral note to the district hospital (Table 4).

Upon arrival at the hospital, the patients are recorded in the EHR system, given a unique ID, and then directed to the appropriate clinical department. During and after the investigation and eventual treatment of the patient, clinical details are recorded in the EHR system.

Within the same hospital, all the information about a patient is easily accessible in the EHR of the hospital. However, patients are often transferred to the next highest-level hospital, and, except for the summary of information on the referral note, the new caregiver at the hospital does not have access to the transferred patients' complete medical history, examinations and management from previous hospitals. Consequently, the complete patient's medical information is not shared between different hospitals, which constitutes a disruption of information during the healthcare delivery process. In case there is missing information on the referral note, the caregiver can either ask the accompanying paramedic or make a call to the referring personnel.

Table (4) Discontinuation of patient's health information

Challenge	Description	Number of respondents	Examples of quotations
Discontinuation of patient´s information	The information of the patient is not available at every point of care	6	"Up to date, there is no system that links together all these healthcare facilities such that there is a way of accessing or sharing clinical history of the transferred patient." "Except a summary of information on the referral note, we do not have a way to know the medical history of a new patient." "When there is missing information on the referral note, we can ask the paramedic or call the referring physician." "[...]checking a patient from Hospital A while I am here and being able to find his/her record? We don't have that system yet. But here in the hospital, we can do it for our patients in the OpenClinic system using the hospital ID number."

3.1.4 No clear interoperability data model

Interoperability at the information level typically involves the adoption of a unified data model and the utilization of semantic standards (Table 5). This common data model encompasses specific terminology and data structures, establishing a standardized language for the exchange and sharing of information across various EHR systems in different healthcare facilities. A common data model can for instance allow healthcare professionals to share interoperable clinical documents bearing health data that can be transferred between and integrated into different EHR systems of different healthcare facilities [25]. Some of the respondents were not aware of any data model used or any applicable standards supporting interoperability, whereas others were familiar with standards in use in healthcare systems (i.e. ICD and ICPC).

Table (5) Lack of interoperability data model

Challenge	Description	Number of respondents	Examples of quotations
No clear data model supporting interoperability	The different healthcare facilities use different EHR systems and do not use a common healthcare model supporting interoperability	8	"I do think the system we use has complied with the standards because it is an international system[...]. Our system uses ICD10 and ICPC […]." "We do not know about the interoperability standards […]."

3.1.5 EHRs are not interoperable

All healthcare facilities on the secondary and tertiary levels participating in the study have EHR systems, which are presented in Table 6.

Table (6) EHR used in healthcare facilities

	Polyclinic 1	Polyclinic 2	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7
OpenClinic	√				√	√	√		
OpenMRS			√	√	√	√	√	√	√
CMS Clinic		√							

The EHRs in different healthcare facilities are not integrated with each other. Some healthcare

facilities such as Hospital3, Hospital4 and Hospital5 have both the EHR systems OpenClinic and OpenMRS, but they are not integrated even if they are in the same healthcare facility, and, therefore, cannot work as a single system. In other words, the EHRs are locally managed by each hospital and polyclinic and do not exchange patients' health information, between each other, nor are they connected to any exchange platform (Table 7).

Table (7) EHRs are not interoperable

Challenge	Description	Number of respondents	Examples of quotations
EHRs are not interoperable	EHRs do not exchange information between each other, and no exchange platform is used	8	"The health systems we have in the country do not exchange information." "There is no health information exchange platform, every hospital uses its EHR locally." "There is a need for a system or a platform for all systems to allow them to exchange health information." "[…] there is a project that has been initiated for interoperability of EHR/EMR, but we ignore the current progress." "The infrastructure is good but there is a lack of systems integration." "They are not integrated because the suppliers are different."

3.1.6 Insufficient number of computers

Some healthcare facilities do not have an adequate number of computers. That is, not every healthcare professional who requires a computer for their daily tasks has access to their own personal device, although there is a computer in every consultation room (Table 8).

Table (8) Computers are not sufficient

Challenge	Description	Number of respondents	Examples of quotations
Insufficient computers	There are too few computers available for the large number of needy staff	8	"I can say that the computers are enough and not enough at the same time. I have more than 120 computers but there are even more users than that […]." "They are not enough. We have around 318 employees and not everyone has a computer."

3.1.7. Internet disruptions

Two polyclinics are not connected to the national fiber optic backbone for Internet access. They use wireless media for connectivity, and these are often disturbed by weather or other signals causing frequent internet outages. Also, the hospitals could experience internet disruptions (Table 9).

Table (9) Internet disruptions

Challenge	Description	Number of respondents	Examples of quotations
Internet disruptions	Frequent internet outages	8	"The internet connectivity is a challenge; we often have shortages, and this is related to our location." "Here we are still having challenges for Internet access, we do use the wireless router, but it does not operate as expected […]." "In some rooms, the Internet does not work properly, it is often very slow."

3.2 Result of the literature study

The document study identified eight documents related to personal data sharing and interoperability of EHR and HIE. The findings of each of these documents are provided in Table 10. These findings are also related to ReEIF levels (Table 10).

Table (10) Summary of Document analysis

Number	Item	Type	Code	Content	ReEIF Level
1	Law (058/2021 of 13/10/2021) relating to the protection of personal data and privacy	Law	Personal data	Article 46: "[…] personal sensitive data are processed based on the subject's consent." [17]	Legal and regulatory level
			Transfer	Article 48: "[…]data can be transferred outside Rwanda for protecting vital interests of the subject on a basis of a signed contract […] they should be an authorization from a supervisory authority […] the transfer should not be repetitive." [17]	
2	Standard Operating Procedures for Management of Routine Health Information at Referral/Provincial and District Hospital (public and private) Version 2019	Policy	Data sharing	Chapter VI: "Health data is accessed only by medical staff and other authorized staff. Other people outside the hospital require an authorization from the hospital management and approval from national research ethics committee […] they should ensure anonymity and confidentiality." [26]	Policy level
3	Health Sector Policy 2015	Policy	Data sharing	"Need of Data Sharing Policy that is designed to enhance access to data and engage approved data users in the process of continuous data quality improvement […]." [20]	Policy level
4	Fourth Health Sector Strategic Plan 2018-2024	Strategy	Interoperability	"Synchronize all HIS systems together and link them with EHR/EMR to improve the patient. management and data-use for decision making." [21]	Information level and Application level
5	National Digital Health Strategic Plan 2018-2023	Strategy	Data sharing	"Resolve questions about data access to all stakeholder groups and update the Health Data Sharing and Confidentiality Policy accordingly. Develop legal framework and policies for data exchange, access and security of personally identifiable data, use of mobile devices and social media, telemedicine." [22]	Policy level and Legal and regulatory level
6	East African Community Digital Health and Interoperability Assessments. Rwanda,2020	Report	Interoperability	"There exists Rwanda Health Information Exchange (RHIE) aiming at making easily available medical history and information for maternal and childcare since 2010. The architecture has not been used since 2014." [19]	Information level and Application level
7	Digital REACH Initiative Strategic Plan 2019-2028 (East African Community)	Strategy	Data sharing	"Develop data sharing, security, and management guidelines, protocols, and standards […] Support and promote the exchange of unique IDs and patient health records across EAC Partner States for effective care delivery and continuity of care." [23]	Information level and Application level

			Interoperability	"Develop data exchange standards and regional guidelines for diagnosis and treatment to facilitate continuity of care across the region." [23]	
8	African Union Health Information Exchange Guidelines and Standards,2023	Framework	Data sharing	"African Union Member States are required to set a standard data sharing agreement for use and signature by the Africa Centre for Disease Control and Prevention (Africa CDC) and each Member State." [24]	Legal and Regulatory level
			Interoperability	"The African Union Member States should provide a common set of platforms, services, and repositories for shared public health data. […] Associated services for HIE of digital functions shall be based on interoperable software components." [24]	Application level

According to the existing legal framework of Rwanda, the subject to care, i.e., the patient, needs to provide his/her consent before the patient data are used for care and research [17]. The patient gives his/her consent before receiving medical treatments and before his/her personal data are used for research or transferred.

The current law related to data protection and privacy does not include specific articles either describing the share of personal data through electronic means (i.e. EHR and others) or the interoperability of systems in the Rwandan healthcare system. This could be considered as a challenge, since it is unclear how the regulations address issues related to interoperability.

Additionally, there exist different healthcare-related policies in Rwanda. The manual of Standard Operating Procedures for Management of Routine Health Information, Rwanda, which specifies how to handle patient data [26], is one of them. However, it only describes how to handle aggregated data, who should access it, and the required authorization. It does not give guidelines on the interoperability of EHR, neither is HIE mentioned. This could be seen as a challenge since it does not support the hospitals to promote interoperability.

The prioritization of EHR interoperability by the top management in Rwanda´s healthcare sector has been evident since 2018, aligning with the strategic objectives of the Ministry of Health (MoH). Nevertheless, it has not yielded the desired effectiveness [22]. Some work has been done to set a health information exchange architecture, such as Rwanda Health Information Exchange (RHIE). However, it has been discontinued since 2014 [19]. The efforts of the government of Rwanda towards the interoperability of EHRs and HIE is a part of the strategic objectives of the regional and pan-African bodies, the East African Health Research Commission (EAHRC) and African Centre for Disease Control and Prevention (Africa CDC) [23], [24].

All challenges identified from the analysis of the interviews and documents are summarized in Table 11.

Table (11) Identified challenges and their corresponding levels of ReEIF

ReEIF levels	Challenges
Legal and Regulatory	1. Lack of articles specific to interoperability and HIE
Policy	2. Lack of interoperability and HIE policies
Care Process	3. Discontinuation of patient's information
Information	4. No clear interoperability data model
Application	5. EHRs are not interoperable
IT Infrastructure	6. Insufficient number of computers 7. Internet disruptions

4. Discussion

The study presented in this paper focused on EHRs interoperability at different levels of interoperability in the healthcare system of Rwanda. The data analysis was based on the ReEIF model, and the result is organized according to challenges identified at each interoperability level. In this section, the results of the study are discussed by relating them to research and solutions in other parts of Africa as well as the rest of the world.

4.1 The lack of laws and policies for interoperability and HIE

This study indicates that there are challenges related to the legal aspect and policy in interoperability of EHR and HIE. These challenges existed decades ago; however, some progress has been made. Today, the African Union Health Information Exchange Guidelines and Standards exist in Africa, with clear guidelines on the protection of personal data and the transfer of such data among its country members [24].

Though such general guidelines have been set, there still exist discrepancies in law and policies related to health data sharing and interoperability of EHR, because the guidelines are still quite new and countries, for example Rwanda, need time to comply with these guidelines. Additionally, the countries in Africa have the sovereignty to make their own rules [27]. Previous studies have also mentioned similar discrepancies in other continents. In the USA, certain states mandate written consent for sharing health information beyond the emergency department, while others necessitate specific permission for the sharing of certain types of health information. In the European Union (EU), member states have divergent rules of data sharing among healthcare facilities, though all are guided by the same EU regulations [27], [28]. In Rwanda, personal data sharing requires consent and a signed contract [17], however, the governmental policies in force in healthcare do not mention health information exchange or sharing guidelines [26].

In the fast digital changing environment of today, countries in regions could harmonize their laws and policies regarding health information sharing as we observe an increased movement of people worldwide seeking healthcare treatments. The government in Rwanda, and other African countries, could

update the legal framework to abide by the guidelines and standards of the African Union Health Information Exchange to enable health information sharing within the country and between African Union member-states.

4.2. The Discontinuation of patient's health information

In this study, we have also identified that the discontinued health information during the care process at different points of care is challenging. There exist a number of guidelines and routines for referring a patient to the appropriate healthcare facility. However, referral notes (see Appendix 1), which is an important inter-healthcare facilities communication tool when referring patients to facilities with specialized care, frequently contain inadequate information. In certain instances, critical details such as the patient's name, age, blood pressure, the referring physician, and facility, among others, are missing [29]. This deficiency in information on referral notes undermines the continuity and quality of healthcare.

This challenge is not new, as many researchers and actors have mentioned it and contributed to propose solutions. Previous research has proposed a unique patient identifier (UPI) because of its characteristics of creating individually linked medical records across different services and healthcare facilities, enabling quick access to health information and improvement of medical services on a continuous basis [30]. Other research has suggested reforms aiming at establishing networks of EHRs and HIEs to allow smooth health information sharing among all healthcare providers [31]. Such a network could make use of an information exchange mediator, also called an EAI tool, supporting messages exchanged [9-10], as mentioned in the introduction. Such a tool can automatically exchange, re-structure and re-format messages sent between connected EHRs based on a rules base used by the information exchange mediator. All messages that aim to be sent between the EHRs are therefore sent via this information exchange mediator, which applies applicable rules from the rule base given a certain type of message.

Moreover, a discussion of developing a national information infrastructure which already exists in many European countries, is also ongoing in Rwanda. National information infrastructure often includes basic patient information, a drug list for the patient, and recently carried out healthcare investigations and treatments. For such a system to work, EHRs in different healthcare facilities need to be able to access the data for a certain patient from this national information infrastructure as well as update data when, for example, a new drug is added to the drug list of a patient, or a healthcare investigation or treatment is carried out.

In Rwanda, some work to address the discontinuation of health information across different points of care has been done so far [19]. However, it is not enough as the challenge is still on the table. The

existing RHIE architecture needs to be used and updated as there are now new technologies available.

4.3 The technological aspect challenges

In this study, the technological challenges are related to information, application and infrastructure levels of ReEIF. These three levels are often grouped into the technical level of interoperability [32]. These challenges are the lack of a common interoperability data model, non-interoperable EHRs, frequent internet disruptions and insufficient number of computers. These challenges have also been identified in other previous studies in Low and Middle-Income Countries (LMIC) [33]– [37]. One study mentioned the difficulties of integrating EHRs in LMIC because of non-existent strategies for EHRs integration [38], while another study also mentioned the complications of implementing EHRs interoperability because of a lack of uniform definitions, concepts and common languages [39].

To overcome these technological hindrances, it requires the commitment of various actors in Rwandan healthcare sector: the government, the funds-donors, the vendors, the insurance companies, the healthcare facilities, social security funds and the end-users [36], [40].

Though these challenges persist [41], Rwanda has made some steps towards interoperability of EHRs, that is, the project initiated for Rwanda Health Enterprise Architecture (RHEA), a published healthcare digital transformation strategy, adoption of International Classification Diseases (ICD11) as standard and the improvement of existing infrastructure [19]. The adoption of interoperability standards will improve managerial reporting and decision-making and increase the interoperability between EHR systems in different healthcare facilities [42].

The Government of Rwanda can achieve the interoperability of EHRs in healthcare facilities by benchmarking and making use of the best practices from neighboring countries that have successfully implemented the HIE architecture [43].

4.4 Consequences of lack of interoperability in healthcare

The lack of interoperability in healthcare may have many negative consequences. Based on the analysis of the semi-structured interviews and the literature review, the most important consequences are the following:

1. Lack of access to patient's health information leads to an increase of incidence of medical errors [44].
2. The healthcare provided to patients who are transferred from one healthcare facility to another for more specialized treatment does not take into account the referred patient's entire medical history, examinations and care management, which could lower the care quality [6].
3. Healthcare costs increase for the patients and healthcare facilities when unnecessary repetitive

laboratory tests are ordered, although the patients have already done them previously [45].

4. Lack of optimal use of the available scarce medical human resources and equipment. It leads to long queues of patients waiting for specialized care (Respondent at Hospital5).
5. The periodical reporting of healthcare activities becomes time-consuming because EHR cannot automatically upload the needed information into the reporting system of Ministry of Health, that is, the Health Management Information System (HMIS); (Respondent at Hospital7).

4.5 Limitations of the Study

We acknowledge that the challenges revealed in our study may not be exhaustive, and that a study with a bigger sample size, encompassing all of Rwanda's healthcare facilities that utilize EHR, could identify additional challenges.

Furthermore, we conducted interviews solely with healthcare personnel in managerial roles. However, it is possible that interviewing front-line staff could have yielded additional insights into the challenges related to interoperability.

5. Conclusion

The EHR systems have been independently implemented in different healthcare facilities, thus, they are not interoperable and do not exchange patients' health information with each other. To overcome the challenges identified in this study, the government needs to play a determinant role. For example, the government can continue to create an environment that complies with the Health Information Exchange guidelines and standards set by the African Union. The challenges pointed out by this study have been observed in different LMIC as well as in developed ones. Thus, clear strategies for implementing interoperable EHR systems can supplement existing HIE guidelines and standards. Further studies are necessary to understand which challenges are perceived to be the most troubling to the interoperability of EHRs by healthcare professionals, and which solutions are the most adequate for the interoperability of EHRs in Rwanda.

6. Declarations

6.1 Abbreviations

CDC: Centre for Disease Control and Prevention

CMHS: College of Medicine and Health Sciences

EAC: East African Community

EAHRC: East African Health Research Commission

EAI: Enterprise Application Integration

EHR: Electronic Health Record

EMR: Electronic Medical Record

EU: European Union

HIE: Health Information Exchange

HIS: Health Information Systems

HMIS: Health Management Information System

ICD11: International Classification of Diseases 11th revision

ICPC: International Classification of Primary Care

ICT: Information and Communication Technology

ID: Identification

IRB: Institutional Review Board

IT: Information Technology

LMIC: Low and Middle-Income Countries

MoH: Ministry of Health

NHRC: National Health Research Committee

NRH: National Referral Hospital

REACH: Regional East African Community Health

ReEIF: Refined eHealth European Interoperability Framework

RHEA: Rwanda Health Enterprise Architecture

RHIE: Rwanda Health Information Exchange

RNEC: Rwanda National Ethics Committee

SIDA: Swedish International Development Cooperation Agency

UPI: Unique Patient Identifier

USA: United States of America

UTH: University Teaching Hospital

6.2 Conflict of Interest Statement

Two co-authors, Alice Mukabalisa and Alpha Arsène Marara, were amongst the participants interviewed, however, their interviews were not considered in the analysis.

6.3 Funding Disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

6.4 Ethical Considerations

This study obtained ethical approval from the College of Medicine and Health Sciences'

Institutional Review Board of University of Rwanda (254/CMHS IRB/2021) and a national ethical approval from the Rwanda National Ethics Committee (007/RNEC/2022). In addition, the study was scientifically approved by the National Health Research Committee (NHRC/2021/PROT/046).

All the participants were given information about the study and were explained their rights to participate and withdraw freely from the study. The participants provided the informed consent forms, and they were assured that their confidentiality and privacy were guaranteed during data collection and analysis, as well as the reporting of the study results.

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6.6 Author Statement

The authors have substantially contributed on one or more of the following:

(a) the conception and design of the study, or data collection or data analysis; (b) drafting the article or critically revising it to improve the content; (c) approving the submitted version.

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