



Towards Secure Interoperability of EHR among Healthcare Organizations in Palestine

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Abstract

Technological development in the e-health field helps to facilitate and enhance healthcare, and improve treatment quality. Different public and private healthcare facilities in Palestine employ different health information systems; consequently, sharing health information has become more challenging and complex. In this paper, the researchers firstly investigate the current status of Electronic Health Records (EHR) in Palestine and the readiness of the various healthcare centers to foster the interoperability of EHRs. Secondly, the researchers propose a secure framework that might be used to deploy interoperability among healthcare centers. The mixed method approach was used to achieve the objectives of the research. Interviews were conducted with IT managers, and questionnaires were distributed to 331 out of 2350 personnel employed in five Palestinian hospitals. The findings of quantitative and qualitative

studies show that there is no electronic exchange of EHRs between private and public healthcare facilities, and they highlight the necessity of putting interoperability into practice to enhance the quality of healthcare in Palestine and keep up with global advancements in health technology. Based on these findings, the researchers propose a technical framework for interoperability in Palestine using UXP/ X-Road, to securely and effectively share EHRs among healthcare centers.

Keywords: Interoperability, eHealth, eHealth Standards, ICT, Infrastructure, UXP/ X-Road

نحو ربط بيني آمن للسجلات الصحية الإلكترونية بين مؤسسات الرعاية الصحية في فلسطين

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الملخص:

يسهم التطور التكنولوجي في مجال الصحة الإلكترونية في تسهيل الرعاية الصحية و تطويرها ، وتحسين جودة الرعاية الصحية في المراكز الصحية المختلفة. ففي دولة فلسطين، نمت أنظمة معلوماتية صحية مختلفة مستخدمة في مختلف مراكز الرعاية الصحية العامة والخاصة؛ وعليه فإن عملية تبادل المعلومات الصحية تُصبح أكثر صعوبة وتعقيداً. وفي هذا البحث، أجرى الباحثان دراسة على الوضع الحالي للسجلات الصحية الإلكترونية في فلسطين، ومدى استعداد المراكز الصحية المختلفة لتطبيق التشغيل البيئي للسجلات الصحية الإلكترونية، كما اقترح الباحثان إطاراً آمناً يمكن استخدامه لتطبيق التشغيل البيئي بين مراكز الرعاية الصحية. تجدر الإشارة إلى أنه تم استخدام منهجية البحث الكمي والنوعي؛ حيث أُجريت مقابلات مع أربعة مديريين لتكنولوجيا المعلومات ، بالإضافة إلى توزيع استبانة على (331) موظفاً من إجمالي (2350) موظفاً يعملون في خمس مستشفيات فلسطينية عامة وخاصة. أظهرت نتائج الدراسات الكمية والنوعية عدم وجود تبادل بيني إلكتروني للسجلات الصحية الإلكترونية بين المراكز الصحية الخاصة والعامة، كما أظهرت الحاجة إلى تطبيق التشغيل البيئي الإلكتروني؛ بهدف تحسين جودة الرعاية الصحية، ومواكبة التقدم في مجال التكنولوجيا الصحية. وبناءً على هذه النتائج، ارتأى الباحثان وضع إطار تقني للتشغيل البيئي الآمن للسجلات الصحية بين المستشفيات الفلسطينية عن طريق الاستفادة من نظام (UXP/ X-Road) ؛ إذ يُتيح هذا النموذج تطبيق التبادل البيئي الإلكتروني للسجلات الصحية بشكل آمن وفعال.

الكلمات المفتاحية: قابلية التشغيل البيئي، الصحة الإلكترونية، معايير الصحة الإلكترونية، تكنولوجيا المعلومات والاتصالات، البنية التحتية، (UXP/ X-Road)

Introduction

Information and Communication Technology (ICT) has positively impacted various fields of healthcare systems worldwide by improving the various facets of these systems, including lowering the cost of healthcare services, raising the quality of the services, and shortening the time required to perform the task aspects (Iroju et al., 2013; Shahmoradi & Habibi-Koolae, 2016).

In the healthcare sector, transitioning from traditional records (papers and others) to electronic records is not an easy process because doing so requires a substantial amount of effort by patients, doctors, and healthcare providers (Majeed, 2010). Electronic Health Records (hereinafter EHR), however, provides a wide selection of tools and resources for better healthcare. The EHR is an electronic version of a patient's medical history that is kept up to date over time by healthcare providers. It may contain all of the essential administrative clinical data relevant to that person's care under a particular provider, such as demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports. The EHR can also support other healthcare-related activities including evidence-based decision support, quality control, and outcomes reporting.

Palestinian healthcare providers rely on independent electronic systems, which makes it challenging for health information systems in most other nations to interoperate. Interoperability between these systems has been established in many industrialized nations, including the United States and several European nations, and a single electronic registry is now used in these countries (Majeed, 2010; Shahmoradi & Habibi-Koolae, 2016).

In Palestine, there have been many efforts to establish an electronic health system to manage EHR among healthcare institutions according to the

globally used standards for electronic information exchange, such as Health Level 7 (HL7) and Clinical Document Architecture (CDA). However, there are many significant obstacles and challenges (El Jabari et al., 2020). According to (Barbarito et al., 2012), independence is the reason for the difficulty of interoperability between information systems and can be overcome by implementing and adopting appropriate standards.

In this research, we will focus on the interoperability in private and public healthcare centers in Palestine, using the concept of information technology and the potential for exchanging and sharing various medical and clinical data among various locations, as well as caring for the security and privacy of the exchanged data. Since interoperability is the basic building block in increasing the quality of healthcare and reducing costs effectively, this research will provide a deep understanding of the current scenario as well as providing a secure interoperability framework to be used by healthcare centers in Palestine.

1. Research Problem and Objectives

2.1. Research Problem

Different electronic healthcare systems are used by both public and private healthcare facilities in Palestine. The lack of fast electronic data sharing between these organizations due to the diversity of healthcare systems has a negative impact on the quality of healthcare in Palestine. Because health information systems are valuable, accurate, and extremely private, it is essential to properly implement all security and privacy measures to ensure that the system complies with the established international standards.

The researchers will propose a framework with an acceptable level of interoperability (semantic level), where two or more systems can exchange

useful information. The framework will satisfy well-known security and privacy standards and will be centrally controlled by the Ministry of Telecommunication and Information Technology (MTIT). To sum up, the paper aims to evaluate electronic systems and infrastructure in public and private healthcare institutions in Palestine and determine challenges, benefits, and obstacles of interoperability deployment. An appropriate framework for interoperability among healthcare institutions in Palestine will also be provided.

2.2. Research Objectives

- To determine the current state of interoperability in private and public healthcare sectors.
- To explore the obstacles of implementing interoperability in the private and public healthcare sectors in Palestine.
- To determine the compatibility level of interoperability between the private and public healthcare sectors in Palestine.
- To achieve a better framework that will satisfy well-known security and privacy standards for the interoperability of healthcare sectors in Palestine.

2. Theoretical Framework and Literature Review

“Healthcare information interoperability is the ability of health information systems to work together within and across organizational boundaries” (National Coordinator of Health Information Technology (ONC), 2019). The target systems must adhere to agreeing on the type of data that will be exchanged and agree on interoperability standards between all parties. The systems inevitably cooperate to exchange complete information only in the event of integration between the various institutions. Interoperability is a broad concept, and conveys different

aspects including technical, syntactic, semantic and organizational. (Lehne, et al., 2019; Majeed, 2010).

The Healthcare Information and Management Systems Society (HIMSS) has established a multi-layered framework to help medical professionals assess data exchange and document management capabilities. An assessment of current capabilities and limitations helps to establish and develop a clear path for improvement, ensuring the best possible productivity, and better outcomes in patient care (Rick, 2022).

Healthcare interoperability uses timely and secure access to electronic health data that can be used to improve health outcomes for individuals and populations. It also allows physicians, patients, and health workers to access the patient's health information according to their authorization levels and access rights.

2.1 Levels of Interoperability

The four levels of interoperability: technical interoperability, syntactic interoperability, semantic interoperability, and organizational interoperability are shown in Figure 1.

2.2 X-ROAD / UXP Background in Palestine

More than 52 governmental institutions in Palestine use the X-Road System, which the Palestinian government purchased from Estonia. Through this system, data is safely exchanged between governmental organizations in Palestine.¹

In an effort to automate all governmental services through a single electronic portal, the Palestinian government has been working since 2019 on the Single Sign On (SSO) and electronic payment through X-Road

¹<https://mtit.pna.ps/>

portals. The government's financial system will be enhanced, and citizens will benefit by saving their time and efforts.

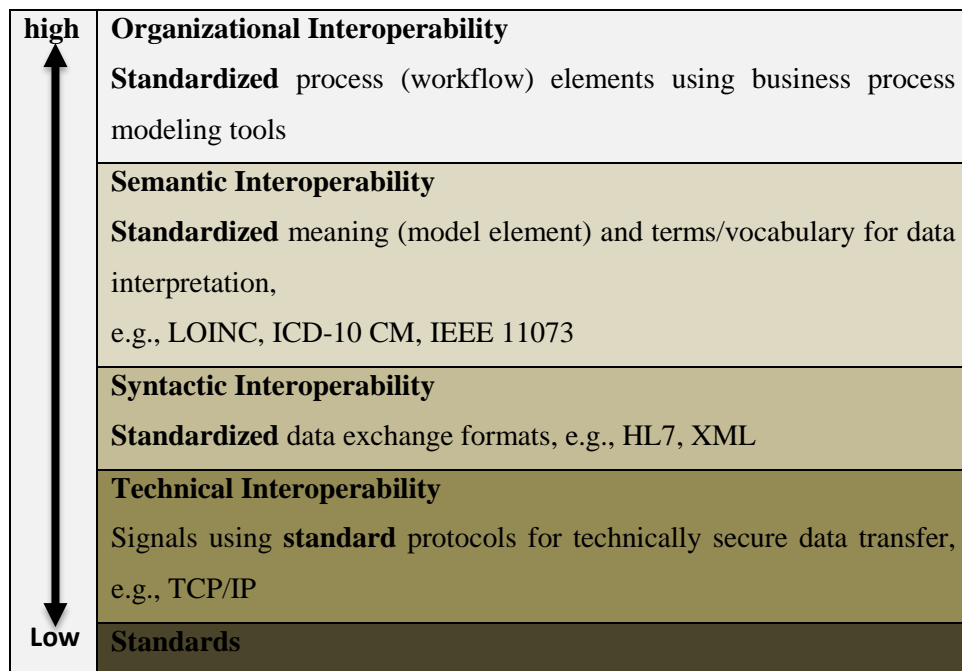


Figure 1: Levels of Health IT Interoperability (VanderMey, 2019)

The core objective of introducing the X-Road system is to examine the possibilities for its use in healthcare interoperability in Palestine, since the Palestinian MTIT has the knowledge and infrastructure required for secure interoperability.

2.3 Related work

In their study *Towards a New Paradigm of Federated Electronic Health Records in Palestine*, El Jabari et al. (2020) sought to develop a federate electronic health system based on a clinical document architecture (CDA) that was appropriate for the Palestinian context. In order to improve interoperability with scalability, fault tolerance, privacy, and security, the system is based on a blockchain architecture.

Al-Najjar et al. (2021) proposed the isLEHR framework, based on HL7 FHIR interoperability standards and artificial intelligence, to enable data sharing in a format that is accessible to both humans and computers. The system evaluation findings showed that isLEHR can be applied with a high level of efficiency and precision, proving that it is a viable strategy for EHR sharing in Hebron and that it can be applied generally to share data throughout hospitals in Palestine.

Alsadan et al., (2015), conducted a study titled *Health Information Technology (HIT) in Arab Countries: A Systematic Review Study on HIT Progress*. The study examined 655 papers and found that the Arab world frequently lags in the implementation of health information technology systems compared to that of Western nations. The findings of the study demonstrated that the majority of Arab nations are falling behind in HIT as a result of inadequate funding and ineffective personnel.

In a study by Fahad Alanezi (2021), a questionnaire was designed and distributed randomly among KSA citizens via social media and the web, and the survey-based quantitative analysis method was utilized; the sample size was 130 Saudi citizens. According to the findings of the study, the doctor-patient relationship prevents the application of this system because of concerns about a potential breach of data privacy and a lack of governmental and regulatory legislation. These difficulties, taken combined, create impediments to KSA's implementation of the e-health system.

In their study *Healthcare Data Warehouse System Supporting Cross-Border Interoperability*, Gavrilov et al.(2020) proposed a new design for a healthcare data warehouse based on the usual extraction, transformation, and loading process structure. The free movement of European citizens across EU member states has an important level of complexity for the

strategic efforts of interoperability between different care organizations in EU countries, where cross-border healthcare depends on the ability to set up common practices regarding patient data across countries. Data flows must comply with legal, security, political, and interoperability requirements. Health Level 7 Standard and the Open National Contact Point Framework can be used to provide a modular, scalable, applicable, and interoperable architecture.

Reegu et al. (2021) conducted a study to identify the interoperability challenges and issues of blockchain EHR frameworks, based on national and international standards for electronic records, and to pinpoint interoperability standards within the EHR framework in terms of medical data distribution, data sharing, and data reliance. The paper proposed an implementation of EHR and provided a solution that will help with data management, patient information security, blockchain benefits, and electronic records interoperability.

2.4 The Knowledge Gaps

There are several standards for addressing clinical information interoperability between healthcare facilities; however, the lack of common standards for clinical health information that may be shared between various facilities has resulted in a number of issues in various areas. Developing and utilizing healthcare information is a top priority for many industrialized nations as they work to provide a variety of healthcare services (Majeed, 2010). The developed countries look at how the interoperability framework can facilitate transmission through many mechanisms, including digital access rules, data integrity, patient identity, and data stability. From another point of view, these countries studied the barriers against patient-driven interoperability supported by the exchange of health information, specifically the volume of clinical data transactions,

safety, privacy, patient participation, and incentives. Developed countries agree that the interoperability of patient care is an exciting trend in healthcare and that there is a necessity for adopting a framework that facilitates the transmission and sharing of data from institution-centric to patient-centric (Gordon & Catalini, 2018).

There are numerous efforts in Palestine to develop a sound EHR system in public and private healthcare institutions, but there are still many hurdles and challenges. El Jabari et al. (2020) proposed the use of a blockchain to construct a single electronic health record based on CDA to highlight the significant contribution in this field in Palestine. Ramzi Shawahna (2019) discussed the significance of integrating EHR with Clinical Decision Support Systems (CDSS), which improves compliance and secure the use of electronic records. Another intriguing contribution was made by Al-Najjar et al. (2021), who advocated an interoperable system between two different hospitals in Hebron District in Palestine.

2.5 Research Contribution

Based on the literature review, the current study will propose a secure framework for interoperability among Palestinian healthcare institutions. The framework has the following characteristics:

- A larger number of hospitals from different Palestinian cities will be covered.
- A centrally controlled interoperability framework with a trusted third party (MTIT) will be proposed
- Privacy of the health data will be leveraged by securing the exchange of data.

3. Research Methodology

A mixed research methodology that includes both quantitative and qualitative research methods was used. Figure 2 shows the five-step research methodology adopted by the present study.

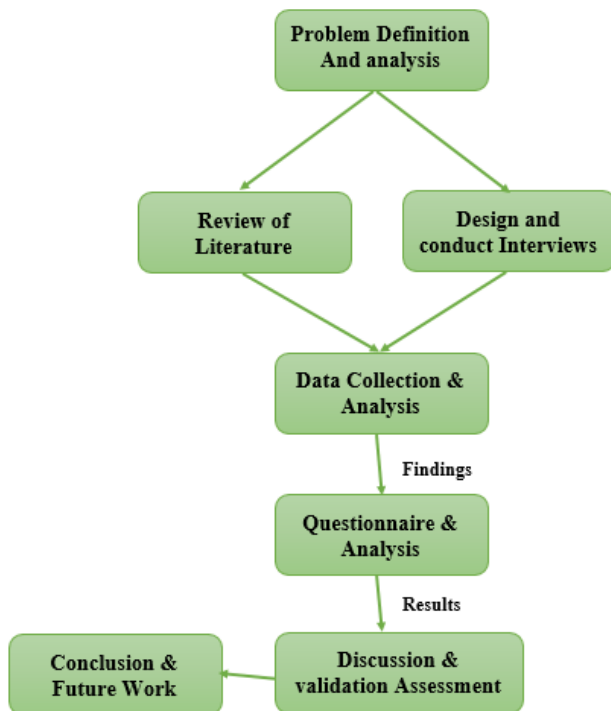


Figure 2: Overview of Research Methodology.

3.1 Interviews

The researchers conducted structured interviews to provide theoretical underpinning for the study, and they collected enough data to conduct interviews with individuals in charge of health electronic systems at the various institutions covered by the study.

The interview's objectives are to conduct an in-depth investigation of the advantages and drawbacks of implementing interoperability, as well as to provide further data and support for the qualitative materials collected in this study. As a result, the researchers devised a series of open-ended

questions to allow interviewees to freely express their opinions on the scope of the study.

3.2 Questionnaire

The questionnaire was designed by the researchers, reviewed by a number of experts in the field of health informatics, and then circulated to various healthcare professionals. The questionnaire was created with the intention of obtaining a qualitative and quantitative data to support the results sought by the study. Questions were created in such a way that health IT professionals and healthcare providers in Palestine could share their opinions on the approaches taken for interoperability. The framework suggested by the researchers to achieve interoperability between healthcare institutions in Palestine, and how Palestinian healthcare providers could profit from interoperability.

3.2.1 Questionnaire Validity

The validity of the arbitrator's "virtual honesty" was used by the researchers to confirm the validity of the questionnaire. The researchers designed the initial draft of the questionnaire, gave it to a panel of six experts in the field of health records and data security for their assessment, and then reworked the initial draft of the questionnaire and produced the final one. (Gregg, 1989)

3.2.2 Questionnaire Reliability

The questionnaire's reliability ensures that the results will not vary considerably if it is administered numerous times over a given period. The questionnaire was distributed to ten health professionals, and all of the questions were discussed with them. Based on the discussions, the questions were modified as needed, and the Cronbach coefficient was used to measure and discover the reliability of each question (Mellenbergh & Adèr, 2008). The questionnaire was re-administered and the necessary

modifications were made and approved by the study sample. Table 1 displays the Cronbach's Alpha results.

Table 1: Cronbach's Alpha results

Scale	Cronbach's Alpha	# of questions	Cronbach's Alpha
Data Exchange Condition	0.771	8	0.816
Interoperability Challenges	0.887	10	0.890
Interoperability Benefits	0.948	15	0.949
Interoperability Data Requirements	0.953	13	0.954
Interoperability Technical Requirements	0.924	12	0.936
Total Degree for The Instrument	0.897	58	0.909

The responses to the questionnaire were converted into numerical values based on a 5-point Likert scale, indicating the response as strongly agree (5), agree (4), neutral (3), disagree (2) strongly disagree (1), and the data was then entered into the SPSS program.

3.3 Study Population

The study population was located by the researchers in five hospitals in the Palestinian cities of Hebron and Ramallah. Al-Ahli Hospital, Al-Meezan Hospital, and the Governmental Hospital of Hebron (aka Alia Hospital) were the hospitals represented in Hebron, while Palestine Medical Complex (PMC) and the Istishari Arab Hospital were the hospitals represented in Ramallah. The study included healthcare professionals who often interact with patient records and different health information systems. Al-Ahli Hospital, Al-Meezan Hospital, and the Istishari Arab Hospital were among the three private hospitals in the study population. The Palestine Medical Complex (PMC) and the Governmental Hospital of Hebron were among the two public hospitals.

According to the departments of human resources in the aforementioned organizations, the study population is shown in Table 2.

Table 2: study population

Healthcare center	Number of health workers
Al-Ahli Hospital	640
Al-Meezan hospital	110
The governmental hospital of Hebron (Alia)	550
Palestine medical complex (PMC)	670
Istishari Arab hospital	380
Total Population	2350

Table 3 shows the number of employees covered by the research in private hospitals relative to employees in public hospitals. The percentage of employees in the private sector is higher than in the public sector because the study includes three hospitals from the private sector in contrast with two hospitals from the public sector.

Table 3: population study quotas

Subgroup	Subgroup Weight age	Quota Size	Population
Private centers	60 %	199	1410
Public centers	40 %	132	940

3.4 The Study Sample

The size of the study population is 2350 employees - as shown in Table 2 - working in the health field in five hospitals, including two public hospitals representing 1220 employees and three private hospitals representing 1130

employees. A sample of the study was selected with 6% of the population and represented by 41.4% from the public sector and 58.6% from the private sector. This difference was based on the difference in the population size of the two subgroups used, 40% public sector hospitals versus 60% private sector hospitals.

The study sample consisted of 331 participants, with a margin of error of 5%, and a confidence level of 95%. The researcher distributed 331 questionnaires to employees in the study hospitals, and the number of responses to the questionnaire was 140 out of the total number, this low response rate was due to the lack of cooperation from employees in filling out the questionnaire.

With a 95% confidence level, the sample response from 140 questionnaires, which represents 6% of the research population, has an error margin of 8%. The permissible margin of error in clinical survey research, according to Suresh and Chandrashekara (2012), is between 5 and 10%; hence, the margin of error in this study is acceptable.

4. Results and Discussion

4.1 Results of Interviews

When we analyzed the interview data, we found that there were many interoperability problems in both the public and private health sectors, as well as some unique ones. The public and private sectors are both familiar with the concept of interoperability and its significance, and health information systems differ in terms of programs and systems but are identical in terms of content. While the private sector uses a proprietary system that varies from hospital to hospital, the public sector uses a unified system and database across all government hospitals. Everyone underlined the significance of interoperability in terms of improving the quality of care, which benefits patients, medical professionals, and

healthcare providers. All interviewees concurred that interoperability in Palestine faces significant obstacles, the most significant of which are the lack of laws and policies governing this area, the lack of the necessary infrastructure for interoperability, including a secure data exchange system, and the lack of financial resources. Everyone emphasized the significance of implementing international standards for the implementation of interoperability, including standards for the security and privacy of exchanged information and other critical standards like the HL7 standard, while keeping in mind that each healthcare institution has its own policies for maintaining data privacy, such as the distribution of authentication and audit records. The interviewees acknowledged that the proposed framework ought to function in a decentralized setting that applies to Palestine because there is no unified national database.

Public sector infrastructure needs to be constructed and set up for interoperability because it is not yet ready. On the other hand, aside from Al-Mezan Hospital, which has a system under development, the majority of private sector hospitals have an infrastructure that can interoperate - with some modifications and additional tools. All interviewees are supportive of any framework for secure interoperability in Palestine, and they all agree on the significance of information security and privacy for the exchanged EHR.

4.2 Discussion

The study focused on identifying the benefits and challenges of interoperability as well as how private and public health organizations in Palestine could achieve this securely by providing an appropriate interoperability framework. The findings show that interoperability between private and public healthcare centers in Palestine is crucial. For continuity of care, there is currently no option for interoperability, so

patients must transport paper copies of their medical records from one healthcare facility to another. Our analysis and literature review also revealed that there are numerous challenges to implementing interoperability in Palestine.

5.2.1 Interoperability Challenges

Different health institutions face many challenges in interoperability as mentioned in the literature, and in Palestine, a lot of efforts must be made to focus on the challenges facing the existence of a secure and appropriate environment for interoperability, so it is necessary to solve all these challenges to deploy interoperability between the different healthcare centers.

According to the results, one of the important challenges for interoperability, which must be focused more on, is the lack of policies and laws in Palestine that support interoperability, and then achieve information security and privacy. The second major challenge was the lack of an updated infrastructure at the Palestinian Ministry of Health and private health institutions to implement interoperability. The survey revealed that the distribution of authorizations and auditing requests on the system as well as maintaining the security and privacy of information were the next challenge in implementing interoperability among different healthcare institutions.

The researchers believe that if the Palestinian Council of Ministers makes the required policies and laws to protect interoperability available and the Palestinian Ministry of Telecommunications and Information Technology adopts them through the owned interoperability system known as X-Road, the majority of health institutions will view the implementation of interoperability with great importance to increase confidence in the laws.

To solve serious interoperability issues, it is also crucial to apply international standards for information security and interoperability.

The results show that interoperability standards such as HL7 and clinical document structure can be useful in transferring a medical document into digital format. However, the ICT platform should support the sharing of this information to different healthcare centers. A secure electronic system is required, in the researcher's opinion, if the patient's medical record is created in a digital format, in order to move data from one location to another. The X-Road System held by the Palestinian MTIT is a representation of the researcher's framework, which is regarded as one of the most significant and superior frameworks utilized for interoperability in the world..

As for the decentralized approach, it can be the best solution for interoperability in Palestine, Peerto Peer communication is useful to support the exchange of a patient's electronic medical record between two peer entities. However, it will not enable central control over transmitted data among all healthcare centers, and according to the results of questionnaires and interviews, medical and clinical information should be exchanged reliably and securely.

Interoperability contributes to reducing the time it takes for other institutions to get a patient's medical record because, according to the results, this time is often between 1 and 24 hours long and has an adverse impact on both the patient's health and the standard of healthcare services.

5.2.2 Interoperability Benefits

One of the benefits of interoperability is to shorten the time it takes to obtain medical information. According to Gordon & Catalini (2018), interoperability has many benefits, the most important of which are

improving operational efficiency and cutting down on the time it takes to obtain the patient's health record.

The findings show that interoperability enhances healthcare quality by reducing the risk of medical errors, and the repetition of lab tests, or the medical images that could endanger the patient's life. Additionally, interoperability allows medical professionals from diverse healthcare facilities to share information and lowers the cost of the patient's treatment. Along with facilitating the sharing of varied experiences and preventing the need to complete multiple forms. Interoperability also enhances decision-making and advances work in various medical facilities.

According to Robi Karb (2021), there have been many successful health interoperability cases, and these health organizations have benefited from decreasing potential errors, avoiding costly redundancies, and saving time in healthcare.

Another study looked at the benefits of interoperability between healthcare organizations in the United States, which significantly improved health outcomes for Americans, the most important of which are lower healthcare costs, higher healthcare quality, improved patient safety, and better population health.²

5.2.3 Proposed Framework for Interoperability

The suggested framework addresses several of Palestine's interoperability concerns, including information security, patient privacy, decentralization, and the requisite interoperability standards, as well as authentication and

² FACT SHEET: HEALTH IT INTEROPERABILITY:

https://www.ehidc.org/sites/default/files/resources/files/2013-08-26_-_eHI_-_HIT_Interoperability_-_Fact_Sheet_0.pdf.

auditing. The framework offers many benefits at the level of patients, institutions, and health service providers and provides on time medical services. The framework reduces the duplication of examinations and medical images as well as the cost of treatment. Besides, it contributes to reducing medical errors and leads to more accurate diagnosis for patients. Decision-making is improved by the framework and exchanging experiences among healthcare workers is widely utilized. All of these benefits will lead to an increase in the quality of healthcare services in Palestine.

The researchers proposed an interoperability framework through the Palestinian MTIT, which has been utilized for interoperability across ministries and government institutions in Palestine since 2011.

4.3 Recommendations

For e-health professionals and those in charge of the electronic systems in private and public health facilities, the researchers make several recommendations in their research study. Given that the public and private healthcare institutions in Palestine are not yet interoperable, these recommendations will aid in creating interoperability among those institutions. The findings from the questionnaire analysis and the interviews with e-health experts have enabled the researchers to provide some practical recommendations for interoperability in Palestinian commercial and public healthcare organizations.

- ✓ The Palestinian government should work on establishing regulations for interoperability, health information security, and patient data confidentiality.
- ✓ Healthcare centers in both the public (represented by the Palestinian Ministry of Health) and private sectors must implement e-health standards such as HL7 so that the HL7 V3

standard, and CDA can be used to create a digital document for the patient's medical record utilizing the health center database. Some of these institutions have partially used some of these standards (Shabo, 2018).

- ✓ There is a need for an ICT infrastructure to exchange EHR across private and public healthcare facilities because the healthcare systems in Palestine are decentralized. Consequently, a distributed peer-to-peer environment may be beneficial.
- ✓ To provide a better user interface, EHR can be viewed through the browser application or a customized application that supports it.
- ✓ Because there are many healthcare professionals with different scientific fields of specialization and different ranks, access to data must be controlled, and their roles appropriately defined to control accessibility.
- ✓ The framework is a novel system which requires adequate training for the medical team working on it, as well as the availability of a technical support staff to fix problems as they arise.
- ✓ Internal and external budgets and funding are needed to develop the framework and create the infrastructure in the various health institutions necessary for interoperability.

5. Proposed Framework

The researchers are working on a secure framework within the capabilities available in Palestine for interoperability among private and public healthcare institutions, by linking the various healthcare institutions using the secure Palestinian Interoperability System (X-Road) owned by (MTIT) (Palestinian Ministry of Telecommunications and Information technology (MTIT), 2022). X- Road System enables us to use the highest security

standards required for health information to exchange data between different healthcare institutions by encrypting the data that passes through it. X-Road is used as a decentralized system for data exchange, and the data remains the property of the health institution providing it, but the data is shared through the Application Programming Interface (API) without saving it anywhere and we can use it through the databases of the health institution providing the data.

5.1 X-Road / UXP Background in Palestine

The government purchased the X-Road System from Estonia, which allows data to be securely exchanged across governmental organizations in Palestine. More than 52 governmental institutions use the system and communicate data electronically.

The major goal of presenting this system is to evaluate the possibilities of employing it in interoperability across Palestinian healthcare organizations.

5.2 X-Road Framework

The proposed framework's major objective is to enable and accelerate EHR exchange across private and public hospitals in Palestine, where data can be analyzed and managed by specialists in various medical institutes before being shared. The framework is designed to achieve semantic interoperability by utilizing the most recent security and interoperability standards. In addition to applying the HL7 standard to coordinate clinical data in a standard format for exchange, the framework allows for the preservation of patient privacy and the determination of the permission of each portion of data and its accessibility with the patient's agreement (Kivimäki, 2018).

Because the framework focuses on connecting healthcare facilities, the facility must be either a provider or a producer of medical data. The

framework is provided and used by the Palestinian government in Palestine, and it enables the essential tests to assure data security by utilizing internal testing systems at the Palestinian MTIT. Furthermore, the system operates on the Internet, which connects all health institutions in Palestine, allowing users to simply and rapidly access information from any healthcare facility. The X-Road System has a data recovery system outside Palestine, so, in cases of disasters, the services do not stop in healthcare centers, except if the internet line is cut off. Moreover; if a problem occurs in one of the medical centers, it will not affect the other healthcare centers and they continue to function efficiently.

X-Road / UXP collects data from health organizations, information systems, and databases and provides essential components for interoperability and data exchange in a secure and standardized method. X-Road / UXP allows service providers to control their systems and data while making them a member of a decentralized and infinitely scalable data exchange network. Data exchange satisfies the confidentiality, integrity, and availability of data.

5.3 X-Road /UXP Suggested Workflow for Healthcare Institutions in Palestine

Figure 3 shows the framework for interoperability between the various healthcare institutions in Palestine according to the following working mechanism based on the framework architecture:

- The service consumer enters the necessary service information through a SOAP or RESET message.
- The message is pay-loaded to the encrypted channel through the consumer security server, which encrypts the message entered.

- The signatures and certificates used in the message are verified by the central server that passes the message to the service provider or rejects it.
- The service provider's security server receives the message, verifies its authenticity, and then passes it to an adapter server. The adapter server converts the message into a format that the service provider's internal system can use.
- The adapter server accesses the database of the service provider and then inquires about the required data.
- The service provider encapsulates data through a SOAP or RESET message.
- The message is pay-loaded to the encrypted channel through the provider security server, which encrypts the message entered.
- The signatures and certificates used in the message are verified by the central server that passes the message to the service consumer or rejects it.
- The service consumer security server receives the message, verifies its authenticity, and then reads the message and uses it.

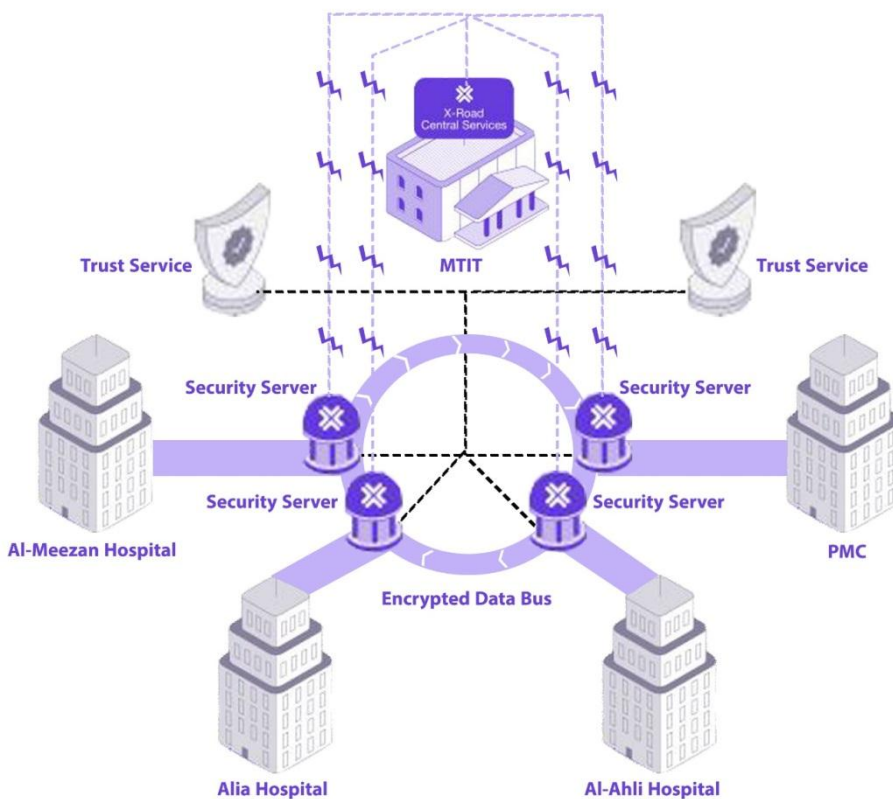


Figure 3: Framework Architecture

6. Conclusion and Future Work

6.1 Conclusions

The research aims to study the secure interoperability between private and public healthcare centers in Palestine. With the help of questionnaire and interview results, we have presented some critical challenges in adopting interoperability, some of which have a high level of importance and should be focused on and include policies and laws regulating interoperability, standards for e-health, integration, information security, privacy, cost, and infrastructure. In the absence of interoperability between

private and public healthcare centers in Palestine, the emphasis must first be on policies and laws, followed by the implementation of relevant standards and the selection of the proper ICT platform for use. The findings reveal that standards, IT tools, and communications account for 90% of interoperability. Some private and public healthcare centers lack interoperability; for the time being, they must construct infrastructure and meet the minimum standards for interoperability in Palestine (Palestinian Ministry of Health, 2021).

When patients are transferred from one healthcare facility to another, they require clinical information such as discharge summaries, various medical records or hospital reports, results of lab tests, health images, and so on. Clinical information and the electronic health record must be saved in the form of a digital document that can be created using electronic health standards. However, in order to exchange electronic health records between healthcare centers, an electronic communication framework that hospitals can share is required.

Interview and questionnaire answers show that if there is interoperability, access to information should be restricted to the patient and the authorized person only to ensure patient privacy and information security. After analyzing all the research studies, it is necessary to focus on:

- Policies and laws regulating interoperability,
- e-health standards
- Information and communication technology
- Access to information in a secure manner.

6.2 Final Findings

- Healthcare personnel in private and public healthcare centers in Palestine believe that implementing secure interoperability in Palestine has significant challenges, limiting the possibility of interoperability at

present, with a statistical average of (3.52) 70.38%. The results are shown in Figure 4 and described below:

- a. Interfacing 70.6%
- b. Integration of different applications 73.4%
- c. Privacy of information 74%
- d. Authentication and auditing 75.2%
- e. The implementation cost of an interoperable system is 72.4%
- f. Security of shareable information 71.2%
- g. Absence of infrastructure for information exchange 68.8%
- h. Absence of trust in outside information 66.8%
- i. The hospital has strict policies regarding information sharing 69.6%
- j. Resistance to the use of a new computer-based system by staff members 61.8%

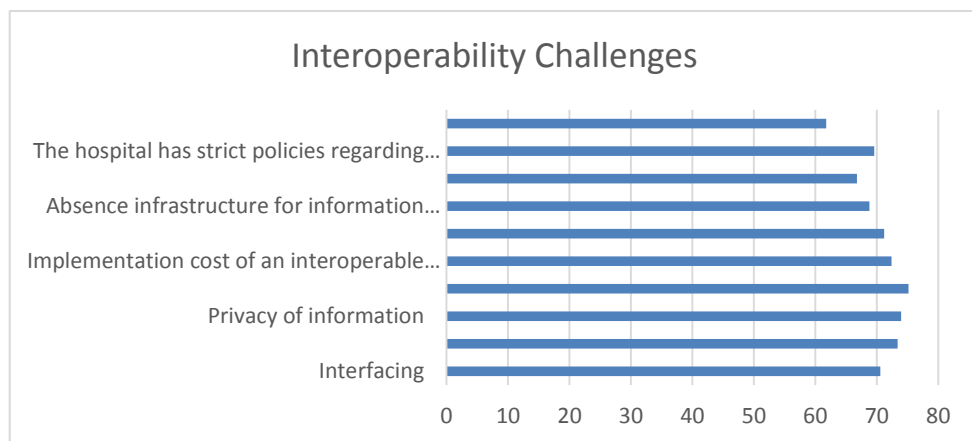


Figure 4: Interoperability Challenges from the viewpoint of healthcare staff.

- Healthcare staff and public healthcare centers in Palestine say that implementing secure interoperability in Palestine has great benefits that would encourage the possibility of interoperability in Palestine, with a statistical average of (3.74) 74.79%.

The results are shown in Figure 5 and described below:

- a. The overall cost of the patient's treatment will be reduced by 69.6%
- b. The quality of patient care will be improved by 73.6%
- c. Safety of patient care will be better guaranteed at 75.6%
- d. Interoperability will help to generate a more accurate diagnosis of 74.6%
- e. Interoperability will help to reduce duplication of lab and imaging tests by 77.6%
- f. Interoperability will help in preventing drug-drug interactions at 75.4%
- g. Interoperability will reduce time in patient sessions by 70.6%
- h. Interoperability will help improve decision making 73.6%
- i. Interoperability will help avoid filling multiple forms 77.2%
- j. Interoperability will help reduce healthcare costs by 73.4%
- k. Interoperability will improve the reputation of hospitals and clinics by 75.4%
- l. Sharing experiences and knowledge between healthcare staff 76.4%

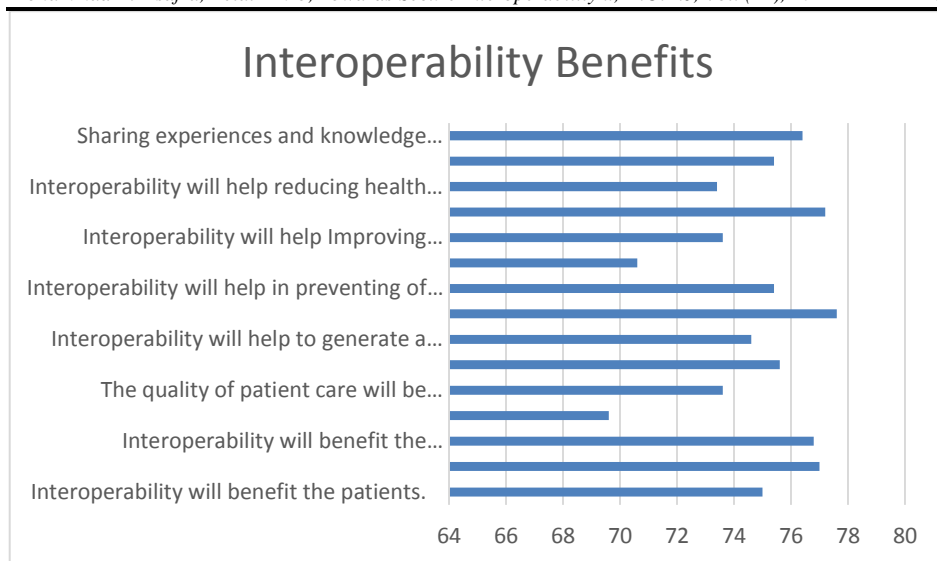


Figure 5: Interoperability Benefits from the viewpoint of healthcare staff.

- In Palestine, healthcare staff in private and public healthcare centers determine the type of patient information for interoperability, with a statistical average of (3.75) 75.06%.

The results are shown in Figure 6 and described below:

- Medical history 76.2%
- Vital signs 74.8 %
- Medication list 77.2%
- Allergy list 79%
- Laboratory results in 78.2%
- Diagnostic imaging results 77.2%
- Discharge instructions/ notes 74.6%
- Implanted medical devices list 74.2%
- Full health record (HR) information 71%
- Personal information 70.4%
- Patient’s medical diagnoses 74.6%
- Referral services 73.6%

m. Family history 74.8%

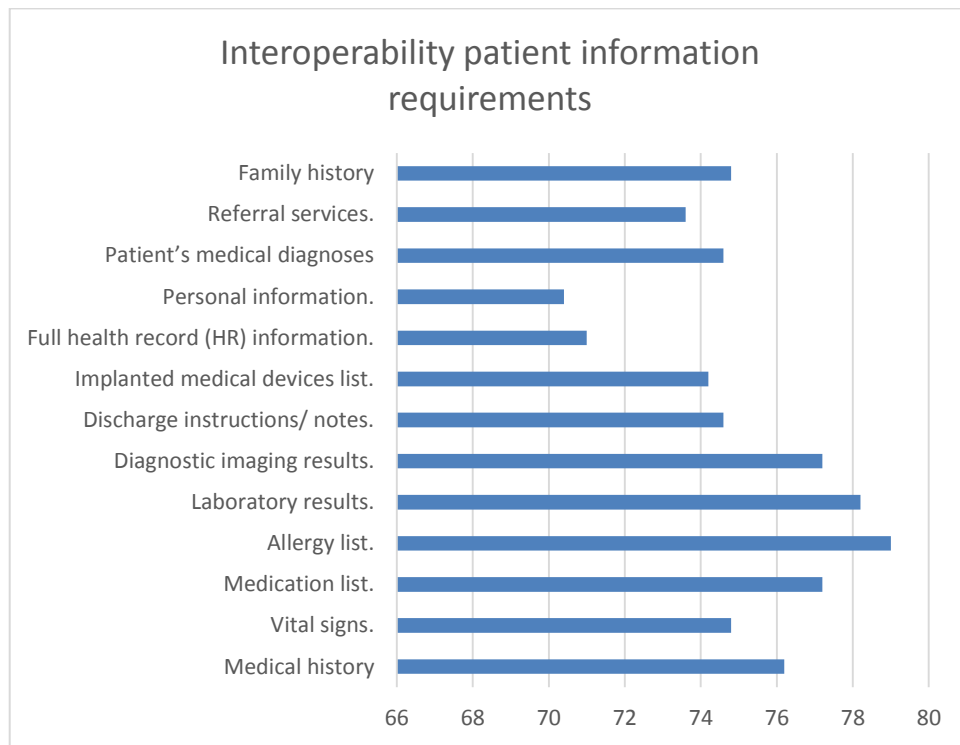


Figure 6: Interoperability of patient information requirements from the viewpoint of healthcare staff.

- Healthcare professionals in both private and public hospitals in Palestine recognize the technical requirements for interoperability, with a statistical average of (3.9) 78.08%.

The results are shown in Figure 7 and described below:

- Using the necessary hardware, and equipment to maintain the confidentiality of information interoperability 78%
- Using the necessary software to maintain the confidentiality of information interoperability 80.2%
- The need for dedicated computers & tablets to be used in interoperable systems is 77%
- Need software programs for better use of interoperability 79.8%

- e. Need mobile applications for better utility of interoperability 75.8%
- f. The need for dedicated internet connection for users of interoperable systems is 78.4%
- g. Need for dedicated information technology staff for troubleshooting 81%
- h. Need training for healthcare professionals to use the system 81%
- i. Need the establishment of a help desk to follow up on system problems and take the appropriate action 79.4%

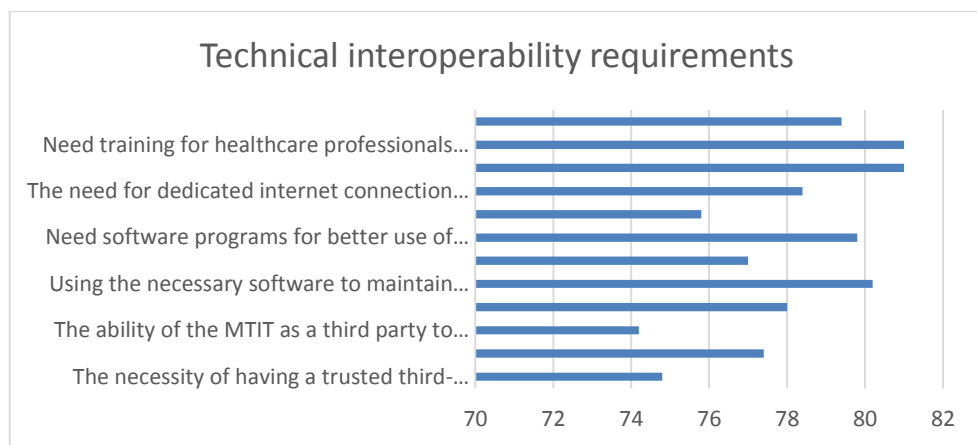


Figure 7: Technical interoperability requirements from the viewpoint of healthcare staff.

6.3 Directions for Future Work

Future study should concentrate on the architecture of a distributed peer-to-peer system between different healthcare organizations, as represented by the X-Road /UXP system proposed by the researchers as the best solution for interoperability in Palestine. Collection of the requirements and needs of implementing the real system is also recommended. A comparative study can be conducted to determine the benefits and challenges of interoperability between private and public healthcare

institutions in Palestine using the information and communication technology platform described in this paper. It is also recommended that the findings of the study be presented to the Palestinian Council of Ministers, the Ministry of Telecommunications and Information Technology, and the Ministry of Health in order for them to adopt them and begin the steps needed to put them into practice due to its great benefit to all citizens of the State of Palestine.

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