DEVELOPMENT OF AN INTEROPERABILITY PLATFORM FOR INFORMATION SYSTEMS IN THE EHEALTH DOMAIN, FOR THE PORTUGUESE HEALTH SYSTEM

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ABSTRACT

EHealth has emerged as a new field at the intersection of medical informatics, public health and business, referring to healthcare services and information provided or enhanced through information technologies. Today, it is very focused on improving the interoperability between Electronic Health Records (EHRs), Electronic Medical Records (EMRs), and between them and the applications installed on patients' devices (smartphones and IoT), with the development of new platforms. Developments of this type imply the use of standards such as Health Level 7 Fast Healthcare Interoperability Resource (HL7 FHIR), openEHR, and Clinical Data Interchange Standards Consortium (CDISC), which guarantee that health data transmission policies are respected.
The work presented in this article is developed within the framework of the Health for Portugal agenda (HfPT), of the "Agendas Mobilizadoras para a Inovação Empresarial" promoted by the "Plano de Recuperação e Resiliência portugês" (PRR), in collaboration with the Centro de Computação Gráfica (CCG/ZGDV), which is the organization responsible for development of this platform. This article is based on the initial phase of the development of a platform that allows the integration of different information systems, to solve the lack of interoperability of the EHRs of health stakeholders in Portugal and also to reduce the fragmentation of the HIS of the Portuguese SNS.

KEYWORDS

Ehealth, Interoperability, Architecture, Health Information Systems

1. INTRODUCTION

Today, eHealth is very focused on the interaction between patients and healthcare professionals, through improvements in EHRs and the development of new platforms that allow sharing and receiving health data directly from applications on patients' devices. To ensure interoperability, respecting privacy policies, and health data integrity, the development of this type of platform implies the use of standards such as HL7 FHIR, openEHR, and CDISC.

Within the scope of the HfPT agenda, promoted by the PRR, this work will be based on the development of a platform that allows the integration of different information systems, which guarantees compliance with standards, norms, and benchmarks for health data. In Portugal, there are several public and private health institutions that have their own information system operating in isolation, so that when a patient is transferred between hospitals, he needs to carry documentation with his clinical data in paper format and the medical examinations performed at the previous health institution are repeated at the hospital where the patient arrives.

Another situation that occurs, due to the lack of interoperability, is that the health information system (HIS) of the Portuguese SNS is also not capable of efficiently and effectively integrating the clinical information that is produced in private clinics and some public hospitals, which obliges the users' family doctors to manually update this system whenever there is new data. This is a problem that makes health services inefficient, increases the probability of medical errors, implies unnecessary expenses with repeating exams and forces family doctors to spend time on these tasks.

In this article the beginning of the development of a solution for this problem is documented. A literature review is carried out on interoperability platforms in the eHealth domain, which encompasses infrastructure, technologies and the application of standards related to health data transmission policies. It will serve as support for decisions on the architecture of the common platform, which allows interoperability between public and private hospitals, health centers, clinics, medical examination centers, the patient himself, the SNS, and in the future, other countries of the European community.

The work is based on a search carried out in the Scopus database, with the string "KEY (interoperability AND information AND systems AND eHealth)" and filtering of documents of the type "article" and "conference paper". With the aim of understanding the main theme of the project in a broader way and perceiving architectural, technological and regulatory trends, in order to make informed design decisions.

2. E-HEALTH

The designation eHealth emerged in 2001 by Eysenbach, designating it as an emerging field at the intersection of medical informatics, public health and business, referring to health services and information provided or enhanced through the Internet and related technologies (Eysenbach, 2001). It includes medical informatics, telemedicine, health telematics and health ICTs. It encompasses the interaction between patients and healthcare professionals and is seen as the most important revolution in healthcare since the advent of modern medicine or hygiene (Dinevski et al., 2010). The World Health Organization also defines eHealth as the safe and cost-effective use of information and communication technologies in support of health and health-related areas.

In today's society and also in eHealth, multichannel platforms, where patients are at the center, are gaining ground, but in this domain it is still systems such as EMR and EHR that play a central role. In Portugal, there is a scenario of lack of interoperability in the eHealth domain, related to the fact that the various health institutions have EHRs and EMRs that operate completely independently of each other, causing difficulties for patients, professionals, related industries and also to the main entity responsible for health in the country, the SNS.

3. E-HEALTH INTEROPERABILITY

Heterogeneous enterprise applications, at either the business or the manufacturing level, either within a single enterprise or among networked enterprises, need to share information and cooperate in order to optimize their performance. This information may be stored, processed, and communicated in different ways by different applications. The problem of managing heterogeneous information coming from different systems is referred to as the interoperability problem (Jaskó et al., 2020).

3.1 Developments on E-Health Interoperability Platforms

The Enterprise Electronic Cloud-Based Health Record System (E2CHRS) project for recording, retrieving, archiving, and updating medical records was presented by (Adebayo et al., 2014). It uses a unified cloud database for all hospitals, middleware that provides a common platform for all EHR systems in remote hospitals, an authentication server manages access to the system, and an e-web portal serves as the front end and connects the app to the cloud. This type of approach also facilitates the interoperability of HER systems with the pharmacy's computer systems and even with the applications of the users' electronic devices.
The availability of such a platform would later allow the development or integration of a solution such as the one proposed by (Pereira et al., 2018), which consists of a citizen-centered Electronic Prescription system. Where the patient enjoys a simplified and comfortable electronic prescription system, which will allow him to buy the medicines through an application, later the medicines will be delivered at home. As it is integrated with the RES, the physician simply writes down the prescription, normally, and the patient accesses it through this multichannel application.

In their article, (Lemus-Zúñiga et al., 2022) proposed a health monitoring system based on the integration of rapid prototyping hardware and interoperable software to build a system capable of transmitting biomedical data to health professionals. The system allows IoT devices and other systems to be interoperable, using standards

for data exchange such as FHIR and the universAAL (universal Ambient Assisted Living) platform. They presented a new layer based on rapid prototyping sensors so as not to limit data acquisition with specific equipment suppliers. In this way, adopters or developers of this type of system can build the system to coexist with existing systems/platforms/services, as long as interoperability is guaranteed with the use of FHIR standards and the universAAL platform.

Several authors have already described attempts to incorporate blockchain technology and public cloud in this type of platforms, also (Carter1 et al., 2019) proposed a health data sharing platform that includes security through multilayer cryptography, data storage through of Amazon Web Services and data transfer using the Ethereum blockchain. For these authors, the combination of these technologies is promising, but they still do not consider it capable of solving the immediate problems in the eHealth area, as it will take some time to adapt these technologies to the standards and government policies required in the eHealth domain, such as the HITECH law applied in the United States.

Argentina's National Digital Health Strategy 2018-2024 aims to reduce quality gaps in healthcare through the implementation of interoperable information systems. In 2019, they launched the National Digital Health Network, using a service bus technology infrastructure to connect different systems across the country, which will enable new eHealth services and integrate existing ones. In an article by (Rizzato Lede et al., 2020), the work developed by the Ministry of Modernization of Argentina, together with the Ministry of Health, was presented, which consists of the Citizen Health Digital Portal (Mi Argentina / Mi Salud) for personal access of Argentine users. This allows them to access your information and change your consent to exchange health information for the National Digital Health Network. It has tools such as the Electronic Vaccination Card and intend to include the patient's international summary, laboratory results, and electronic prescriptions.

The work (Weber-Jahnke & Obry, 2012) presents a mechanism for peer-to-peer interoperable systems that restricts access to confidential medical data based on defined consent policies, allowing policies to be overridden when necessary. The project includes monitoring, audits, and is open source, designated CDAShip and available on SourceForge.

An interoperability solution for sharing data between heterogeneous data sources was presented by (Masud et al., 2012). Includes a metadata management framework for multimedia medical content, eg X-rays or ECG. The framework identifies resources, generates and represents metadata, and produces identifiers for multimedia content.

Also to achieve interoperability in the medical field, (Mazouz et al., 2017) proposed a system to integrate heterogeneous HIS using schema matching technique. In order to automatically find semantic correspondence between XML schemas to allow their integration into information systems. To achieve this, they used Metathesaurus in the Unified Medical Language System (UMLS).

A semi-distributed system architecture approach was proposed by (Fragidis et al., 2016) for an integrated national electronic health record system, incorporating the advantages of centralized architecture and distributed architecture. The architecture provides robust interoperability without healthcare providers changing their on-premises EHR systems. It is a pragmatic approach that takes into account the characteristics of the Greek national health system, together with the data communication network infrastructure of the national public administration, to achieve EHR integration with low implementation costs.

In Brazil, an architecture called SMART was developed to integrate the different telehealth platforms developed independently by the 9 Brazilian telehealth centers. The architecture aims to standardize information so that the Ministry of Health can monitor and evaluate the results of Telehealth actions (de Paiva et al., 2018). It has four components: a web tool for data manipulation, a web service to receive production data from the center, a component to convert the received data into decision support data, and a component that collects data from external sources to compose the data warehouse.

In an article published by (Id & Kim, 2018), an eHealth system with the Semantic Sensor Network (SSN) was presented, which is composed of an eHealth device, client, and server, which aims to solve the interoperability problem of the device using IETF YANG to model eHealth data semantics to represent sensor data. The developed ontology builds metamodels of eHealth sensors, for data that support different formats. The solution generates the broadcast message based on the semantic model, through a message generator. It includes YANG-to-JSON translator and eHealth client to present the meaningful SSN information to the user. The proposed approach assists in the self-configuration of eHealth sensors and in querying the sensor network, supporting semantic interoperability for the eHealth system.

In order to meet the urgent need for interoperability in EHR to improve healthcare delivery, the study by (Adel et al., 2017) recommends fuzzy ontology as an intelligent information system solution. These authors

recommend the fuzzy ontology, involving current technology, such as a fuzzy database or Fuzzy Markup Language (FML).

Schiza et al. provided an article that articulates a framework for deriving a national health system based on interoperable EHRs. This eHealth ecosystem has been proposed for Cyprus and its most important components are the Central Citizen Data Warehouse, which uniquely links each citizen to the Central eGovernment Portal, the country's cloud-integrated EHR system is regulated by NeHA, ensuring interoperability, confidentiality and security. According to (Schiza et al., 2019), adopting EU principles following the relevant guidelines for a fully interoperable healthcare system is not simple. At social, political, and scientific levels, incorporating and developing modern eHealth IT technologies requires a major effort from all stakeholders.

The Evgeniy et. al., presented an article whose main objective is to investigate the most used definitions of clinical data structures and propose a model to adapt them to CEN 13606. More specifically, to develop a common methodology to transform existing information into XML documents, exchanged in the domain of health, using the CEN 13606 Archetype model. This research effort, combining medical and computer science professionals, resulted in a UML model. To develop the model, clinical documents generated during the provision of general medicine services were used. First, the global elements of the XML Schema definitions document (XSD) are converted into Java classes, and then these classes are used to extend the CEN 13606 reference model, preserving the original structure of the main classes, placing their relationships in the international standard. According to these authors, the model can support the construction of a prototype of an information system that allows semantic interoperability between clients in terms of RESTful web services provided by a NoSQL database (Evgeniy et al., 2020).

In any case, to achieve interoperable eHealth systems, platforms or applications that integrate EHRs, EMRs and even patient or wearable applications, interoperability standards are needed that meet the data protection standards and policies required by healthcare institutions and governments.

4. INTEROPERABILITY HEALTH STANDARDS

Reviewing the literature, some standards specially developed to be applied in HIS architectures and development are found.

With the aim of providing a comprehensive framework and standards for the exchange, integration, sharing, and retrieval of electronic health information Health Level Seven International (HL7) was born. It has members in over 50 countries, including Portugal, which could be relevant for this project. Developed the FHIR standard, intended to facilitate the exchange of health information between health professionals, patients, caregivers, payers, researchers, and anyone else involved in the health ecosystem (HL7 International). In the same vein, openEHR also publishes technical standards, including interoperability, for EHR platforms. It includes architectural concepts such as patient-centric shared lifetime health record, future-proofing data, and supporting clinical processes (openEHR). Another organization that develops data exchange standards is the CDISC, its standards facilitate the sharing of structured data between different information systems. Its standards transform incompatible formats, inconsistent methodologies, and diverse perspectives into a framework for generating clinical research data, making them accessible (CDISC).

4.1 Use of Standards in E-Health Interoperability Platforms

The intention to develop modern eHealth platforms, combined with the availability of standards and technologies that allow it, gave rise to the evolution of various solutions capable of meeting the needs of patients, professionals, health institutions, and governments. In this context, (Malaquias & Filho, 2021), developed a middleware based on HL7 FHIR. Also (Calamai & Giarré, 2012) proposed a unified structure for the interoperability of patient summary (SP), electronic prescription (with the involvement of the HL7 Italia Group) and the Chronic Care Model (CCM), based on the HL7 Version 3 Clinical Document Architecture Release 2.

The authors (Nayak et al., 2019) proposed a wearable medical device called Electronic Bracelet (E-BRACE) that allows secure temporary access to a patient's EHR in an emergency, which uses the FHIR protocol to make a call-to-service request and obtain the patient's health record.

In 2019 came GIRLS, a gateway to EHR interoperability that uses both the openEHR and FHIR standards. These authors started from a system that uses the openEHR standard to another that uses the FHIR standard,

proposing an interoperability layered architecture, capable of exchanging data between different standards. It includes an API that connects different systems through endpoints, an intermediary server that maps data from different standards to the FHIR standard and manages microservices for data access and exchange, but the semantic interoperability between HIS using openEHR and FHIR is still a challenge. The openEHR standard is more complete than FHIR resources and can fully represent medical knowledge. However, the FHIR is much less disruptive for existing vendors due to its adherence to RESTful design principles (Gomes et al., 2019).

A new standards-based IT system has been proposed to help seniors navigate a safe path with public transport in a smart city for their routine medical checkups during epidemic outbreaks like COVID-19. The system supports evidence-based decision making for the elderly, integrating health and public transport data (provided by transport systems and using APIs such as Google Maps or Open Street Map), resorting to medical interoperability standards (HL7 FHIR standards can be used in other domains, for example smart city) and compliance tests were performed applying the HL7 FHIR 3.0.1 specification through the official HL7 FHIR validator (Urbauer & Forjan, 2020).

Using experiments, (Krastev et al., 2022) concludes that representing EHR using ISO/EN 13606 archetypes in conjunction with openEHR makes it possible to achieve a higher level of interoperability between HIS than with HL7 standards. According to these authors, using the dual information model of ISO/EN 13606 and openEHR, the new open platform architectures demonstrate cost efficiency in management and high quality of health services.

To achieve semantic interoperability in the eHealth domain, a terminology server provides information systems with the concepts needed to encode information correctly. The Semantic Competence Center (SCC) of ELGA GmbH has proposed an FHIR server, for the Swedish healthcare system, which will work together with a Git-based terminology server (“TerminoloGit”), the HL7 FHIR IG editor and some tools that were developed internally (Kleinoscheg et al., 2022).

The national eHealth systems implemented in Serbia as "MojDoktor" (MyDoctor) and in Macedonia as "MojTermin" (MyAppointment) are based on the same integrated health information platform, but a change in architecture towards a more formal approach is required to ensure their interoperability. To achieve this goal, the study by (Atanasovski et al., 2018) defined the Platform Independent Model (PIM), to represent the relationships and execution semantics, which allowed the development of a model to formalize data transformation to improve the system interoperability capable of transforming system data into HL7 messages.

4.2 E-Health Interoperability in The European Union

The EU Digital Agenda emphasizes the individual patient's right to access their own medical data in a secure manner, supporting patient empowerment and greater involvement in their own care. eHealth has experienced dynamic development across the European Union in recent years and enjoys the support of the European Commission, which seeks to achieve interoperability of national health systems to facilitate free movement, hampered by observed differences between member states on legal regulations, cultural approaches and technological solutions. It is necessary to reconcile differences in data protection policies between member states so that interoperability between European national eHealth systems is achieved (Kautsch et al., 2016).

In this sense, the European Commission funded the epSOS project and the KONFIDO project, to solve these problems of cross-border exchange of health data (Staffa et al., 2018). This new platform that we are going to develop, for the Portuguese health services, has to be developed taking these developments into account, so that it is fully interoperable with the other existing eHealth platforms in the other European member states.

Again, with the aim of making cross-border eHealth services available, the European Commission promoted the eHealth Digital Services Infrastructure (eHDSI), also known as “MyHealth @ EU”. In this context, a selection and compilation of data elements for cross-border care was carried out to serve the eHealth Network Guidelines on Patient Summary as a format for health data exchange in Europe.

To be part of this network, countries must adopt international standards to transmit the content of the Patient Summary in a structured and codified way, understandable by the Health Professional at national and cross-border level. The CEF eHDSI Interoperability Infrastructure has currently adopted HL7 CDA Level 3 and Level 1 as the standard for document exchange. However, Member States are free to nationally adopt the same HL7 standard or another standard, e.g. HL7 FHIR (European Commission, 2022).

5. CONCLUSIONS

The results of the research carried out consist of a set of developments that had the main objective of achieving interoperability in the eHealth domain. It was found that there is a solution for recording, retrieving, archiving and updating medical records, which uses a unified cloud database for all hospitals, with middleware that provides a common platform for all EHR, an authentication server, and a web portal. A service bus technology infrastructure was developed to connect different systems across an entire country. There is a solution for sharing data between heterogeneous sources, which includes a metadata management framework for multimedia medical content. Another system integrates heterogeneous HIS using the schema matching technique to automatically find semantic matches between XML schemas.

The use of different architectural approaches was verified, such as a semi-distributed system architecture, to achieve EHR integration with low implementation costs, another architecture to integrate the different independently developed telehealth platforms, which aims to standardize information for of monitoring and evaluation, and the use of fuzzy ontology as an intelligent health information system solution.

Proposals were presented for a citizen-centered Electronic Prescription system and also a health monitoring system based on the integration of rapid prototyping hardware and interoperable software to transmit biomedical data, using standards such as FHIR and the universAAL platform.

Authors claim that the combination of technologies such as blockchain and public cloud, in this type of platforms, is promising, but it is not yet adequate to the standards and government policies required in the eHealth domain.

About eHealth developments, taking into account the references and standards for the exchange of health data, a middleware based on HL7 FHIR was developed, a unified structure was proposed for the interoperability of the patient summary, electronic prescription, and the model of chronic care, based on HL7 Version 3. A wearable medical device called the Electronic Bracelet (E-BRACE) has been proposed that allows safe temporary access to the EHR in an emergency, which uses FHIR. GIRLS is a gateway to EHR interoperability that uses the openEHR and FHIR standards capable of exchanging data between the different standards, includes an API that connects systems through endpoints, an intermediary server that maps data from different standards to the FHIR standard and manages microservices for data access and exchange. They developed a standards-based system to navigate a safe path on public transport in a smart city, using APIs such as Google Maps or Open Street Map, using HL7 FHIR. A model was developed to formalize data transformation to improve system interoperability capable of transforming system data into HL7 messages

Some authors claimed that the openEHR standard is more complete than the FHIR resources, one of these authors claims that the openEHR is able to fully represent medical knowledge, but the FHIR standard is much less harmful for the existing providers due to its adherence to the principles of RESTful design, another author claims that representing EHR using ISO/EN 13606 archetypes in conjunction with openEHR makes it possible to achieve a higher level of interoperability between HIS than with HL7 standards.

Another important observation is that to achieve semantic interoperability in the eHealth domain, a terminology server provides information systems with the necessary concepts to encode information correctly. It was also observed that architectures with a more formal approach are better at ensuring interoperability.

Therefore, to solve the problem that originated this work, the best solution will involve developing a structure to achieve a national health system for Portugal, based on interoperable HER system, with a central data warehouse, centered on the citizen, so that health data can be received, and accessed based on the identification of the citizen. But APIs must also be developed and made available that allow the future development of applications that citizens install on their connected personal devices, so that they can enjoy and produce their own health data, also APIs that allow access to data for statistical purposes and for feed prediction systems.

The architecture and development of this solution should take place in accordance with the unanimously accepted norms and standards that are as closely aligned as possible with the intended platform, so that the future work to be carried out next, in this project, is to make a detailed analysis and comparison between the existing standards, in order to make that decision.

Within the scope of the HfPT agenda, of the PRR, the preliminary phase of the development of an architecture of a platform that allows the integration of different information systems, to solve the lack of interoperability of the EHRs of the interested parties in health in Portugal and also to reduce the fragmentation of the HIS of the Portuguese SNS. The literature review has already been completed, which allowed observing trends and advances in the eHealth domain, analyzing and discussing the results of this work, which allowed reaching some

conclusions and determining the path to follow for future work. The future work to be carried out next is to make a detailed analysis and comparison between existing standards, such as HL7, FHIR, openEHR or CDISC, in order to select the most suitable standards for this platform.

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