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A Systematic Literature Review of Interoperability in Healthcare using FHIR

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ABSTRACT [1]

Despite the available modern technologies, we live in a "fragmented" healthcare system, in which data is stored in multiple sources and a variety of formats and standards without direct communication. However, in the upcoming years, interoperability is emerging, defined as the ability of different information systems, devices, or applications to connect within and across organizational boundaries to access, exchange, and cooperatively use data amongst physicians and patients. We conducted our study using two databases, PubMed and Web of Science, to explore Fast Healthcare Interoperability Resources (FHIR) standard and how we can use FHIR technology to improve interoperability and exchange data between different hospital services. We also expect to find purposes for further research.

Keywords: Fast Healthcare Interoperability, FHIR, FHIR interoperability, Health Level 7's Fast Healthcare Interoperability Resources.

1. INTRODUCTION

Considering the highly specialized organization of the healthcare system in developed Countries, patients, particularly those suffering from chronic or multi-organ diseases, generally receive care from different hospitals, medical laboratories, and medical centers [1]. Even if electronic health records (EHR), also called electronic medical records (EMR), replaced paper to store documents [2], the medical information is often kept in different, and incompatible systems, even in the same medical center, without the possibility of exchange, making it difficult to keep track of patient data and make correct diagnostic or treatment decisions. Furthermore, this prevents data from being shareable and, thus, interoperable. In this scenario, the difficulty in improving healthcare interoperability across medical providers impacts physicians, patients, and public health. Therefore, multi-site clinical healthcare organizations must transform all healthcare data into a standard format and through standardized terminologies to allow records exchange [3]. In December 2016, the 21st Century Cures Act became law, and the legislation addresses better EHR use and supports health data interoperability [4].

Interoperability, defined as the ability of computer systems or software to exchange and use information, will facilitate secure access to patient data for patients and healthcare professionals, regardless of their location [5]. The term interoperability does not refer simply to communication between server and client; it deals not only with accessing server resources or connectivity [5]. The Healthcare Information and Management Systems Society (HIMSS) outlines the interoperability concept as the ability of different information systems, devices, or applications, to connect, in a coordinated way, within and across organizational boundaries to access, exchange, and cooperatively use data amongst stakeholders, to optimize the health of individuals and populations [2]. More in detail, the HIMSS describes four levels of health information technology based on interoperability. The foundational interoperability provides the information exchange between different systems by creating the inter-connectivity requirements required for one system to share data from another one. Structural interoperability defines of data exchange structure where there is the uniform movement of healthcare data from one system to another. Semantic interoperability is the ability of two or more systems to exchange records and to read and use that information. Lastly, the organizational interoperability covers the technical components and clear policy, social and organizational components [2].

The standards developing organization Health Level Seven (HL7) International first introduced Resources for Healthcare, a new standard to improve interoperability in digital health [6]. This standard, renamed Fast Healthcare Interoperability Resources (FHIR), extends previous HL7 specifications (such as HL7 Version 2 and Version 3) through more recent web knowledge [7]. The fundamentals of FHIR are known as resources that can be exchanged in eXtensible Markup Language (XML) or JavaScript Object Notation (JSON format) [6]. To date, FHIR guarantees about 140 resources, which can be used for typical clinical practices [6], but their use can cover more specific fields, such as clinical research.

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This systematic literature review explored HL7 and FHIR standards and analyzed how FHIR technology can improve interoperability and exchange data between different hospital services. The research questions investigated are the applications of FHIR and the potentials of FHIR in the future.

2. METHODOLOGY

FHIR is an international standard for healthcare information exchange. It is an area of research that has become ever more prevalent as medical records information exchange is a critical unmet need in clinical practice. The primary driver of this research is to identify the potential and the challenges of FHIR technology in the current and future healthcare system. A secondary objective is to identify any gaps in the recent research to build a path for future research. To guarantee that our review was performed effectively and correctly, we began by defining the framework for how we would conduct the review. The PRISMA framework was used to identify, screen, and include the most relevant literature for this systematic literature review, as shown in Figure 1. The first step was to identify a set of research questions to direct our search process. After defining our research questions, we developed a set of keywords to search for articles.

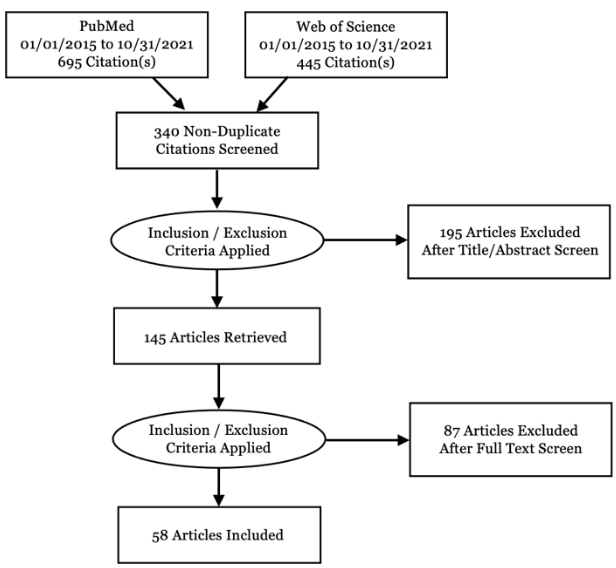


Figure 1 – PRISMA (preferred reporting items for systematic reviews and meta-analysis) diagram

Research Questions
RQ1: What are the applications of FHIR?
RQ2: Which are the potentials for FHIR in the future?

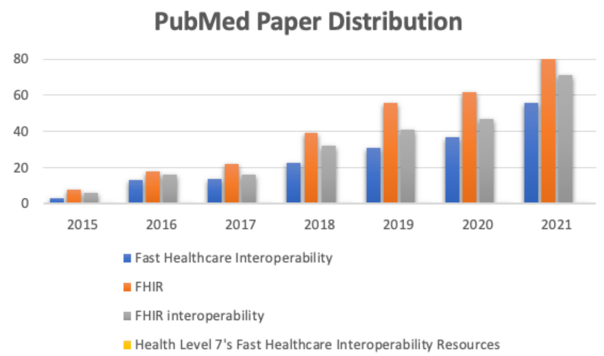
Search and Article Selection Strategy
Our article searches focused on the following keywords (1) "Fast Healthcare Interoperability," (2) "FHIR," (3) "FHIR interoperability, (4) Health Level 7's Fast Healthcare Interoperability Resources. We performed the search using two databases: Web of Science and PubMed. For PubMed, we performed the search on the titles and abstracts, whereas, for Web of Science, we searched for the Topic (title, abstract, author keywords, Keywords Plus®).

The search (date of search October 31, 2021) was limited to only include papers from January 1, 2015, through October 31, 2021, to ensure the research remains focused on the latest methodologies. Another set of exclusion factors used to limit the results was only to include journal articles and conference proceedings in English and where the full text was available. Inclusion criteria included at least one of the following criteria: (1) articles discussing methods to aggregate or integrate health data from different sources, (2) articles proposing solutions that support health data integration, (3) articles discussing methods to utilize health data from multiple sources. In addition, we excluded the articles if any of the following criteria were fulfilled: (1) articles that are not related to health data integration for patient healthcare management, (2) articles that mainly focus on a specific part of integration other than the integration itself, (3) articles discussing only applying specific health management applications, platforms, or services.

3. RESULTS

Following a PRISMA-based approach [8], we reduced the initial search results (695 from PubMed and 445 from Web of Science) by removing all duplicates [9]. Removing duplicate entries left us with a total of 340 results to investigate. The abstract of each article in the result set was used to apply the inclusion and exclusion criteria. After a precursory review of the articles with a focus on techniques, we excluded an additional 195 articles that did not fulfill the inclusion criteria, leaving us with 145 articles to complete a full analysis of. Upon completion of the full analysis, we were able to further reduce the number of articles to 58 total articles. Most of the papers were published in health technology informatics journals. In the PubMed and Web of Science search, the number of papers related to any keywords in the period from January 1, 2015, to October 31, 2021, is represented in figure 2 below.

We chose to divide the papers according to four main topics: (1) general healthcare information management, (2) interoperability technology related to mobile applications, (3) specific clinical application of FHIR technology, and (4) clinical trial related to FHIR technology. We identified 33 papers in the first group and two papers in the second group, the third group included 17 papers, and the last group encompassed six papers. The third group included oncology, radiology, pediatric, and coronavirus pandemic disease papers. In table 1, the selected papers are divided according to the topic.



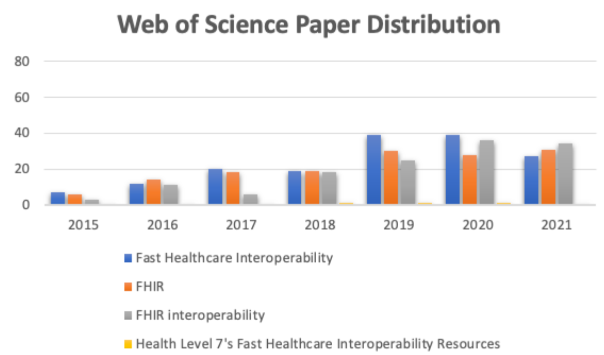


Figure 2 – Distribution of papers according to keywords search in PubMed and Web of Science from January 1, 2015, to October 31, 2021

Table 1 – Selected papers categorized into 4 main topics

Topic	**Title**
General healthcare information management	[15], [19]-[21], [24]-[52]
Interoperability technology related to mobile applications	[12], [18]
Specific clinical application of FHIR technology	[16], [17], [53]-[67]
Clinical trial related to FHIR technology	[16], [22], [68-71]

4. DISCUSSION

The rapid development and acceptance of EHRs and standards to exchange EHRs have improved various aspects of health practices and patient care. However, in most cases, the data kept in an EHR is only accessible to the providers and specialists within the same medical center, but generally not by the patient or other clinicians outside a specific clinic. The importance of FHIR is expressed by its introduction in the 21st Century Cures Act, signed into law in 2013. Furthermore, since its first appearance, the use of FHIR is constantly on the rise; in 2018, six big technology companies, including Amazon, Google, IBM, and Microsoft, signed a letter that indicates FHIR as an emerging tool for health data exchange and trying to remove barriers in healthcare interoperability field [10].

FHIR technology is emerging as a valuable tool, driving the healthcare information exchange industry to consider how their platforms align with FHIR. The systematic literature review of articles about FHIR on Web of Science and PubMed leads to identifying the main topics associated with FHIR in digital health.

Stratifying by year of publication, it emerged that interest in these technologies is constantly growing in the healthcare community, as shown in Figure 2. This trend suggests that the FHIR standard might see a more significant and faster usage in health IT than other standards. It will be interesting to analyze whether the number of FHIR publications will confirm this trend in the coming years. Regarding the geographical distribution of publications, we detected a focus in the United States. However, probably in the future, with the push imposed by the COVID-19 pandemic, many other countries outside the United States will develop interoperable systems.

We have also divided the selected articles according to the main topic. As revealed by this subdivision, a common theme in these publications is that these mechanisms are still largely unknown among the scientific community. Regardless of the unmet need for sharing clinical data and the accessibility to modern technologies, FHIR standards are still not widespread worldwide, even in developed countries. Much effort must be placed to ensure that the various world governments recognize the importance of adopting interoperability systems in a world that is now global. Moreover, an interoperability framework is central to achieving the development goals in developing countries.

Surprisingly, we found only a few articles related to applying the FHIR methodology to mobile applications. Some agencies, such as the Australian Digital Health Agency, aim to increase the use of mobile applications from both healthcare professionals and patients by connecting the health record platform to mobile healthcare applications through standard Application Programming Interfaces (APIs) [11]. At the beginning of 2010, Harvard Medical School and Boston Children's Hospital began an interoperability project to develop a platform to enable medical applications to be written once and run unmodified across different healthcare Information Technology (IT) systems [12]. The project was named Substitutable Medical Applications and

Reusable Technologies (SMART). Thanks to the federal investment, SMART on FHIR was developed as an open, free, and standards-based API. The SMART APIs are widespread today. The SMART on FHIR API has been built into the major EHR products, used by Apple® to connect its health app to hundreds of healthcare systems, and is used for app launch on the Microsoft Azure product [13]. In Europe, during the COVID-19 outbreak, many member states of the EU and the EEA have implemented or plan to implement voluntary and temporary mobile apps that provide contact tracing as part of public health strategies to fight the COVID-19 pandemic [14]. However, member States reported on 31 May 2020 that mobile apps are presently not yet interoperable. Thus, most Member States consider interoperability a high priority and support the eHealth Network role in designing interoperability elements and specifications [14]. There are, of course, several challenges to the broad implementation of those apps, such as legislation issues, leading to the need to establish a good balance between security, user privacy, usability, and public perception. Other obstacles are technical since the app will be dependent on the two operating systems for mobile phones (iOS, Google's Android) provided by US-based corporations (Apple/Alphabet), which leads to questions of technological sovereignty [14].

In our literature search, we found relatively few articles related to clinical trials on FHIR; we believe it would be helpful to implement this side of the research to identify the best strategy for applying this technology. Leroux et al. [15] showed that using the FHIR standard to capture and manage clinical data from research studies makes it possible to reduce the risk of introducing errors and losing fidelity. A recent study that aimed to design, create, and assess an FHIR-based system for automating the case report forms (CRFs) population for cancer clinical trials using real-world EHRs is an excellent example of the FHIR standard used in clinical trials. This study demonstrated that it is possible to complete CRFs with EHR data in an automated manner with suitable performance; thus, these results offer useful insight into future directions in implementing FHIR applications for clinical trials [16].

An interesting aspect of our research is the unmet need for medical data sharing during the ongoing COVID-19 pandemic; the COVID-19 outbreak has clearly shown that significant human challenges need to be managed with global answers and shared decisions. Medical data and their analytics are critical components of such a decision-making process [17]. The pandemic taught us that the world is still unprepared, despite numerous digital tools capable of slowing or stopping COVID-19 and future pandemics. We present a summary of predictive, preventive, and personalized digital methods that could be deployed quickly to aid in the fight against COVID-19 and future pandemics. Suggested preventive and personalized solutions to improve healthcare management in the future, even in non-pandemic periods, are based on the integration of sharable medical data, wearable device data, mobile apps data, and individual data inputs from registered users, acting as a social tool following high security and privacy protocols [17]. These solutions could be possible by the interaction of humans and computers, which we can consider social machines, and the increased connectivity of people and devices [17]. Another advantage of FHIR support is accessing patients' data in the enrollment phase of clinical trials.

With our data analysis complete, we can turn our attention to how the articles have helped us answer our research questions.

RQ1. What are the applications of FHIR?

One of the prime beneficiaries of the FHIR standard is the SMART on FHIR implementation, which defines the way through which health apps can connect to EHR systems with appropriate security guarantees [12]. In addition, mobile applications utilizing FHIR based data transfer have been integrated into hospital workflow to demonstrate medication and vaccine list portability with EHR [18]. A non-real-time FHIR Bulk Data Query Protocol is another promising application; it provides a rich search and data-query capability on existing EHR systems containing millions or even billions of data items cutting across many patients supporting critical applications without sacrificing system performance [19]. One such application is in public health, where the aggregated health status of the entire population of specific geography is of interest.

FHIR addresses the two crucial issues that hindered the widespread acceptance of clinical decision support despite its early recognition and potential - duplicate data entry and the lack of integration into the workflows and processes of clinical practice [20]. FHIR is also seen as an emerging clinical data standard for modeling and integrating structured and unstructured EHR data for various clinical research applications. FHIR-based EHR phenotyping research showcased improving the data aspect of phenotyping portability across EHR systems and enhancing machine learning-based phenotyping algorithms [21]. Clinical trial registries also benefited from employing HL7 FHIR as a data storage and exchange format. Utilizing FHIR resources, the results have established a harmonized view of study information from heterogeneous sources in a standardized way, increasing medical research transparency by making information and results of planned, ongoing, and completed studies publicly available [22].

RQ2: What are the potentials of FHIR in the future?

The advent of the FHIR standard will bring significant advancements to reliability and standardization. In addition, FHIR will empower researchers and application developers to access enormous volumes of interoperable data. In this context, shortly, we would consider the healthcare system as a place where science, administration, and informatics are aligned for continuous improvement and innovation.

Therefore, we must become accustomed to considering these secure systems of medical data exchange, not as the concept of interoperability in healthcare using FHIR, but as improving interoperability in healthcare using FHIR. The technology behind FHIR represents a significant step forward from a "paper-data-centric" approach to a data level. The FHIR-based standard will provide exchanging health care data faster and in a more effective way.

Furthermore, health industry leaders and policymakers are increasingly interested in building great interoperability between and among health IT systems. In this scenario, interoperability would not be just a resource for patients and the health system more generally in the upcoming years. Still, it will represent an essential part of economic development and research in computer engineering.

5. CONCLUSION

The HL7 healthcare standards organization created the FHIR standard. HL7 provides a connection between healthcare, engineering, and information technology. It deals with almost all functional domains of the healthcare system, including patient management, administration, and observation reporting. FHIR is a standard describing data formats and elements, known as resources, and an application programming interface for exchanging EHRs. It uses resources to access and perform operations on health data at granular levels.

From an informatics perspective, a learning health system needs data and the ability to access them. This, in turn, requires the widespread implementation of EHRs systems, the ability of those systems to represent the data they keep in a standardized way, and universally supported tools of accessing those standardized data for patient care, research, and other relevant scopes.

FHIR is a reliable alternative to outdated document-centric methods by directly exposing discrete data elements as services. The results of this technology are beneficial, especially for chronic patients that require care assistance from many specialist physicians, regardless of the location of the hospital or medical center in which they receive health care. However, in this pandemic period, the sill not widespread technique represented an unmet need for clinicians and patients. For this reason, the FHIR Business Alliance developed an open-source COVID-19 focused pandemic toolkit that enables people to get information, report their status, and track their movements [18].

This systematic literature review does not address any issues related to patient privacy, security, or authentication is a potential limitation of this study. The goal was to evaluate the usability and capabilities of HL7 FHIR to design and implement interoperable personal medical data. The review is also limited to the articles published in the English language and searched two databases, PubMed and Web of Science only. Nevertheless, our study can be of interest to researchers and health professionals to address This systematic literature review does not address any issues related to patient privacy, security, or authentication is a potential limitation of this study. The goal was to evaluate the usability and capabilities of HL7 FHIR to design and implement interoperable personal medical data. The review is also limited to the articles published in the English language and searched two databases, PubMed and Web of Science only. Nevertheless, our study can be of interest to researchers and health professionals to address the current interest in FHIR in the scientific community and its potential impact on digital health.

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