Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 220 (2023) 856–861

Procedia Computer Science

www.elsevier.com/locate/procedia

The 4th International Workshop on Hospital 4.0 (Hospital),
March 15 - 17, 2023, Leuven, Belgium

Interoperability of Clinical Data through FHIR: A review

Nuno Pimenta[a], António Chaves[a], Regina Sousa[a], António Abelha[a], Hugo Peixoto[a,*]

[a]ALGORITMI/LASI, University of Minho, Braga, Portugal

Abstract

Interoperability of clinical data remains an issue in healthcare despite technology advancements. FHIR, Fast Healthcare Interoperability Resources, is a standard for electronic exchange of healthcare data that is built on web standards, flexible, user-friendly and easy to implement. This research aims to assess FHIR's potential as a solution for interoperability by identifying critical components of FHIR that can improve interoperability and bridge the gap between healthcare systems and sources of clinical data. By leveraging FHIR as a standard, healthcare professionals are able to more effectively communicate and access patient information leading to better patient care and more efficient clinical operations.

Keywords: Interoperability; HL7; FHIR; Clinical Data

1. Introduction

The health care industry is a data-intensive one, with massive volumes of data and information created, accessed, and transferred on a daily basis [1]. The application of digital technology capabilities in the manipulation of such large amounts of data could improve disease prevention, promote engagement between different levels of care, support care providers, and improve productivity and quality by enabling new ways of facilitating information flow, thereby promoting more integrated and responsive services [2].

Despite advancements in health information technology and increased use of electronic systems, one of the major impediments is a lack of regulation that allows healthcare providers to select their Electronic Health Record (EHR) system based on technical, operational, economic, and legal criteria [3]. This often results in segregated patient records in institution-centric EHRs, resulting in information fragmentation [4] with effects ranging from ineffective treatment to a lack of crucial information during crises [1, 5]. In fact, according to a 2016 BMJ report [6], medical errors are the third highest cause of mortality, with 44% of medical error fatalities preventable.

* Corresponding author. Tel.: +253 510 180
E-mail address: hpeixoto@di.uminho.pt

10.1016/j.procs.2023.03.115

Proper treatment of a patient is only possible when healthcare practitioners have access to the most up-to-date and comprehensive collection of personal and clinical data. As a result, healthcare interoperability is critical to achieving excellence in care, as it refers to the ability of various healthcare technology systems to meaningfully transmit information with one another, within or across organizational boundaries [7]. Large clinical datasets may be generated by diverging from isolated data silos, increasing the possibility of health data secondary usage for research collaborations and enhancing patient care [8, 9, 10]. As a consequence, healthcare professionals' job and patients' quality of life increase, as more effective treatments result in better clinical outcomes [11].

Although syntactic and semantic interoperability between different health information systems remains difficult in some cases, an emerging standard based on modern web technologies, such as Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR), may aid in addressing interoperability concerns [12]. FHIR takes a modular approach, with granular information represented as separate modular entities called Resources. This basic item can be viewed as a single healthcare Lego® brick. Similar to plastic building toys, multiple FHIR Resources are combined, for example, to form a message to be transmitted with patient data or to construct an EHR [8]. These units may be utilized alone, expanded, or coupled with others to meet the vast majority of clinical use cases, overcoming the inherent unpredictability of healthcare without steadily increasing costs and complexity [13]. APIs, a set of well-defined interfaces to interoperate applications [14] and Representational State Transfer (RESTful) web services generate, manage, and distribute these Resources [7].

As Vorisek et al. 2022 [15] observed, there has been a growth in the adoption of FHIR in recent years, with distinct application objectives, including data standardization, data collecting, recruiting, analysis, and consent management. Furthermore, it is worth noting the 5-year gap between the release of the FHIR standard and the first publication of interest regarding it, as well as the fact that Germany and the United States had the largest number of publications. In this regard, the authors argue that the increased occurrence is mostly attributable to previous initiatives and regulatory measures implemented in such nations, underlining the critical importance of regulatory legislation and guidelines in improving interoperability.

The purpose of this work is to present a not-to-exhaustive review approach to FHIR, namely by identifying some of its points of appliance and giving illustrative examples.

2. Methods

The current research included three data sources: Scopus and Springer, which specialize in health information, and Google Scholar, a multidisciplinary platform. The first two search engines indicated were picked with the goal of obtaining more technical and specialist works - thus more suited to the offered work subject - and the latter was chosen with the goal of broadening the diversity of thoughts and issues investigated.

The query phrases used were ”health FHIR interoperability communication”, ”health FHIR interoperability”, ”health FHIR security”, ”application FHIR security”, and ”security FHIR communication”. To reduce the chosen studies for the required scope, the results were largely organized by relevance, using the methodologies of the own search engines, and the main eligibility criteria were defined: (i) open or unrestricted access, (ii) written in English, and (iii) publication year equal to or greater than 2017. The first analysed aspects for each returning scientific paper were the title, abstract, and keywords. When these criteria were insufficient, a thorough reading of each paper was used to determine its inclusion.

The analysis of the flow of information throughout the various phases of publications—the identification, screening, eligibility assessment, and inclusion processes—was partially guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [16], particularly in its diagram flow for representing the selection process of the further head analysed scientific publications. Figure 1 demonstrates the steps necessary to arrive at the final set of included studies. 96 papers were found through database searches, including 33 from Google Scholar, 54 from Scopus, and 9 from Springer. There were no other database sources used, and the screening was performed concurrently with the database's returned results processing. The screening procedure included removing duplicate entries at the source (a component that differed from the PRISMA Statement) and excluding articles whose abstracts clearly revealed extraneous and unrelated topics. In fact, with regard to Scopus and Springer, some of the returned results were repeated, which supports the apparent decreased preselection of studies from Springer, which was used for searching after Scopus. Finally, 61 records were eliminated from the 96 screened articles because they did not fit the inclusion criteria: no open access, outside of the set time, no explicit focus on healthcare, ontology building or matching, or complete paid book. An additional 23 articles were rejected from the 35 full-text papers reviewed and appraised for eligibility for the following reasons: only practical approach over FHIR, repetitive approach, non-relevant approach, or FHIR Queries focus exclusively. As a result, 12 publications were further examined and discussed.

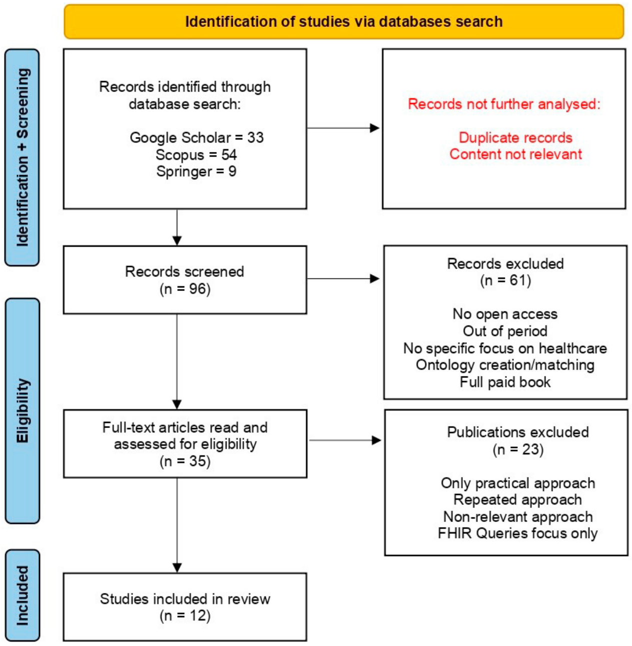

Fig. 1. Schematic representation of the implemented flow diagram for the studies selection.

3. Results

All of the studies offered depict advances and examples of FHIR application sectors. The selected scientific articles, represented in Table 1, cover many aspects of FHIR's application, such as data standards, FHIR API implementation, data analysis, clinical trial enrollment, among others.

The lack of interoperability measures has hampered the use of clinical trial recruiting assistance systems in a broader range of scenarios. As important clinical information and eligibility criteria are appraised in data provided in FHIR Resources, the authors of Scherer et al. 2022 [17] set out to create a recruitment assistance system based on FHIR. Screening for eligible patients may be done more quickly and efficiently by using FHIR Resources, a standard data format. The clinical trial was documented in the FHIR *ResearchStudy* Resource components, sets of rules were developed, and patients are evaluated for trial eligibility based on information on the patients' FHIR Resources upon user demand.

While the Brazilian state health system promotes OpenEHR as the main EHR information model, private providers in Brazil have selected the HL7 FHIR standard. Given this, Gomes et al. 2019 [14] set out to create a low-cost gateway for EHR interoperability that makes use of both standards, allowing semantic interoperability across disparate systems. The goal is to create a platform that acts as an integration hub and a data server, through which all communication goes, allowing communication between systems that adhere to different standards. The platform contains an API gateway that acts as an endpoint for data exchange across various networks, as well as an FHIR Broker that is in charge of mapping and processing data from proprietary structures into the FHIR standard.

Hong et al. 2018 [18] introduced the *MedicationStatement* FHIR Resource, a framework for modulating structured and unstructured data from a clinic's EMR into a consistent and compatible format. Natural Language Processing

Table 1. Selected FHIR-related studies.

Authors	Title	Year	FHIR Application
Scherer et al. [17]	Implementation of a Clinical Trial Recruitment Support System Based on Fast Healthcare Interoperability Resources (FHIR) in a Cardiology Department	2022	Clinical trial recruitment support system definition, as both clinical trial eligibility criteria and patient health data are defined in FHIR Resources
Gomes et al. [14]	GIRLS, a Gateway for Interoperability of electronic health Record in Low-cost System: Interoperability between FHIR and OpenEHR Standards	2019	FHIR Resources used for structuring data and allowing Brazilian-nationwide services communication
Hong et al. [18]	Integrating Structured and Unstructured EHR Data Using an FHIR-based Type System: A Case Study with Medication Data	2018	MedicationStatement FHIR Resource as standard data model and HAPI FHIR used for serialization of NLP output into JSON or XML
Gruendner et al. [19]	KETOS: Clinical decision support and machine learning as a service – A training and deployment platform based on Docker, OMOP-CDM, and FHIR Web Services	2019	FHIR applied for standardizing heterogenous hospital data prior to statistical analysis and creation of decision support systems
Hidayat et al. [20]	A Preliminary Implementation of HL7 FHIR to Achieve Interoperability in Indonesia's Local EHR	2020	FHIR Resources used to standardly represent data comprehended in Indonesian EHRs
Zampognaro et al. [21]	Definition of an FHIR-based multiprotocol IoT home gateway to support the dynamic plug of new devices within instrumented environments	2021	FHIR Adapter established to convert certain types of devices data into Resources
Semenov et al. [22]	Experience in Developing an FHIR Medical Data Management Platform to Provide Clinical Decision Support	2019	FHIR format as the accepted entering format for the clinical decision support system
Lee et al. [23]	Implement an International Interoperable PHR by FHIR—A Taiwan Innovative Application	2020	FHIR Resources as a standard data model and HAPI FHIR used for format validation
Storck et al. [12]	Interoperability improvement of Mobile Patient Survey (MoPat) implementing fast health interoperability resources (FHIR)	2019	FHIR Questionnaire Resource used for standard metadata import and clinical data export
Kiourtis et al. [24]	Health information exchange through a Device -to-Device protocol supporting lossless encoding and decoding	2022	A diverse number of FHIR Resources structure data exchange in offline data transaction through a device-to-device messaging protocol
Xu et al. [25]	FHIR PIT: an open software application for spatiotemporal integration of clinical data and environmental exposures data	2020	FHIR Resources represent data used for environmental exposures analysis and study of its effect on health
Scheible et al. [26]	AHD2FHIR: A Tool for Mapping of Natural Language Annotations to Fast Healthcare Interoperability Resources – A Technical Case Report	2022	Presenting NLP-resulting text analysis in FHIR format

(NLP) technologies were utilized to identify clinical aspects as two distinct modeling workflows: one for unstructured data and another for merging the output of the first workflow with structured data, resulting in the creation of a full FHIR Resource. A rule-based method implemented in HAPI FHIR, a java-based open-source implementation of the HL7 FHIR standard [27], was outlined for allocating NLP output types to the relevant and desirable FHIR components in the clinical NLP pipeline. Although it received favorable outcomes, the authors mention the fact that FHIR's standardization effort is ongoing as a continuing quest.

Furthermore, Gruendner et al. 2019 [19] saw a lack of a platform that would allow researchers to undertake statistical studies and deploy the derived models in a safe hospital setting. As a result, they created a system for doing data analysis, training, and deploying decision support models in a hospital or healthcare context using standardized input data. Given that high quality standardized data is essential to implement accurate models, the developed FHIR Server works as a critical pre-processing service prior to analysis by turning hospital data - generally heterogeneous - into FHIR Resources. After building models with thisstructured data, they are installed within a hospital's IT infrastructure and may be invoked by a professional-facing app. It should be highlighted that one of the linked restrictions is the previously described FHIR Resource preparation, which is regarded the primary bottleneck for performance, since several rest calls and merging of the JSON FHIR Resources required the most time.

Hidayat et al. 2020 [20] intended to enforce an EHR client-server prototype to simulate health data transfer in Indonesian EHRs systems, utilizing FHIR Resources and REST API, mapping EHR components to FHIR Resources elements, and resorting to profiling to further meet the requirements of Indonesian health centers; Zampognaro et al. 2021 [21] characterized a smartphone-based Internet of Things (IoT) Home Gateway design that allows devices, such as sensing devices and smartphones, to continue to stick to their own protocol, while also establishing interoperability and heterogeneous communication, because their native format is always converted to FHIR Resource by an FHIR Adapter; Semenov et al. 2019 [22] predefined FHIR format as the input structure for their clinical decision-making system and uses this format to collect information into the stated internal Rule Engine; Lee et al. 2020 [23] developed an interoperable FHIR-based Personal Health Record (PHR) translation method that transforms and saves medical data as FHIR Resources, with conversion validation performed by HAPI FHIR Server; in Storck et al. 2019 [12], an electronic patient reported outcome system Mobile Patient Survey (MoPat) was tailored to sustain metadata import and clinical data transfer using FHIR, where MoPat questionnaire data model fields were mapped to FHIR *Questionnaire* Resource elements, resulting in a wider variety of options and types in the FHIR format; Kiourtis et al. 2022 [24] investigated an alternative to the multiple methods for transferring data without internet connection, offering a device-to-device offline short-range distances protocol and leveraging HL7 FHIR Resources to format healthcare data; Xu et al. 2020 [25] observed a lack of attention concerning environmental exposures data and its influential role in health and diseases, so the researchers designed an application to facilitate studies of the health impact of these exposures, and FHIR Resources performed the function of representing data (particularly geocodes, which are important for the needed spatiotemporal data analysis); and finally, Scheible et al. 2022 [26] introduced a server-based software capable of accepting clinical text, transmitting it to a German-language medical NLP engine, and returning the text analysis results to the client as FHIR Resources.

4. Conclusions

Naturally, national and international terminologies and standards are required by software systems when managing scientific data between health-related institutions. Throughout this review, it is possible to notice that FHIR has a wide range of application areas, and it is believed that other areas must exist besides those mentioned in this review.

From assisting in the recruitment of people for clinical trials to presenting itself as a format of choice in the standardization of data stored and communicated in processes inherent to health care, collaboration on large-scale data research is facilitated, and integration at the local, regional, national, and international levels is more readily resolved. Furthermore, systems, communication, and frameworks become easier, since the translation and correspondence between distinct data representations are no longer required. Furthermore, with connected medical devices and enhanced electronic health information exchange, healthcare practitioners may manage clinical evidence, communicate, and evaluate it, eventually improving patient information coordination and care processes.

Essentially, interoperability has become a must, rather than a choice in healthcare. Reusing health-related data allows for a broader picture of real-world patient populations, better understanding illness demographic and socioeconomic patterns, enrolling patients for clinical trials, analyzing therapeutic efficacy, and long-term monitoring, among other things. As previously said, FHIR has its applicability in all of these domains, particularly in terms of interoperability characteristics, and that provides a remarkable value to the standard.

Acknowledgements

This work has been supported by FCT—Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

References

[1] R. H. Hylock, X. Zeng, A blockchain framework for patient-centered health records and exchange (healthchain): Evaluation and proof-of-concept study, J Med Internet Res 21 (8) (2019).

[2] M. Rosa, C. Faria, A. M. Barbosa, A. I. Martins, A. F. Almeida, N. P. Rocha, A platform of services to support community-dwelling older adults integrating fhir and complex security mechanisms, Procedia Computer Science 160 (2019) 314–321.

[3] S. K. Mukhiya, Y. Lamo, An hl7 fhir and graphql approach for interoperability between heterogeneous electronic health record systems, Health Informatics Journal 27 (3) (2021).

[4] J. Machado, A. Abelha, J. Neves, M. Santos, Ambient intelligence in medicine, in: 2006 IEEE Biomedical Circuits and Systems Conference, 2006, pp. 94–97.

[5] S. N. Kasthurirathne, B. Mamlin, H. Kumara, G. Grieve, P. Biondich, Enabling better interoperability for HealthCare: Lessons in developing a standards based application programing interface for electronic medical record systems, Journal of Medical Systems 39 (11) (2015).

[6] M. A. Makary, M. Daniel, Medical error—the third leading cause of death in the us, BMJ 353 (2016).

[7] R. Saripalle, C. Runyan, M. Russell, Using hl7 fhir to achieve interoperability in patient health record, Journal of Biomedical Informatics 94 (2019).

[8] R. K. Saripalle, Leveraging FHIR to integrate activity data with electronic health record, Health and Technology 10 (1) (2019) 341–352.

[9] M. Rosa, C. Faria, A. M. Barbosa, H. Caravau, A. F. Rosa, N. P. Rocha, A fast healthcare interoperability resources (fhir) implementation integrating complex security mechanisms, Procedia Computer Science 164 (2019) 524–531, cENTERIS 2019 - International Conference on ENTERprise Information Systems / ProjMAN 2019 - International Conference on Project MANagement / HCist 2019 - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS/ProjMAN/HCist 2019.

[10] Y. Petrakis, A. Kouroubali, D. Katehakis, A mobile app architecture for accessing emrs using xds and fhir, in: 2019 IEEE 19th International Conference on Bioinformatics and Bioengineering (BIBE), 2019, pp. 278–283.

[11] N. Pimenta, R. Sousa, H. Peixoto, J. Machado, A comprehensive study on personal and medical information to predict diabetes, in: S. Omatu, R. Mehmood, P. Sitek, S. Cicerone, S. Rodríguez (Eds.), Distributed Computing and Artificial Intelligence, 19th International Conference, Springer International Publishing, 2023, pp. 197–207.

[12] M. Storck, L. Hollenberg, M. Dugas, I. Soto-Rey, Interoperability improvement of mobile patient survey (mopat) implementing fast health interoperability resources (fhir), Studies in Health Technology and Informatics 258 (2019) 141 – 145.

[13] Y. Aliakbarpoor, S. Comai, G. Pozzi, Designing a hl7 compatible personal health record for mobile devices, in: 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI), 2017, pp. 1–6.

[14] F. Gomes, R. Freitas, M. Ribeiro, C. Moura, O. Andrade, M. Oliveira, GIRLS, a gateway for interoperability of electronic health record in low-cost system : Interoperability beetween FHIR and OpenEHR standards, in: 2019 IEEE International Conference on E-health Networking, Application &amp Services (HealthCom), IEEE, 2019.

[15] C. N. Vorisek, M. Lehne, S. A. I. Klopfenstein, P. J. Mayer, A. Bartschke, T. Haese, S. Thun, Fast healthcare interoperability resources (fhir) for interoperability in health research: Systematic review, JMIR Medical Informatics 10 (7) (2022).

[16] Prisma statement, https://www.prisma-statement.org/PRISMAStatement/PRISMAStatement, accessed: 11-01-2023.

[17] C. Scherer, S. Endres, M. Orban, S. Kääb, S. Massberg, A. Winter, M. Löbe, Implementation of a clinical trial recruitment support system based on fast healthcare interoperability resources (FHIR) in a cardiology department, in: Studies in Health Technology and Informatics, IOS Press, 2022.

[18] N. Hong, A. Wen, F. Shen, S. Sohn, S. Liu, H. Liu, G. Jiang, Integrating structured and unstructured ehr data using an fhir-based type system: A case study with medication data, AMIA Joint Summits on Translational Science proceedings. AMIA Joint Summits on Translational Science 2017 (2018) 74–83.

[19] J. Gruendner, T. Schwachhofer, P. Sippl, N. Wolf, M. Erpenbeck, C. Gulden, L. A. Kapsner, J. Zierk, S. Mate, M. Stürzl, R. Croner, H. . Prokosch, D. Toddenroth, Ketos: Clinical decision support and machine learning as a service – a training and deployment platform based on docker, omop-cdm, and fhir web services, PLoS ONE 14 (10) (2019).

[20] I. F. Hidayat, B. R. Hermanto, A preliminary implementation of hl7 fhir to achieve interoperability in indonesia's local ehr, in: 2020 27th International Conference on Telecommunications (ICT), 2020, pp. 1–5.

[21] P. Zampognaro, G. Paragliola, V. Falanga, Definition of an FHIR-based multiprotocol IoT home gateway to support the dynamic plug of new devices within instrumented environments, Journal of Reliable Intelligent Environments 8 (4) (2021) 319–331.

[22] I. Semenov, R. Osenev, S. Gerasimov, G. Kopanitsa, D. Denisov, Y. Andreychuk, Experience in developing an fhir medical data management platform to provide clinical decision support, International Journal of Environmental Research and Public Health 17 (1) (2020).

[23] Y.-L. Lee, H.-A. Lee, C.-Y. Hsu, H.-H. Kung, H.-W. Chiu, Implement an international interoperable phr by fhir—a taiwan innovative application, Sustainability (Switzerland) 13 (1) (2021) 1 – 17.

[24] A. Kiourtis, A. Mavrogiorgou, D. Kyriazis, Health information exchange through a device-to-device protocol supporting lossless encoding and decoding, Journal of Biomedical Informatics 134 (2022).

[25] H. Xu, S. Cox, L. Stillwell, E. Pfaff, J. Champion, S. C. Ahalt, K. Fecho, FHIR PIT: an open software application for spatiotemporal integration of clinical data and environmental exposures data, BMC Medical Informatics and Decision Making 20 (1) (2020).

[26] R. Scheible, D. Caliskan, P. Fischer, F. Thomczyk, S. Zabka, H. Schneider, M. Boeker, S. Schulz, H.-U. Prokosch, C. Gulden, AHD2fhir: A tool for mapping of natural language annotations to fast healthcare interoperability resources – a technical case report, in: MEDINFO 2021: One World, One Health – Global Partnership for Digital Innovation, IOS Press, 2022.

[27] A. Chatterjee, A. Prinz, Representation of personal and person-generated data with HL7 FHIR and HAPI endpoint security with TSD: Proof-of-concept study (2021).