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Procedia Computer Science 219 (2023) 1249–1256

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022

The Fast Health Interoperability Resources (FHIR) Standard and Homecare, a Scoping Review

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Abstract

The scoping review reported by this article aimed to analyze the state of the art of the use of Fast Health Interoperability Resources (FHIR) in the development of homecare applications and was informed by the following research questions: (i) what type of homecare applications benefit from the use of FHIR?; (ii) what FHIR resources are being implemented?; (iii) what publicly available development tools are being used?; and (iv) how privacy and security issues are being addressed? An electronic search was conducted, and 27 studies were included in the scoping review after the selection process. The results show a current interest in using FHIR to implement: i) applications to provide interoperable measurement devices for home monitoring; (ii) applications to remotely collected Patient Reported Outcome Measures (PROM); (iii) Personal Health Records (PHR); and (iv) specific applications for self-management. According to the results, the FHIR resources being implemented are quite diverse and contribute for the challenge of handling the variability caused by diverse healthcare processes. However, the use of publicly available development tools (e.g., SMART on FHIR or HAPI) is not yet generalized. Moreover, just a small number of studies reported the validation of the implemented resources using publicly available FHIR validators. Finally, in terms of privacy and security issues, different approaches were identified: authentication and authorizations mechanisms, end-to-end encrypted messaging mechanisms, and decentralized management and audit trail based on blockchain technologies.

Peer-review under responsibility of the scientific committee of the CENTERIS – International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022

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Peer-review under responsibility of the scientific committee of the CENTERIS – International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022
10.1016/j.procs.2023.01.408

Keywords: Homecare; Interoperability; FHIR; Fast Health Interoperability Resources; Scoping Review.

1. Introduction

Currently, extensive research is focused on the development of a wide range of products or services based on information technologies to support homecare. It is generally accepted that these solutions might support patients with chronic conditions, namely in terms of home monitoring, self-management, or adherence to treatments [1,2]. However, the efficiency and efficacy of these digital solutions are dependent of the degree of their interoperability with other healthcare information systems, which, in general, constitutes an issue requiring further developments [3].

During the last years, Health Level Seven International (HL7) Fast Health Interoperability Resources (FHIR) has gained popularity and has been increasingly adopted by the healthcare industry to guarantee the interoperability of information systems [4]. FHIR presents a more flexible approach towards interoperable systems when compared to its predecessors HL7v2 and HL7v3 [5].

FHIR resources correspond to generic definitions of common healthcare concepts (e.g., patient, observation, practitioner, device, condition) and constitute the basic building blocks of FHIR. The FHIR resources might be implemented according to a Representational State Transfer (REST), which means that their access might be performed using RESTful Application Programming Interfaces (API).

Although there are reviews and surveys studying the application of FHIR (e.g., [4,6,7]), none of them was focused on homecare. In this context, the scoping review reported by this article aimed to analyze the state of the art of the use of FHIR in the context of the development of applications to support homecare and, therefore, to complement other reviews addressing other aspects of the implementation of FHIR.

After this first section with the introduction, the rest of the paper is organized as follows: the methods that were applied and the respective results, and, finally, a discussion and conclusion.

2. Methods

Considering the research objective of analyzing the current use of FHIR in the context of homecare applications, the following research questions (RQs) were formulated:

- RQ1 - what type of homecare applications benefit from the use of FHIR?
- RQ2 - what FHIR resources are being implemented?
- RQ3 - what publicly available development tools are being used?
- RQ4 - how privacy and security issues are being addressed?

After the identification of the research questions a research protocol was specified to define the process to select the studies to be included (i.e., data sources, search queries, inclusion/exclusion criteria, and selection steps), as well as the synthesis and reporting processes.

2.1. Selection of the Studies

Scopus, Web of Science and PubMed were the selected databases. Boolean queries were prepared to include all the articles that have in their titles, abstract or keywords on the following expressions: "Fast Healthcare Interoperability Resources" or "FHIR".

As inclusion criteria, the authors aimed to include peer-reviewed studies that reported evidence of the use of FHIR to implement digital solutions to support homecare. The exclusion criteria were defined to exclude references that: (i) did not have abstracts or authors' identification; (ii) were not written in English; (iii) their full texts were not available; (iv) reported on reviews or surveys; (v) were books, tutorials, editorials, special issues announcements, extended abstracts, posters, panels, transcripts of lectures, workshops, and demonstration materials; (vi) reported on studies already covered by other references (i.e., when two references reported on the same study in different venues, such as scientific journal and conference, the less mature one should be excluded); and (vii) reported on studies that are not relevant for the objective of this scoping review.

The selection of the studies to be included in this scoping review was performed according to the following steps: (i) first step, the authors removed the duplicates, the references without abstract or authors, references not written in English, and references reporting on reviews or surveys; (ii) second step, the authors assessed all titles and abstracts for relevance and those clearly not meeting the inclusion and exclusion criteria were removed; and (iii) third step, the authors assessed the full text of the remaining references against the outlined inclusion and exclusion criteria to achieve the list of the references to be included in this scoping review (i.e., the included studies).

2.2. Synthesis and Reporting

The included studies were analyzed in terms of (i) their demographic characteristics, (ii) purposes of the applications being developed, and (iii) characteristics of the technological developments.

Concerning the demographic characteristics of the included studies, a synthesis was prepared considering (i) the number of studies published in scientific journals and conference proceedings; (ii) the distribution of the studies according to their publication years; and (iii) the distribution of the studies by geographical areas, according to the affiliation of the first author.

Since the objective of this scoping review was to analyze the state of the art of the use of FHIR in the context of homecare applications, a synthesis of the purposes of the studies was prepared, which included the aims of the respective homecare applications, as well as the motivations for using FHIR.

Finally, in terms of the characteristics of the technological developments, an analysis and a synthesis were performed to identify (i) the FHIR resources that were implemented, (ii) the publicly available development tools that were used, and (iii) how privacy and security issues were addressed.

3. Results

3.1. Selection of the Studies

The search of the studies to be included in this scoping review was conducted in April 2022. A total of 1343 references was retrieved from the initial search: (i) 599 references from Scopus; (ii) 394 references from Web of Science; and (iii) 350 references from PubMed.

Table 1 presents the results of the three steps of the studies' selection. The initial step of the screening phase yielded 594 references by removing duplicates, references without abstracts or authors, references not written in English, and references reporting on reviews or surveys. Based on titles and abstracts, 545 references were removed since they reported on studies not relevant for the specific objective of this scoping review. Finally, the full texts of the remaining 49 references were screened and 22 were excluded because they did not meet the outlined inclusion and exclusion criteria. Specifically, five of them [8-12] were excluded because they report on studies also reported by more recent articles that were considered for inclusion. Therefore, 27 studies were considered eligible for this scoping review [13-39].

3.2. Demographics Characteristics of the Studies

In terms of publication types, 14 studies [13,18,20,22,26,31-39] were published in scientific journals, being the remainder 13 [14-17,19,21,23-25,27-30] published in conference proceedings. The included studies were published between 2015 (i.e., two studies) and 2022 (i.e., one study), but most of the studies (i.e., 24 studies) were published during the last four years.

In terms of geographical distribution, Europe has the highest contribution, with 13 studies (i.e., Austria, three studies [13,17,18], Germany, two studies [30,33], Greece, two studies [22,28], Italy, two studies [15,32], Norway, two studies [19,21], and Spain, also two studies [31,39]). In turn, Asia has contributed with seven studies (i.e., South Korea, four studies [16,20,25,37], India, one study [14], Japan, one study [35], and Twain, one study [36]), and North America (i.e., United States) has contributed with five studies [24,26,29,34,38]. Finally, South America and Oceania have contributed with one study each (i.e., Brazil, one study [27], and Australia, one study [23]).

Table 1. Number of references removed during the three screening phases.

First screening phase		Number
	Duplicates	660
	Without abstract or authors	60
	Reviews or surveys	29
	Number of articles excluded in the first screening phase	749
Second screening phase		
	Number of references excluded in the second screening phase since they were out of scope	545
Third screening phase		
	Extended abstracts	6
	Not written in English	1
	Without access to the full text	1
	Out of scope	9
	Reported on studies covered by other articles	5
	Number of articles excluded in the third screening phase	22
Inclusion		
	Number of articles included in the review	27

3.3. Purposes of the Studies

All the included studies were focused on the development of applications to support homecare, although four different categories were identified: (i) applications to provide interoperable measurement devices for home monitoring; (ii) applications to remotely collect Patient Reported Outcome Measures (PROM); (iii) Personal Health Records (PHR); and (iv) specific applications for self-management.

Considering that recent concepts such as Internet of Things (IoT) or Internet of Medical Things (IoMT) present a great potential to increase the efficiency of healthcare provision if data interoperability is guaranteed, ten of the included studies [13,14,17,18,20,22,24,32,33,39] developed standardized approaches supported on FHIR for the integration of data from different measurement devices, including devices to measure weight [13,18,20,22,32], blood pressure [13,14,18,20,22,32,39], heart rate [13,14,17,20], blood glucose [13,18,20,22], blood oxygen saturation [14,22,39], body temperature [14,32,39] and Electrocardiogram (ECG) [33], or to track activity [17,18,22,24] and sleep behavior [17]. All these studies present a technological perspective highlighting the efforts to integrate different technologies. Moreover, all the studies provided generic solutions that are independent of specific pathologies, although article [20] referred the interest in supporting type 1 diabetes patients.

PROM are important instruments to evaluate the progress of the patients and ensure their follow up if required. Three studies [21,29,30] proposed applications supported on FHIR to remotely collect PROM. Two studies [29,30] did not specify what PROM are being considered. In turn, one study [21] was focused on the implementation of a prototype to follow mental health problems, using instruments such as Montgomery-Asberg Depression Rating Scale (MADRS), Patient Health Questionnaire-9 (PHQ-9), Major Depression Inventory (MDI), Generalised Anxiety Disorder Assessment (GAD-7), and Adult Attention-Deficit/Hyperactivity Disorder (ADHD).

Twelve studies [15,16,19,23,25-28,35-38] are related to the development of interoperable PHR or to the integration of PHR in healthcare provision ecosystems. Five of these studies [15,16,26,35,38] describe the implementation of generic PHR, supported on FHIR: article [15] presents an Android based PHR; article [16] examined the limitations of current PHR and proposes a PHR system connected to an IoT cloud platform; article [26] describes the design and prototype an interoperable mobile PHR that allows bi-directional communication with OpenEMR; article [35] focuses on a PHR application to present FHIR data; and article [38] presents an application that allows patients to access their data and to share that access. Moreover, four studies [19,23,25,37] are focused on the implementation of special purpose PHR: a PHR for mental health patients [19]; a PHR to integrate different data sources to build a predictive model for fall prevention [23]; a PHR to support the recording of medication history integrating blockchain technology [25]; and a worker centered PHR [37]. In addition, three studies are related to the interconnection of PHR and healthcare ecosystems [27,28,36]: article [27] presents a blockchain-based health records for the storage of partial electronic medical records using FHIR; article [28] presents an interoperability infrastructure to enable citizens to use a PHR of their choosing for accessing their own medical record information stored at multiple sites; and article [36] describes a FHIR-based PHR transformation process to bridge the interoperability gap between different PHR.

Finally, two studies [31,34] are focused in self-management applications. Article [31] introduced a chatbot architecture for chronic patient support that includes an automation mechanism to convert FHIR resources into Artificial Intelligence Markup Language (AIML) files, thus facilitating the interaction and data gathering of medical and personal information that ends up in patient health records. In turn, [34] describes an application to track COVID-19 symptoms (e.g., fever or cough), risk factors (e.g., age or comorbidities) and possible exposures (e.g., recent travel).

3.4. Characteristics of the Technological Developments

The FHIR community has defined more than 150 resources [4], which were divided into five major categories: (i) administrative (e.g., location, organization, device, patient, or group); (ii) clinical (e.g., care plan, diagnostics, medication, allergy, or family history); (iii) financial (e.g., billing, payment or support); (iv) infrastructure (e.g., conformance, document, or message profile); and (v) workflow (e.g., encounter, scheduling or order). As a result of the analysis of the included studies, it is possible to conclude:

- Five studies did not specify what FHIR resources were used [16,23,27,33,38].
- Three studies only used the FHIR Observation resource [17,18,22].
- Six studies were focused on the use of the FHIR Observation resource, but considered additional resources: Device [13,39]; Device and DiagnosticReport [14]; CarePlan [15]; Patient, Device and CarePlan [20]; and Device and DeviceDefinition [32].
- One study used the Medication FHIR resource [25].
- Two studies were focused on the use of the FHIR resources Questionnaire and QuentionnaireResponse, but considered additional resources: Observation and Patient [21]; Observation and Device [29].
- One study used the FHIR resources Patient and DocumentReference [28]
- One study developed an extended FHIR resource to capture patients' physical activity and exercise data [24].
- Eight studies used comprehensive sets of FHIR resources [19,26,30,31,34-37].

Looking specifically the studies reporting the use of comprehensive sets of FHIR resources the following FHIR resources were identified: (i) Observation, CarePlan, EpisodeOfCare, Procedure and Condition [19]; (ii) Observation, Patient, AllergyIntollerance, Medication, Encounter, Procedure and Condition [26]; (iii) Patient, Organization, PlanDefinition, CarePlan, Activity, Questionnaire and QuestionnaireResponse [30]; (iv) Patient, RelatedPerson, Practitioner, Organization, Appointment, CarePlan, Questionnaire and QuestionnaireResponse [31]; (v) Patient, PlanDefinition, CarePlan, Activity, Questionaire and QuestionnairResponse [34]; (vi) Observation, Patient, Encounter, Condition, AllergyIntollerance, Coverage, Organization, Practitioner, DiagnosticReport, ServiceRequest, Medication, MedicationRequest and MedicationDispense [35]; (vii) Observation, Patient, Encounter, Condition, Organization, Procedure, MedicationRequest, AlleregyIntollerance and Immunization [36]; and (viii) Observation, Patient, Condition, Appointment, Consent, Practitioner, Organization, DiagnosticReport, Procedure, and Medication [37].

Concerning the publicly available development tools being used to support the implementation of FHIR, five studies [21,28,29,33,34] referred the use of SMART on FHIR, while seven studies [17,25,26,35-38] referred the use of HAPI. Notably, only three articles [17,29,39] reported the use of FHIR validators to validate the FHIR resources being implemented.

Finally, analyzing how the studies dealt with privacy and security related concerns, it is possible to conclude that six studies [17,18,25,28,33,35] did not mention any effort to deal with these issues, while seven studies [13,15,20,22,24,26,39] clarified that these concerns were not taken into account, although they might be considered in future work. Moreover, different approaches were identified in the remainder studies.

First, nine studies [16,19,21,29,31,32,34,36,38] implemented authentication and authorization mechanisms: (i) the solution reported by [16] is supported by the security mechanisms provided by the ARTIK Cloud; (ii) in [19] a FHIR interceptor was implemented to handle users authorization to access FHIR resources; (iii) [21,34] reported the use of authorization servers to authenticate users and grant authorizations; (iv) the solution reported by [29] was based on the resources provided by SMART on FHIR; (v) [31] reported the implementation of and authorization server supporting finer-grained way using the eXtensible Access Control Markup Language (XACML) framework for policies definition and evaluation; and (vi) [32,36,38] used the OAuth2 authorization framework.

Moreover, two studies implemented end-to-end messaging mechanism [14,37]: the messaging mechanism referred in [14] is supported on the 128-bit Advanced Encryption Standard (AES) encryption, while in [37] data are encrypted and decrypted by applying ARIA 256 and Secure Hash Algorithm (SHA) 256.

In turn, [30] reported the use of several security measures including OAuth 2.0 for access, short-term access codes, pseudonymization, and encryption-at-rest. Additionally, two studies [23,27] used blockchain technology to support trust able data management to aggregate the data stored in various data sources while enhancing the data provenance, data availability, security and privacy through decentralized mechanisms and immutable audit trails.

4. Discussion and Conclusion

Considering the diversity of their purposes, the included studies contributed for the study of the potential of FHIR, in general, and specifically, when used in the context of homecare. As stated in [15], FHIR might contribute for the challenge how to handle variability caused by diverse healthcare processes and it seems that FHIR is more flexible, lightweight and resources efficient when compared to Cambridge Health Alliance (CHA) compliant solutions. Moreover, FHIR extensions might support needs not considered in the FHIR profile, such as the measurements of the wearable activity tracks [17] or to capture the patient’s physical activity and exercise data [24].

Considering the demographic characteristics of the included studies, is possible to conclude that the interest of using FHIR to implement homecare applications is recent, since most studies were published during the last four years. Moreover, in terms of geographical distribution, Europe has the highest contribution, since almost 50% of the included studies were published by European researchers.

In terms of the first research question (i.e., what type of homecare applications benefit from the use of FHIR?), a large percentage of the applications being reported aimed to provide interoperable measurement devices for home monitoring, or to provide interoperable PHR and assure their integration in healthcare provision ecosystems. Moreover, two other types of purposes were identified: (i) applications to remotely collect PROM; and (ii) specific applications for self-management.

Concerning the FHIR resources being implemented (i.e., the second research question), 27 different FHIR resources were identified. Observation was the most used FHIR resources (i.e., its use was reported by 16 studies), which is justified by the fact that Observation is the basic FHIR resource to capture vital data (e.g., heart rate, blood pressure, pulse, BMI, weight) or symptom data. Moreover, Patient, CarePlan, Device, Questionnaire, QuestionnaireResponse, Condition and Organization were used by at least five studies. Moreover, the following FHIR resources complete the list of FHIR resources used by at least two of the included studies: Activity, AllergyIntollerance, DiagnosticReport, DeviceDefinition, Encounter, Medication, MedicationRequest, PlanDefinition, Practitioner and Procedure.

In what concern the use of publicly available development tools to support implementation of FHIR (i.e., the third research question), only five studies referred the use of SMART on FHIR, and seven studies referred the use of HAPI. Moreover, an important limitation is related to the fact that only three studies validated the implemented FHIR resources using FHIR validators, which are publicly available.

Finally, considering the fourth research question (i.e., how privacy and security issues are being addressed?), almost half of the included studies did not address these issues, although some of them pointed that privacy and security issues will be addressed as future work. In turn, ten studies reported different approaches to implement authentication and authorizations mechanisms, being the OAuth2 the most used framework since its use was reported by three studies. Moreover, two studies reported the implementation of end-to-end messaging mechanisms supported on data encryption. Finally, blockchain technology was used by two studies to support trust able data management using geographically distributed systems.

Acknowledgements

This work was supported by Programa Operacional Competitividade e Internacionalização (COMPETE 2020), Portugal 2020 and Lisboa 2020 of the Fundo Europeu de Desenvolvimento Regional (FEDER) / European Regional Development Fund (ERDF), under project project ACTIVAS - Ambientes Construídos para uma Vida Ativa, Segura e Saudável, POCI-01-0247-FEDER-046101.

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