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The Use of FHIR in Digital Health – A Review of the Scientific Literature

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Abstract. Fast Healthcare Interoperability Resources (FHIR), an international standard for exchanging digital health data, is increasingly used in health information technology. FHIR promises to facilitate the use of electronic health records (EHRs), enable mobile technologies and make health data accessible to large-scale analytics. Until now, there is no comprehensive review of scientific articles about FHIR and its use in digital health. Here, we aim to address this gap and provide an overview of the main topics associated with FHIR in the scientific literature. For this, we screened all articles about FHIR on Web of Science and PubMed and identified the main topics discussed in these articles. We also explored the temporal trend and geography of publications and performed some basic text mining on article abstracts. We found that the topics most commonly discussed in the articles were related to data models, mobile and web applications as well as medical devices. Since its introduction, the number of publications about FHIR have steadily increased until 2017, indicating an increasing popularity of FHIR in healthcare (in 2018, publication numbers remained stable). In sum, our study provides an overview of the scientific literature about FHIR and its current use in digital health.

Keywords. Health Information Interoperability, Review Literature

1. Introduction

In 2011, the standards developing organization Health Level Seven (HL7) International first introduced Resources for Healthcare, a new standard for better interoperability in digital health. Renamed to Fast Healthcare Interoperability Resources (FHIR) soon after, the standard extends previous HL7 specifications (such as HL7 Version 2 and Version 3) by modern web technologies [1]. It features, for example, a Representational State Transfer (REST) Application Programming Interface (API) [2] for data exchange (other modes of data exchange, such as messaging or document-based exchange, are also possible [3]). The basic building blocks of FHIR are so-called resources – generic definitions of common healthcare concepts (e.g. patient, practitioner, condition, observation, device etc.), which can be exchanged in XML or

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JSON format. To date, FHIR specifies around 140 resources, which are intended to cover typical use cases but can be extended where necessary.

Since its introduction, FHIR has gained in popularity and is increasingly adopted by the industry. In 2018, six big technology companies – including Amazon, Google, IBM and Microsoft – pledged to remove barriers for healthcare interoperability and signed a letter that explicitly mentions FHIR as emerging standard for the exchange of health data [4]. Similarly, the Argonaut Project unites technology vendors and provider organizations to accelerate the use of FHIR in digital health [5]. (Apple's Health app already makes basic use of FHIR.) With SMART on FHIR, a platform for interoperable apps [6], FHIR can be expected to gain even more traction in digital health in the future.

Using FHIR for the exchange of health data can provide potential benefits in a large number of domains, including electronic health records (EHRs), mobile health applications, wearable devices, precision medicine, clinical decision support or big data analytics. As FHIR is still relatively new, there is, however, until now, no comprehensive overview of its current use in digital health. In this literature review, we aim to address this gap and investigate which digital health topics are most associated with FHIR. For this purpose, we screened all scientific publications about FHIR on Web of Science and PubMed and grouped the publications into different topic categories. We then analyzed the number of publications in each category. We also explored temporal trends by looking at the number of FHIR publications per year as well as geographical distributions and journal types. To further explore main topics associated with FHIR, we also used simple text mining methods to analyze the most frequent words in the abstracts of the articles.

Our study provides an overview of the current use of FHIR in digital health, identifying the main topics that are discussed in the context of FHIR in the scientific literature.

2. Methods

2.1. Article Selection

Using the search term "FHIR OR 'Fast Healthcare Interoperability Resources'", we identified all articles about FHIR on Web of Science and PubMed (date of search: February 4, 2019). After removal of duplicates, we excluded search results that were not scientific journal articles or conference proceedings papers (removing, for example, editorials and commentaries). We also excluded articles in which the word "FHIR" occurred in a different context (apparently, "fhir" means "man" in Gaelic, resulting in some articles about Irish poetry!).

2.2. Analysis

Based on the title and abstract (and full text if necessary), three of the authors (ML, SL and PVFGI) identified – independently of each other – up to three main topics that best described the content of each article. The resulting list of topics was discussed, and topics were grouped into main categories (broad and therefore uninformative categories such as "e-health" or "interoperability" were avoided). Topics that did not occur frequently and could not be assigned to one of these categories were subsumed under "Other". We then grouped each article into one of these final categories (again,

independently of each other). The category assignments were reviewed and possible differences were discussed and resolved, resulting in a single category for each article.

To get an overview of the topics most commonly associated with FHIR in the scientific literature, we then counted the number of articles in each category. To explore the temporal trend of publications as well as geographical distribution, we also analyzed the articles with regard to their year of publication and country of origin (assessed by the institution of each article's first author). To be able to assess the temporal trend of FHIR publications in relation to other health IT standards, we compared the annual number of publications about FHIR with publications about openEHR, another typical health IT standard [7]. OpenEHR publications were identified using the search term "openEHR" on Web of Science and PubMed. We also investigated the type of journal in which articles about FHIR were published, grouping them into "IT / Informatics" (including bio- and medical informatics) or "Medical".

Last, we performed a simple text mining analysis, identifying the most frequent words in the article abstracts. For this, we extracted the words of all abstracts, converted them to lowercase letters, removed numbers and punctuation as well as verbs and function words (prepositions, pronouns, articles, conjunctions etc.) and ordered them by their frequency of occurrence.

All analyses were done in R (Version 3.5.1, R Project), using the additional packages "tm" for text mining and "ggplot2" for graphics.

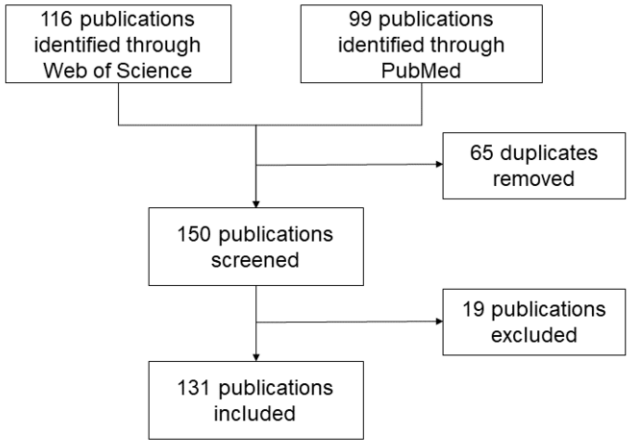

Figure 1. Flow chart of article selection.

3. Results

After removal of duplicates, we screened 150 distinct articles from Web of Science and PubMed. We excluded 19 articles that did not fulfill the inclusion criteria, resulting in 131 articles used in the final analysis (Figure 1). A list of the articles included in our analysis is available from https://doi.org/10.5281/zenodo.3207709.

The large majority of articles (n=123) was published in IT and informatics journals; only a small number of articles (n=7) was published in medical journals (one article published in PLOS ONE was considered neither "IT / Informatics" nor "Medical"). The largest number of articles (n=52) was published by authors with affiliations in the US, followed by Germany (n=13), Austria (n=10) and Italy (n=6).

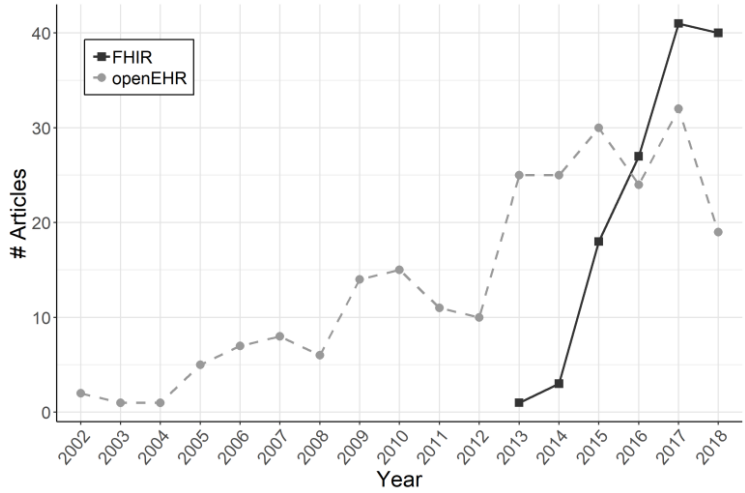

Figure 2. Annual publications on Web of Science and PubMed about FHIR (black solid line) compared with publications about openEHR (gray dashed line).

Figure 2 shows the temporal trend of publications with the number of FHIR articles per year between 2013 and 2018. Starting with only one and three publications in 2013 and 2014, respectively, the number of publications steadily increased to 41 in 2017 and then appeared to remain stable in 2018. Compared with openEHR, which was characterized by a relatively slow increase in publication numbers from 2002 to 2018, FHIR showed a steeper increase in publication numbers since its introduction.

Table 1. Categories and corresponding example topics to which articles were assigned.

Category	Topics
Mobile and Web Applications	Mobile Application, Web Application
Medical Devices	Sensor Device, Wearables, Internet of Things, Biosignals
EHR	Electronic Health Record, Medical Record, Patient Summary
Data Protection / Security	Data Protection, Data Security, Reliability
Genomics	Genomics, Genetics, Phenotyping
Digital Imaging	Imaging, Radiology
Decision Support	Decision Support
Ontology / Terminology / Data Models	Ontology, Terminology, Data / Information Model, Mapping
Analytics	Data Analysis, Predictive Modelling, Machine Learning
General / Overview	General Information about FHIR, Overview Articles
Other	Laboratory Data, Clinical Trials, Risk Assessment and other topics

With regard to the content of the FHIR publications, we identified the following ten main categories, into which articles were grouped: “Mobile and Web Applications”, “Medical Devices”, “EHR”, “Data Protection / Security”, “Genomics”, “Digital Imaging”, “Decision Support”, “Ontology / Terminology / Data Models, “Analytics” and “General / Overview” (Table 1 shows the main categories and corresponding topics). “Ontology / Terminology / Data Models” was the category with the largest number of articles (n=25 / 19.1%), followed by “Mobile and Web Applications” (n=14 / 10.7%) and “Medical Devices” (n=13 / 9.9%); 23 articles (17.6%) that could not be grouped into any of the main categories were subsumed under “Other” (Figure 3).

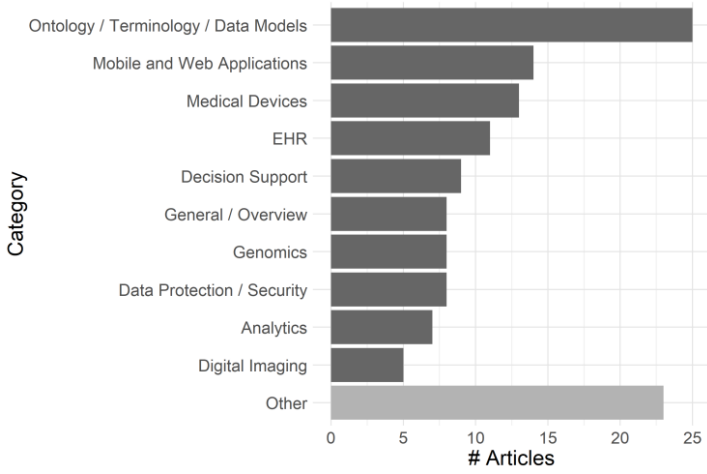

Figure 3. Number of articles per category.

Text mining revealed the words used most frequently in the abstracts of the articles. The ten most frequent words (in order of frequency) were: “data”, “health”, “standard(s)”, “patient(s)”, “clinical”, “system(s)”, “interoperability”, “information”, “healthcare” and “medical”.

4. Discussion

Reviewing all articles about FHIR on Web of Science and PubMed, we identified main topics associated with the use of FHIR in digital health. Reflected by the large number of articles in the category “Ontology / Terminology / Data Models”, many articles dealt with topics related to developing data and information models as well as standardized vocabularies and terminologies. This category included, for example, the development of a FHIR terminology server [8] or mappings of other data models to FHIR resources [9,10].

As to be expected, “Mobile and Web Applications” and “Medical Devices” (including, for example, articles about wearable sensors) were also main topics associated with FHIR. Many publications in these categories were related to the SMART on FHIR platform for interoperable apps [6]. With its increasing adoption by technology companies, FHIR can be expected to become even more important in this area in the future.

Interestingly, only a relatively small number of articles was associated with the broad category "Analytics". As FHIR is still relatively new, this could be due to most FHIR projects still being in the initial development phases more concerned with implementation and data definitions (as reflected by the category "Ontology / Terminology / Data Models") and not yet with large-scale data analysis.

A relatively large proportion of articles could not be assigned to one of the main categories and was subsumed under "Other". Within this group, no main topics emerged that could have been grouped into a new category. This shows the diversity of topics associated with FHIR and can perhaps be interpreted as an indication that FHIR increasingly permeates many different areas in healthcare.

With regard to the annual number of FHIR publications, the steep increase in publications since its introduction, especially compared with openEHR, indicates a high interest in FHIR in the healthcare community. It also suggests that FHIR might see a faster adoption in health IT than other standards. However, the number of FHIR publications appeared to level off in 2018, suggesting that interest in FHIR could have reached a maximum. It will be interesting to see whether the coming years will confirm this observation or whether publication numbers will change again.

Investigating the geography of publications showed a main focus on the United States. Other countries that featured prominently in terms of FHIR publications were Germany and Austria, probably reflecting national initiatives aiming to improve the exchange of digital health data, such as the German medical informatics initiative [11-14] or the electronic health record "ELGA" in Austria [15].

The text mining of the abstracts revealed, unsurprisingly, typical words associated with digital health ("data", "interoperability", "EHR" etc.) and also confirmed our previous observation that many articles were associated with the development of data models (as indicated by the frequent use of the word "model(s)" in the abstracts).

Our study included all articles about FHIR listed on Web of Science and PubMed and can therefore be expected to cover most of the existing scientific literature. As a limitation, however, it should be noted that uses of FHIR not described in scientific articles or conference proceedings are not covered by this review. Topics associated with FHIR in other sectors (e.g., commercial and business use) could therefore differ from the ones presented here. To better assess the adoption of FHIR in health IT (which may be independent from the more "academic" interest in FHIR in the scientific community), future studies could investigate the implementation status of FHIR projects more closely.

5. Conclusion

Our study provides a review of the scientific literature about FHIR. Investigating topics associated with the use of FHIR in digital health, we identified data models and terminologies as well as mobile and web applications and medical devices as main themes discussed in the literature. The analysis was complemented by an exploration of temporal trends and geography of FHIR publications. Our study can help researchers and health IT professionals to assess the current interest in FHIR in the scientific community and its potential impact on digital health.

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