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The impact of interoperability on medical record sharing: review

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Abstract---*Background: The process of integrating and sharing information across health organizations and system providers is difficult because of the differences in their internal ecosystems and the use of proprietary electronic health record systems. Current studies highlight the advantages of a unified environment for inpatient treatment, with a specific emphasis on enhancing the quality, effectiveness, and long-term viability of healthcare procedures. Aim of Work: This research aims to investigate the benefits of semantic interoperability in electronic health records, enabling the smooth transfer of information across different healthcare entities and sectors within organizations. Methods: Seven databases were searched for papers published between October 2010 and September 2020 as part*

of an extensive, systematic literature evaluation. The research concentrated on identifying typical situations, methods, and instruments used to tackle interoperability obstacles in healthcare environments. A classification system was presented to describe the discoveries related to semantic interoperability in health records. Results: The research emphasized efficient technologies and methods for attaining semantic interoperability, which allows for the smooth exchange of data and encourages data sharing among healthcare professionals, such as physicians, nurses, labs, and other organizations in the healthcare field. Diverse approaches were discovered to resolve the problems of outdated and diverse data sharing across healthcare institutions. Conclusion: In conclusion, semantic interoperability is essential for improving healthcare ecosystems. It helps to eliminate isolated data systems, facilitates the flow of data across different organizations, and supports coordinated care delivery. Healthcare providers may increase patient care, minimize medical mistakes, and optimize operational efficiency by using interoperable technologies.

Keywords---*data exchange, Electronic Health Records (EHRs), healthcare ecosystems, interoperability, review.*

Introduction

A semantically integrated health system facilitates the exchange of data across enterprises and their internal ecosystem while ensuring that the meaning of the data is not lost. Seeking semantic interoperability in health records and other clinical annotations has been a prominent problem for systems. It has been a consistent focus of research in recent years, as seen by publications (Kopanitsa, 2017; Roehrs et al., 2018; Maldonado et al., 2020). By implementing interoperability, healthcare personnel may effectively manage the whole electronic patient record, independent of the entity responsible for generating the clinical session records (Martínez-Costa et al., 2010). The importance of health record interoperability has increased significantly in the healthcare industry, particularly during the COVID-19 pandemic, to enhance disease management.

Semantic interoperability (SI) is the process of exchanging data across different organizations or systems in a way that guarantees mutual understanding and interpretation. This is achieved by using domain ideas, contextual knowledge, and formal data representation. Alternatively, semantic interoperability may be comprehended by considering the concept of semantics, which pertains to the study of meaning and the connection between individuals and their language. This connection is crucial in facilitating mutual understanding among people, even when they have diverse experiences or perspectives (Alexopoulos, 2020). Interoperability refers to the capacity of many systems to collaborate effectively, even if they use various interfaces, platforms, and technologies (Interoperability, 1996).

The HIMSS, a worldwide adviser that assists in the development of the health ecosystem, has categorized interoperability technologies into three levels: Foundation, Structural, and Semantic. HIMSS has 480 provider organizations and over 450 non-profit partners. The Foundational level established the necessary criteria for establishing connections between various systems and safely exchanging data. The Structural level encompasses the format, syntax, and data required to read information at the field level. On the other hand, the Semantic level enables the manipulation of terminologies, vocabularies, and publicly declared standardized values, facilitating a comprehensive grasp of meaning.

As stated by Gansel et al. (2019), to establish an electronic health record, many issues need to be addressed. These include comprehending the diverse range of words, resolving any ambiguities, and recognizing and updating the ideas involved. The authors (Hayman et al., 2019; Angula & Dlodlo, 2018) have described the three basic layers of interoperability that may enhance workflows across health information systems, enabling real interoperability. In the healthcare field, interoperability refers to the capacity of various systems, apps, and devices to exchange, use, and analyze data from any location while maintaining its true significance.

Aim of Work

Utilizing standardized protocols enables the exchange of data across healthcare professionals, laboratories, hospitals, and pharmacies, irrespective of the specific software or systems used, hence attaining semantic interoperability. Interoperability enables health information systems to function seamlessly across different organizational boundaries. The objective of the present research is to identify the primary methods often used to achieve semantic interoperability in Electronic Health Record (EHR) systems.

ISO/TS18308

ISO/TS18308 (2011), defines an Electronic Health Record (EHR) as a system that seeks to consolidate health data into a format that can be easily processed, securely stored, and shared. Utilizing a widely established information model to facilitate the interchange of data and ensure accessibility for authorized users. The goal is to guarantee the patient's lifelong integrated healthcare, effectively and with a focus on high quality and security. The EHR architecture contains the patient's health information, which has to be digitized and preserved properly in a repository throughout their lifetime (ISO/TR 20514, 2005).

EHR systems include several data forms, including structured data and unstructured textual data. An Electronic Health Record (EHR) encompasses a substantial portion of individuals' medical histories, providing comprehensive information and identifying relevant risk factors. Furthermore, it manages patient health information and facilitates the delivery of everyday treatment in hospitals and primary care clinics (Taweel et al., 2011). Moreover, it enables the use of patient data for many objectives, such as overseeing individual patients, conducting medical and health services research, and administering healthcare facilities (Yang et al., 2019).

Implementing an Electronic Health Record (EHR) is crucial for effectively managing healthcare operations and facilitating the sharing of data across healthcare institutions. An Electronic Health Record (EHR) facilitates seamless communication among physicians, nurses, labs, and hospitals, even in the presence of disparate systems. Effective sharing of data across health organizations and health agents should prioritize accurate interpretation, ensuring that the same level of accuracy and meaning is maintained as intended by the sender (ISO 13606, 2019), therefore attaining semantic interoperability. Semantic interoperability refers to the capacity to exchange data across different systems and guarantee comprehension at the conceptual level of the domain (ISO C técnico, 2011).

Various health standards are designed to facilitate the exchange of data across healthcare institutions. Nevertheless, the implementation of standards continues to pose many obstacles in attaining semantic interoperability. The primary objective of the semantic web is to facilitate the exchange, integration, and reutilization of data by using ontologies, linked open data, and knowledge graphs. This ensures the accurate interpretation of the shared data. The semantic web sometimes referred to as a key technology for achieving semantic interoperability in health information systems, commonly utilizes ontologies, a well-established technology that aids with knowledge-intensive activities associated with EHR systems.

Literature Review

Lately, there has been a growing interest in systems that enable semantic-level data interchange, particularly across health system providers. Various researchers investigate different techniques for resolving interoperability issues. Nevertheless, there are challenges in implementing health standards and tools for accurate data representation (such as ontologies, databases, and clinical models) that guarantee healthcare practitioners can effectively handle the data.

The writers in Salomi & Claro (2020), examine the issue of interoperability in electronic health records from the standpoint of management and business. They emphasize how integrating and sharing data across different organizations may enhance the quality of care, streamline work procedures, and increase efficacy, resulting in cost reduction and improved efficiency. In addition, the writers demonstrated the interconnectedness of healthcare with other fields such as Telemedicine, Big Data, and Business Intelligence. From a technological standpoint, it aids in the elimination of repetitive tasks, minimizes mistakes, and facilitates personalized healthcare for each patient. From the perspective of people, it emphasized the endorsement of establishing essential public health programs, monitoring and managing illnesses, cutting down expenses, and enhancing efficiency (Aishammari et al., 2019).

Conversely, Gagalova et al. (2020), examined the technical elements of integrating health systems, ensuring compatibility and facilitating the interchange of data. The first publication outlines the benefits of adopting integrated data repositories, which are clinical data warehouses that enable clinical research, specialized analysis, and enhanced data processing. The second study suggests a global approach that combines health records. The paper proposes the implementation of HL7 FHIR, a commonly used health standard, together with vocabularies and terminologies.

The systematic review by Adel et al. (2019), examines the prominent tendency towards the adoption of standards. The authors demonstrated a keen interest in assessing the literature based on ontologies, particularly focusing on fuzzy ontology. The research provides a thorough overview of the backdrop around the prominent health standards and their distinct structures, emphasizing any shared qualities they may possess. The article also referred to the established requirements as the "e-Health Standard," although we prefer to use the more general term "health standard." The authors have identified four categories that highlight trends in semantic interoperability. These

categories address challenges and research opportunities related to: a) frameworks for solving semantic interoperability problems, b) the use of ontologies to address interoperability issues, c) the role of standards in achieving interoperable Electronic Health Records (EHRs), and d) the barriers and challenges associated with heterogeneous EHR semantic interoperability.

Moreover, the research conducted by [Adel et al. \(2019\)](#), extensively showed the increasing use and significance of using standards for electronic medical records in the healthcare industry. This includes overcoming organizational obstacles and attaining seamless communication and cooperation among healthcare providers. In this situation, we analyze the changes in the adoption of standards in recent years and the instruments that contribute to the development of a semantically interoperable Electronic Health Record (EHR) system.

The Health Criteria Used in the Research

The absence of a universally agreed-upon worldwide standard for electronic health records is evident, and the papers included in this study further support this situation. Nevertheless, the data that has been retrieved indicates a consistent pattern in the preferred selection, which involves using a multilayer strategy, such as openEHR, ISO/CEN 13,606, and HL7 formats. The dual model approach enables experts in the fields of health and technology to collaborate effectively. The majority of the research focused on advancements in selecting standards for semantic datasets to achieve semantic interoperability. The data obtained from research indicates that there is a growing use of open health standards, particularly to two specific standards, namely openEHR and ISO 13606. In addition to data exchange and addressing challenges related to semantic interoperability, the authors of the study [Moreira et al. \(2018\)](#), created a system that combines ontology resources to identify high-risk events during pregnancy. In addition, the essay included a concise examination of three open standards, namely openEHR, ISO 13606, and HL7 CDA, outlining their respective strengths and weaknesses. Conversely, the research ([Maldonado et al., 2020](#); [Martínez-Costa et al., 2010](#)), aims to provide solutions for the concurrent use of openEHR and ISO13606, which are two open standards with comparable specifications. This method of approximating the standards would enable the standardization of data. Even though both standards use the ADL (Architecture Description Language), there are still many discrepancies in their types and definitions that need alignment.

The writers ([Yang et al., 2019](#); [Sinaci & Erturkmen, 2013](#); [Yuksel et al., 2016](#)) have investigated other possibilities that deviate somewhat from the established criteria. For example, [Yang et al. \(2019\)](#), introduced a technique to depict the interconnections between data items, ideas, and archetypes using a three-level Bayesian network. They then used the inference process to identify significant archetypes and achieved promising outcomes compared to the conventional search platform CKM. In contrast, the authors of [Yuksel et al. \(2016\)](#), enhanced the existing post-sale medication tracking mechanism for patients. The data is derived from voluntary reports, namely spontaneous reports, focusing mostly on unpleasant incidences. Implementing EHR would enable the comprehensive tracking of a patient's full medical history and the ability to anticipate future risk factors.

The writers in reference [Sinaci & Erturkmen \(2013\)](#), also investigated an alternative possibility. They created a federated Metadata Registry/Repository (MDR) which is a store of metadata that combines Common Data Elements (CDE) and HL7 CCD (Continuity of Care Document) models. They also suggested making additions to ISO 11179. Furthermore, it was integrated into the Health Level 7 (HL7) Virtual Medical Record (vMR) as a service-based component. Its purpose is to gather patient data from various databases and serve as a gateway between data sources and components, enabling the use of EHR data for clinical decision support ([Fagin et al., 2005](#)).

The Terminology or Health Repositories Used

Terminologies and vocabularies are comprehensive compilations of terminology used in a certain field of study, which serve to establish a shared language. Terminologies serve the purpose of excluding regional phrases, newly coined words, and human errors from being included in the EHR. Instead, they rely on established categories like illnesses, events, procedures, and specimens. Healthcare institutions exchange confidential data, therefore it is crucial for systems to accurately express and not overlook the intended message. An option is to create a local repository and oversee an environment that implements exclusive notions. Nevertheless, the use of international terminology guarantees that the utilization of worldwide words and other categorizations will possess identical significance to any recipient ([Fernández-Alemán et al., 2013](#)).

Health standards often conform to various terms, since they consist of data that can be inputted into a repository and then viewed and modified. Table 6 displays the terms that were most often used in the chosen research. We emphasize SNOMED-CT, which is the most often used terminology since it provides a clinically proven,

semantically robust, and regulated vocabulary. This promotes the development of expressive abilities to fulfil new demands in evolution (SNOMED International). ICD, which stands for International Categorization of Diseases, is a widely cited and analyzed diagnostic categorization system used in both clinical and research settings. The International Classification of Illnesses (ICD) encompasses a wide range of illnesses, disorders, injuries, and other health issues (Organization WH). The next edition, ICD-11, is scheduled to be released in 2022.

To accomplish interoperability in electronic health records (EHR) and successfully transmit information across various providers, it is crucial to follow standards. However, taking it to the next level involves sharing knowledge and enhancing the information with semantic value. A shared language facilitates the understanding of information between the sender and receiver, enabling the extraction of insights from data and the construction of new connections based on current data. As stated by reference [Alexopoulos \(2020\)](#), semantic modelling involves the task of connecting words and phrases to their specific meanings, which is the primary difficulty in this context.

Implementing a certain set of terms involves many HIMSS levels, as it encompasses strategic considerations related to system architecture, team composition, and organizational preferences. The medical personnel of the institution must willingly comply with, employ, and openly demonstrate their commitment to using the specified terms. Once the company and team have achieved compliance, the information is standardized and shared with other suppliers ([Frow et al., 2016](#)).

Due to the limited dissemination of information about patterns, only a small number of systems include terminology, classifications, and dictionaries in their designs, since these elements are not considered essential in the healthcare context. Hence, it is important to focus on programs that encourage the progressive incorporation of terminology into everyday language. The absence of such possibilities hinders the ability to suggest and implement a health standard, identify potential challenges, and provide practical guidelines for healthcare facilities ([Leal et al., 2019](#)).

Interoperability

Interoperability, which refers to the capacity of different software systems to work together and share information, is a significant challenge for software firms. Healthcare systems often see semantic interoperability as a luxury, but it should be seen as a necessary need. This is because semantic interoperability directly affects the quality of the stored data, which is crucial for future secondary research. Thus, promoting the development of systems focused on achieving semantic interoperability will enable the exploration of secondary use of electronic health records (EHR), data recycling, and clinical models, making clinical research inside institutions a tangible possibility ([Patel et al., 2009](#)).

Conclusion

This article provides a comprehensive introduction to the international health standards that are often used to ensure semantic interoperability in health data. We performed a Systematic Literature Review using the technique suggested by [Kitchenham et al. \(2009\)](#). We used a total of seven scientific databases in our study, from which we picked 6032 papers. Following the application of the inclusion and exclusion criteria and quality evaluation, a total of 28 articles were deemed acceptable. These were used for comprehensive reading and analysis based on the issues of interest.

The prevalence of adopting two levels (ISO13606 and openEHR) is mostly attributed to the open nature of these standards, the availability of significant documentation, and their intrinsic purpose to facilitate accessibility for healthcare professionals. Their accessibility enables individuals to construct the requisite clinical models alone, without the aid of qualified personnel. It also pertains to the degree of precision that the pattern permits in describing information, since the archetypes may include very precise levels of information related to a particular clinical notion, enabling a contextualized semantic level. Ultimately, it is feasible to assemble a compilation of archetypes to form a template.

Typically, we examined research conducted on medical records in hospitals, including studies that used laboratory data and experiments focused on investigating clinical models (such as ISO13606 and openEHR standard). In addition, we examined many possibilities for optimizing the features suggested in the models, such as recovery, semantic representation forms, approaches for enhancing semantic connections using metadata, and adherence to ontology standards. The research revealed an increasing worry over the use of open data models for representing clinical information. The primary standards that were aligned with were openEHR, ISO13606, and the HL7 framework.

This study supports a positive outlook for exploration since there is currently no universally accepted worldwide norm or global agreement on the techniques to be taken. Recent research has shown attempts to provide a

comprehensive framework including the four levels of interoperability as a guiding principle for a final directive. Several studies have focused on facilitating the investigation of secondary data, namely in the fields of clinical research and decision support systems. Ontologies have been extensively used, and we have noticed favorable outcomes in the adoption of semantic web technologies, particularly by incorporating ontologies with patterns, to enhance data representation in forms that emphasize semantics. By using ontologies to describe data, this situation promotes the investigation of linked databases (LOD) as well as graph-based databases such as Neo4J and Virtuoso. However, the specific benefits of adopting these databases have not been conclusively determined. Ultimately, we emphasize the pattern of embracing semantic web technologies as suggested by the W3C. The benefits of using health standards, such as clinical models and reference models, in conjunction with graph structures (ontologies) for capturing data from electronic health records include the ability to capture complex relationships, limitations, and rules.

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