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The importance of interoperability among different health information systems: Review

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***Abstract*---**Background: The absence of interoperability across health information systems diminishes the quality of patient treatment and squanders resources. Hence, it is essential to establish integration mechanisms among the different health information systems. Aim of Work – The objective of this research was to examine the interoperability prerequisites for diverse health information systems and to condense and present them. Methods – An extensive electronic search was performed on the issue using six databases, namely PubMed, Web of Science, Scopus, MEDLINE, Cochrane Library, and Embase, up to 2018. The inclusion criteria were to choose English-written papers that were accessible in full text and had aims that closely aligned with the study. A total of 36 articles were chosen for further examination. Results – The concept of interoperability has gained prominence in the realm of health information systems since 2003 and has been a subject of significant interest among academics. The efforts undertaken in this subject mostly focus on a nationwide scale and aim to accomplish the implementation of electronic health records. HL7 FHIR, CDA, HIPAA, SNOMED-CT, SOA, RIM, XML, API, JAVA, and SQL are crucial prerequisites for achieving interoperability. To ensure effective data sharing, semantic interaction is the optimal approach as it allows computers to uniformly detect and process information that is semantically identical. Conclusion – The healthcare sector has gotten more intricate and has developed new requirements. Interoperability fulfills these requirements by facilitating communication between the output and input of processing systems, hence simplifying access to data in the desired formats.

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Keywords---interoperability, healthcare sector, health information systems, quality, patient treatment, review.

Introduction

Every civilization need high-quality and dependable healthcare, which is integrated as an essential component of everyday existence. The healthcare area is very complex due to the introduction of new diagnostic and therapeutic techniques, processes, and the presence of several professional groups, each with its own features, needs, and working styles [1]. To secure the long-term stability of the healthcare system, it is necessary to use health information technology. Over the last several decades, many health information technologies have been created to convert paper-based health information into electronic format. As a result, numerous hospitals worldwide have adopted health information systems [2].

A health information system is a comprehensive system that combines the collecting, processing, reporting, and use of data to enhance the efficacy and efficiency of health care administration at all levels [3, 4]. These systems enhance care coordination, streamline information organization, ensure timely, accurate, and comprehensive information, enable information analysis, decrease medical errors, lower costs, ensure continuity of care, facilitate information exchange, provide quick and convenient access to providers and information across different locations and times, and enhance communication between healthcare professionals and patients [5].

The advantages of health facilities using health information systems are evident. Nevertheless, the present systems being used are exclusive, and they may vary from one healthcare institution to another. These systems were designed for local usage, which has led to a lack of consistency in the existing ecosystems [6]. A patient's health information may be disseminated throughout an indeterminate number of healthcare institutions. The medical information of a hospital is not transferable or accessible to another healthcare organization. Unless the patient is conscious and able to provide the necessary information, the health professional does not have complete access to the patient's medical records. This hinders their ability to make an informed and personalized decision regarding the best course of action in a specific situation [7]. In order to make a well-informed judgment on which treatments to adhere to, a healthcare professional need access to information that is dispersed throughout several institutions. If an organization commits a mistake as a result of insufficient knowledge, resolving the issue will be much more challenging, if not entirely unattainable. Hence, it is essential to establish integration methods across different health information systems in order to provide universal access to patient health information [8].

Information sharing across various tiers of healthcare is directly correlated with the quality, effectiveness, and safety of patient treatment. Interoperability, as defined by [9], is the capacity of systems to seamlessly connect and share information with one another, without any restrictions, in terms of both implementation and access. The compatibility and integration of health

information systems are crucial for the administration of health services, public health, ensuring high quality and safe patient treatment, and facilitating clinical research. The absence of interoperability results in duplicated, chaotic, disconnected, and unattainable medical information, which may impact the quality of patient treatment and result in the squandering of financial resources [10].

Aim of Work

Although the significance of ensuring the compatibility of health information systems is widely recognized, the many methods used to achieve this and the increasing scholarly attention it receives, the present status of this matter is chaotic. As far as we know, there has not been a comprehensive investigation of the problem of interoperability in health information systems. Hence, within the framework of health information systems interoperability, it is necessary to place more attention. This necessitates the collection of a dataset including several research papers on the interoperability of health information systems from various scientific sources, followed by the implementation of the suggested technique on this dataset. The objective of this research was to examine the interoperability prerequisites for diverse health information systems and to condense and present them.

Methodology

The studies were found up to 2018. The individuals were chosen after a thorough search of several online databases, including PubMed, Web of Science, Scopus, MEDLINE, Cochrane Library, and Embase, as well as a search on Google Scholar. The search included several sources such as online books, published papers, conference abstracts, and seminar and reference publications. This approach aimed to minimize publishing bias and maximize the inclusion of articles. In addition, the reference lists of the chosen publications were examined to identify any additional relevant research. Furthermore, the bibliographies of published papers and reviews were manually examined to identify possibly relevant publications.

Results

The majority of the studies conducted were on a national scale, with the objective of establishing a connection between clinical information systems and medical devices, with the ultimate goal of implementing electronic health records. They were citizens of the United States, Italy, Portugal, Korea, and Spain, in that order. Hospitals were the predominant research venues.

The corpus of research supports the interchange of data. Furthermore, the activities of gathering, storing, searching, obtaining, accessing, updating, modifying, and deleting were documented. The aforesaid procedure revealed that medical decision making, reimbursements, telemedicine, and illness monitoring were the predominant applications that were often used. The interoperability across systems mostly relied on semantic compatibility and was established via the use of the Open EHR and RIM information source.

The predominant transport standards used were HL7 FHIR and DICOM. The prevailing content standards were CDA. The often-employed terminology standards were SNOMED-CT, LOINC, and ICD 10. The usually employed security standards included HIPAA and ASTM (Figure 1). Figure 2 depicts the specifications of interoperability implementation standards.

The digitization of healthcare presents substantial enhancements in worldwide health, however accompanied by its own array of challenges. The healthcare business is filled with several health information technology systems, such as electronic health records, billing software, different portals, and unique medical devices with their own user interfaces [11-13]. Due to the presence of segregated data and regulatory requirements, some of these technologies are unable to function in conjunction with each other. As a result, healthcare professionals and workers are forced to do manual tasks, which may be very expensive. Interoperability may be advantageous in this particular scenario. Interoperability solutions in healthcare are crucial for addressing the industry's most challenging issues and have the potential to significantly reduce healthcare expenses [14].

Currently, a significant portion of healthcare expenses is allocated towards administrative purposes. The sector is already reaping the benefits of automation in activities that formerly required time-consuming and error-prone human effort. Health systems are now using interoperability solutions to save costs and medical mistakes by facilitating the seamless exchange of health data across providers, payers, laboratories, and other stakeholders [15]. Extending interoperable solutions throughout a health system leads to better patient outcomes, faster service delivery, and enhanced financial performance. Healthcare interoperability solutions essentially provide clinicians with the necessary information to effectively coordinate treatment, whilst reducing patient healthcare expenses, resulting in a mutually beneficial outcome. In addition, the information and analysis may be shared with members to improve their compliance with medication and treatment of chronic diseases, leading to a greater return on investment for health plans [16].

Research done in an inpatient environment has shown that medical mistakes leading to adverse drug events are driven by a lack of information accessible to patients. Medical mistakes rank as the sixth leading cause of mortality in hospitals, making them a significant issue in the healthcare sector. Furthermore, it has been said that medical errors result in a significant number of fatalities in hospitals annually. Furthermore, it is worth noting that more than one million persons sustain injuries annually as a result of defective health-care procedures and failures in the system [17].

Interoperability enables significant time savings. In cases when a patient's communication abilities are impaired, healthcare practitioners have the ability to compensate for the lack of good communication without having to reach out to general practitioner offices or other organizations. Furthermore, the use of the medical interoperability gateway enables the extraction and display of patient data inside an established system, hence allowing healthcare personnel to allocate more time towards patient care. Ensuring patient safety is of utmost importance while delivering high-quality treatment [18]. Accessing data at the

moment of service is crucial for clinicians to avoid medical mistakes. Interoperability solutions that enhance accuracy and accessibility mitigate these risks and simultaneously enhance the quality of treatment. The availability of real-time patient data reduces the duplication of effort and mistakes in patient care. The information provides healthcare practitioners with a comprehensive overview of a patient's medical and social background [15]. Consequently, there will be no repetition of testing across settings, and the patient will only need to provide their medical history once. Various reasons contribute to delays in data transit. However, interoperability may help mitigate these concerns. Expedited and secure clinical choices may be made by reviewing the medical record, resulting in decreased patient transfers, anguish, and prolonged hospital stays. Facilitating the synchronization of treatment and exchange of information across healthcare and social care entities may assist in assessing a patient's readiness for release, hence reducing the likelihood of readmissions [19].

In contrast to other sectors, digital transformation has not simplified the work for physicians and administrators in the healthcare industry. Instead, it has resulted in additional burdens due to the growing demands of regulatory compliance, a lack of compatibility across different systems, and the overwhelming number of software options available. Interoperability in healthcare streamlines administrative processes for staff and obviates the need for manual data input. Interoperability solutions are facilitating the easy interchange of health data, therefore lowering the need for manual chores, minimizing unnecessary work, and relieving clinicians from the load imposed by payers [20].

Facilitating the exchange of healthcare data across health systems, payers, and providers enhances both the quality of care and the effectiveness of its delivery. Interoperability solutions in healthcare are facilitating the coordination and provision of patient care as the industry progresses towards value-based care. Healthcare interoperability enables health organizations to provide the necessary technological framework to optimize the value of their electronic health record (EHR) data and deliver more complete healthcare services [21].

Interoperability in healthcare

Interoperability in healthcare enables caregivers to comprehend words and ideas more effectively when data is transmitted across different systems, while preserving the integrity of the information. Interoperability will enhance healthcare progress by providing accurate interpretation of medical language in communication systems. Therefore, doctors have the ability to efficiently examine data from all interconnected systems in order to formulate diagnoses and make informed judgments [22].

Patients rely on their healthcare providers to maintain the confidentiality of their clinical data, which is why adherence to regulations is crucial for the seamless exchange of healthcare information. Hospitals are striving to maintain a delicate balance between ensuring the accessibility of patient health data and safeguarding patient privacy, especially in light of the increasing frequency of cyber-attacks against healthcare organizations. Modern healthcare interoperability solutions include security protocols to guarantee the proper and

safe flow of data, which is also certified. Reducing the number of healthcare staff who manually update patient data decreases the likelihood of security breaches [23].

According to the findings, interoperability was higher at the semantic level. Typically, literature has established many fundamental degrees of interoperability. The following levels are included:

- At the level of technical interoperability, data is transferred across systems via the use of a communication protocol. Technical interoperability ensures harmonization at the plug-and-play, signal, and protocol levels.
- Pragmatic interoperability is achieved when systems that are interoperating have knowledge of one other's processes and procedures. This indicates that the systems involved have a thorough understanding of how the data is used and the specific context in which it is applied.
- Syntactic interoperability refers to the ability of many systems to exchange data and services by using a shared interoperability standard, such as the High Level Architecture [24].
- Functional interoperability is the need for functional requirements to be provided in a consistent and defined way.
- Dynamic interoperability refers to the capacity of two or more systems to comprehend and use changes in their assumptions and constraints throughout time.
- Structural interoperability refers to the capacity of different systems to exchange and interpret multimedia, hypermedia, object-oriented data, and other types of information.
- Conceptual interoperability refers to the state where the assumptions and limitations of a meaningful representation of reality are in agreement, resulting in effective communication and understanding.

Semantic interoperability

Semantic interoperability is the capacity of several systems to automatically understand and process accurate and meaningful information in order to provide valuable outcomes, as determined by the users of the systems. Therefore, even if the instances are represented in a diverse manner, meaning they have distinct structures and utilize different language or terminology, the systems may nonetheless uniformly identify and analyze semantically equivalent information. Semantic interoperability is unique among other levels of interoperability since it guarantees that the receiving system comprehends the significance of the sent information, regardless of whether the sending system is unaware of the methods used by the receiving system. That is why it is more often used compared to other levels [25, 26].

HL7 FHIR served as the predominant transport standards. The interoperability of healthcare organizations necessitates the use of common protocols, such as HL7, to facilitate the exchange of patient information between different systems, as different healthcare systems utilize different applications [27]. FHIR is a standard for application programming interfaces (APIs) that focuses on interoperability and

is considered the next generation in this field. It was developed by HL7 and is used for representing and exchanging health information. FHIR has garnered widespread use and endorsement from several studies due to its amalgamation of HL7 functionalities with cutting-edge web standards. It offers enhanced security, effortless implementation, free accessibility, and exceptional adaptability. The healthcare industry is increasingly adopting FHIR as the preferred method of data exchange. This trend is expected to continue in the future due to the multiple advantages it offers to both system providers and consumers [28].

The most often used content standards were CDA. CDA's popularity stems from its status as an XML-based standard for clinical document content that offers flexibility and can be comprehended by both people and computers. The system enables the whole medical history of a patient to be presented in a single document, which can be used in several applications and avoids variations in content [29].

The widespread usage of SNOMED CT is now acknowledged by the health sector, which emphasizes the need of further adopting this standard. In this particular scenario, the benefit of using SNOMED CT is that it enables the provider to establish a shared and standardized terminology. SNOMED CT-enabled clinical health records enhance population health by enabling timely identification of emerging health concerns, monitoring community health, and promptly adapting to evolving clinical practices. They provide accurate access to relevant data while minimizing expensive redundancies and mistakes [30].

Service-oriented architecture

Service-oriented architecture is now the most renowned and extensively used kind of architecture. Service-oriented architecture (SOA) is a software development approach that enables services to connect across different platforms and programming languages in order to build applications. In the context of Service-Oriented Architecture (SOA), a service refers to a self-contained software component designed to carry out a certain task or activity. Service-oriented architecture is the implementation of the "service concept" or "service model" in computers. In this architectural approach, business activities are constructed as software services. These services may be accessible via a set of precisely specified application program interfaces and integrated into applications using dynamic service orchestration [31].

SOA provides businesses with the advantage of reusability. Services may be reutilized to generate a multitude of applications. SOA services are kept in a service repository and may be accessed on demand, making each service a universally accessible generic resource. Utilizing existing services enables firms to efficiently save both time and financial resources in the context of expansion. Easy to maintain. Due to the self-contained nature of each service, it is easy to alter and update them without causing any impact on other services. This will lead to a decrease in the operational expenses of the company. Enhances compatibility and exchange of information across different systems or devices. Platforms can seamlessly transfer data between clients and services due to the implementation of a common communication protocol, regardless of the

programming languages they are written in. Enhanced availability. Upon request, the SOA facilities are accessible to everyone. Enhanced dependability. SOA (Service-Oriented Architecture) provides more reliable applications since it allows for faster debugging of tiny services compared to large codebases. (6) Capable of being easily expanded or adjusted in size or scale. Service-Oriented Architecture (SOA) allows for the distribution of services over several servers, leading to enhanced scalability. In addition, firms may restrict the level of engagement between consumers and services by using a standardized communication protocol. It is feasible to scale applications without increasing the burden by reducing the level of user involvement [32,33,34].

SOA may be implemented with many service-oriented technologies, including REST, WSDL, and SOAP. SOA-based systems have the ability to operate autonomously regardless of the specific development tools and platforms used, such as Java, XML, and .NET, among others [35].

Undoubtedly, interoperability has a substantial beneficial effect on healthcare. However, a significant problem in the field of healthcare is the presence of obstacles and difficulties that have resulted in a deficiency of interoperability across different systems. In the healthcare sector, there are several standards that often suffer from excessive generality and susceptibility to local interpretation and implementation [36]. Using several standards thereafter results in ambiguity. Several historical health-care systems that are still in use today have limited interoperability capabilities. The problem with legacy systems lies in their specificity to a particular activity or location. Additionally, many of these systems are intentionally designed to prevent interoperability with applications from other manufacturers. This is done to safeguard their market dominance and promote the acquisition of hospital or clinic chains [37]. Furthermore, unlike the majority of companies, the healthcare sector continues to depend on physical copies of handwritten notes (paper records) for the provision of patient care. This is because the majority of healthcare professionals are reluctant to transition from a paper-based to an electronic-based system. Interoperability confronts many hurdles, including limited administrative and legal support for information technology and practice improvements, lack of consistency in systems from various suppliers, constraints on financing for information technology and resources, and issues around privacy and security [38].

Irrespective of the specific definition of customized medicine, it is clear that enhanced cooperation and exchange of data are essential for effectively addressing the increase in complex chronic illnesses. To comprehend the fundamental reasons behind diseases and create diagnoses and treatments that are more effective and safer, it is crucial to have easy access to a substantial amount of different information from many organizations. Customized medical strategies may effectively tackle these challenges. EHR interoperability addresses the need for customized care by facilitating convenient access to data in the necessary formats. In order to get individualized care, it is essential to have interoperable Electronic Health Records (EHRs) that include a vital connection for integrating clinical data. Interoperable technologies and infrastructure facilitate the collection, integration, and correlation of diverse clinical data types with patient information, making the process simpler. By establishing connection, it is

possible to enhance translational research and clinical decision support, resulting in better patient outcomes and achieving the whole cycle of bench to bedside and back paradigm [39].

In recent years, the accessibility of extensive open data for drug development has significantly increased as a result of the growth of data repositories, especially those including chemical and pharmacological datasets. In computational drug development, a typical research effort involves the use of a diverse range of software, programs, and tools to read input files, preprocess data, conduct one or more calculations, and carry out post-analysis. Pre-processing and linking the outputs of one program or tool as input to another software or product is likely necessary for this task. Engaging in such a task might be arduous and need manual pre-processing of the output and input files. The resolution of this issue may be achieved if system or tool developers additionally examine the practical use case scenario about the compatibility of input/output files across different software applications and tools [40].

Recent advancements in manufacturing technology, such as cyber-physical systems, the industrial internet, artificial intelligence, and machine learning, have transformed factory designs into interconnected networks of automation equipment, services, and enterprises. One of the challenges arising from this increase is the increasing need for interoperability across all levels of the industrial ecosystem. The portfolio encompasses a comprehensive selection of shop floor software, devices, and control systems, as well as web-based cloud platforms that provide a wide range of services as needed. Therefore, a successful deployment of interoperability in smart manufacturing will result in effective communication and reliable exchange of data across devices, users, systems, and platforms. The use of complex architecture and platforms by machines and software programs poses a significant challenge to this. Understanding the issue may be improved by using industry-specific interoperability and their accompanying logical semantics [41].

Conclusion

Full interoperability has not yet been achieved in the realm of healthcare. The absence of interoperability across healthcare systems perpetuates the existence of information silos in current paper-based medical records, leading to exclusive control over health data. As a result, there has been an increase in healthcare expenses, a decline in the quality of patient treatment, and a degraded capacity to integrate patient data across different healthcare systems. Hence, the results of this study can be considered as crucial initial steps towards incorporating interoperability principles into the healthcare industry and enhancing the integration of information and communication technology (ICT), especially in nations where e-health planning and development are still in their nascent phases. In addition, the identified concerns have the potential to stimulate necessary transformation in the area of information systems development and facilitate progress towards overall compatibility in healthcare settings at both national and international levels. However, the process of enhancing the capacity of different information systems to work together effectively, particularly when

handling sensitive data, is a time-consuming endeavor that requires the involvement of a substantial and diverse team of experts.

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Figure 1. Regularly occurring standard terms are organized in a cloud format depending on the results obtained.

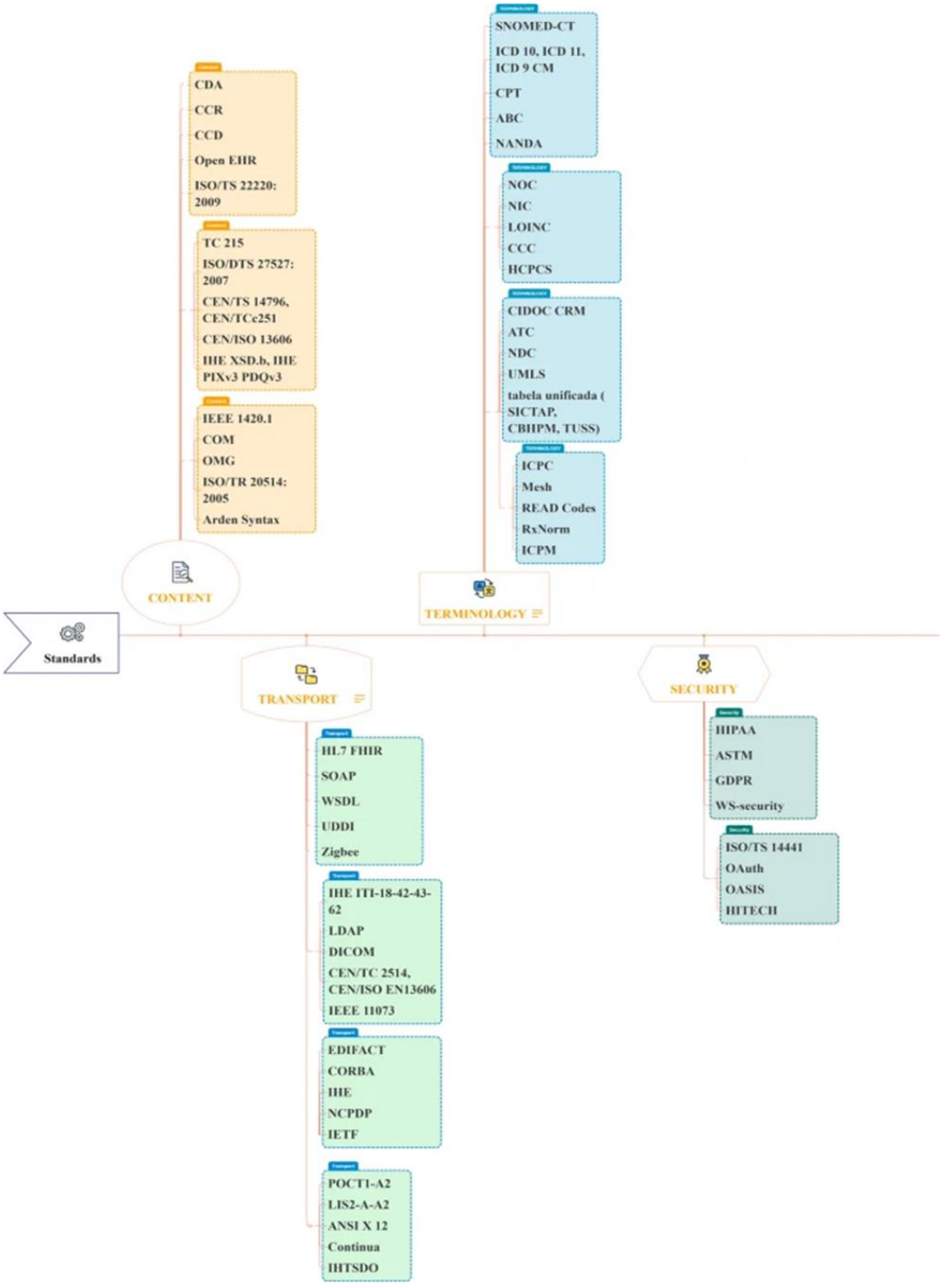

Figure 2. Overview of interoperability standards derived from research results.