Review

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Rai Harpreet * and Rimmy Yadav *

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A Research Review on Semantic Interoperable Archetype Models, Approaches & Methods Implemented for Electronic Health Record Systems in Medical Healthcare

Rai Harpreet * and Rimmy yadav *

Department of Information Technology, Pyramid College of Business & Technology, Punjab, India
* Correspondence: Ryh3636@gmail.com (R.H.); rimmysciences@gmail.com (R.y.)

Abstract: Semantic interoperability is a foundational concept in modern healthcare, enabling seamless communication and meaningful data exchange across diverse EHR systems. At the heart of this concept lies archetype clinical information models, which serve as standardized templates to structure and encode clinical data, ensuring consistency and shared understanding among various healthcare stakeholders. This review paper delves into the intricacies of Electronic Health Records (EHRs) within the context of semantic interoperability and the pivotal role played by archetype clinical information models. Drawing from a wealth of recent research, this review paper examines the theoretical underpinnings of semantic interoperability. By surveying the literature, it synthesizes the diverse approaches and methods employed to achieve semantic interoperability within EHR systems. Furthermore, this review does not shy away from addressing the significant challenges that persist in this arena. These challenges encompass issues related to data quality, governance, resistance to change, and the scalability and integration hurdles that healthcare organizations encounter in their quest for interoperable EHR systems. Through a comprehensive review of relevant research papers from esteemed sources including PubMed, ScienceDirect, and Taylor & Francis, the paper offers a comprehensive understanding of the approaches and methods employed in this domain. This analysis encompasses a time frame ranging from 2015 to 2023, ensuring an up-to-date assessment of the field. By presenting a well-rounded picture of the field, this review paper offers valuable insights for healthcare stakeholders, researchers, and practitioners. It underscores the enduring importance of semantic interoperability in EHR systems, not only in advancing patient care, clinical decision support, and healthcare operations but also in driving data-driven innovations in the dynamic and ever-evolving medical healthcare sector. This comprehensive examination sets the stage for future advancements in the pursuit of truly interoperable and data-driven healthcare systems.

Keywords: EHR; semantic interoperability; clinical information models; Archetype modeling

I. Introduction

The introduction of semantic interoperable archetype models into the realm of EHR systems represents a transformative leap forward in the landscape of healthcare management and patient care. EHR systems have unquestionably revolutionized the way patient data is collected, stored, and shared, ushering in an era of data-driven healthcare. These systems have not only replaced traditional paper-based records but have also paved the way for seamless data accessibility and exchange, enhancing the efficiency and quality of healthcare delivery. Yet, as the healthcare industry rapidly embraces digital transformation, a persistent and formidable challenge remains – the issue of semantic heterogeneity within healthcare data. The extensive diversity of clinical specialties, each with its unique terminology, data formats, and standards, coupled with the proliferation of various EHR vendors, has given rise to a fragmented data landscape. This fragmentation has, for years, posed significant obstacles to achieving a true and effective interoperability that is vital in modern healthcare.[1][2][3]

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This is precisely where semantic interoperable archetype models make their indelible mark. These models serve as structured, standardized templates that not only capture the clinical data itself but, more critically, its inherent semantics. They provide a shared and universal language for healthcare data, ensuring that regardless of its source or the clinical specialty it represents, the data is consistently understood and interpreted. In essence, these models harmonize the cacophony of clinical terminologies, unifying the healthcare ecosystem under a common semantic umbrella. The importance of semantic interoperable archetype models transcends mere data standardization. They are the bedrock upon which dependable data exchange, accuracy, and consistency in EHR systems are built. In a healthcare landscape where patients often receive care from various providers, specialists, and institutions, the ability to exchange data without loss of meaning is paramount. It ensures that a comprehensive and accurate patient record is accessible across the entire continuum of care, from primary care clinics to specialty hospitals.

Moreover, these models serve as enablers of clinical decision support systems, allowing them to provide more effective, data-driven guidance to healthcare providers. As structured templates, they empower EHR systems with the capacity to minimize the risk of medical errors, ultimately improving patient safety and the overall quality of care. The value of these archetype models extends to healthcare research and analytics as well. By providing standardized data structures, they facilitate medical research and population health analytics, enabling more efficient data aggregation, analysis, and insights that can drive evidence-based practice and inform healthcare policies. In an era of evolving healthcare, where the ability to integrate and exchange data is paramount, semantic interoperable archetype models ensure that EHR systems are not siloed entities but interconnected hubs. They open avenues for interoperability and exchange with other healthcare information systems, such as laboratory and radiology information systems, ensuring that a comprehensive and multidimensional view of the patient is always available. The models based on archetype also adhere to established healthcare data standards, such as HL7 and FHIR, ensuring that they are compliant with industry norms and regulations, further promoting interoperability not only at a local but also at a national and global level.[4][5]

II. Objective

The primary objectives of this review paper are to meticulously summarize and critically evaluate the body of existing research in the domain of semantic interoperable archetype models in electronic health record (EHR) systems. This review aims to serve as a comprehensive resource that consolidates the current state of knowledge in this critical field, elucidating the approaches, methods, and challenges associated with semantic interoperability presented in Table 1. After the literature, challenges were discussed.

III. Literature Review

Ref. No	Proposed Methodology/ Approaches/ Models.	Standard& Terminologies	Information Technology	Advantages	Limitation
1	An approach based on an OpenEHR to improve the semantic interoperability of clinical data registry is proposed. The following five phases of approach is as follows:	• OpenEHR	• XML	• Proposed approach improves the semantic Interoperability.	NA

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	• Clinical data registry is implemented for meta-information collection. • Data element definition. • Archetype modeling. Implementation				
2	In this study, authors reused the OpenEHRmodelling approach and also developed virtual different components of a modelling platform as a stable platform or multiple reference model (RM) for ageing population. Authors also described methodology for one- to- one mapping between OpenEHR systems and the column families NoSQL schema.	• OpenEHR	• NoSQL (Not only-SQL)	• Ensures the data interoperability between different components of the multiple platforms. • The developed approach can able to do the following responsibilities ; A) Data collection and Feature Extraction. B) As a decision support system ranging from general health preservation monitoring to critical situation management.	NA
3.	Authors provided the proof-of concept for integrating SISMaster (Material and Neonatal Healthcare	• OpenEHR • ISO 13606	• XML flat model and Schema.	• It allows EMR systems to exchange data with	NA

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	Information System) developed by the federal university of Minas Gerais (UFMG) with EHR system developed of healthcare for the state of Minas Gerais.		• Java (JEE 1.7.0_09/ JDK 1.7.0_0 • XQuery	SES/ MG EHR systems. • Adaptable with all other EMR systems. • Improves the Quality of Care. • Ensure and enhance interoperability based in standards.	
4	• An OpenEHR archetype interoperability solution for Health Information System (HIS) –Clinical Decision Support System (CDSS) data integration is proposed. • In other words, an integration tool to enable CDSS to collect health related data from various institutions without a need for modification.	• OpenEHR • LinkEHR • Archetype Query Language (AQL	• XML Languag e & Schema	• The Proposed Approach can be applicable to other dual-model based standards and other CDSS. • Mapping tables, performed in this study, solve the issue of local terminologies. • Model- to-model transformation s improves efficiency and corrections of the designed approach.	Mapping EHR data to the CDSS become complex due to the heterogeneit y of formats, models, abstraction levels and semantics.

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5.	• Authors in this paper highlighted the feasibility and reusage of OpenEHR archetypes to link EEG Base data and to propose a new OpenEHR archetype data type set describing EEG Base domain. For this authors implemented; A)OpenEHR Reference model and Semantic OpenEHR to link EEGBase experimental data.	• OpenEHR - CKM • OpenEHR -RM • OpenEHR - archetype • odML terminologies	• XML • JAVA	• Granularity of EEGBase between data and metadata is improved. • With the help of this approach researchers can do reverse analysis. • Improves semantic Interoperability.	NA
6.	• Authors defined the data warehouse environment to anticipate the problem of interoperability and infrastructure challenges in clinical archetype based EHR systems. • For this, an OpenEHR compliant instances, stored in an OpenEHR repository, is proposed with the help of aggregation and transformation functions, • For Modelling of clinical data structure, authors implemented OpenEHR and OpenEHR archetypes. • LinkEHR studio for transferring unstandardized clinical to a format or LinkEHR for model mapping.	• OpenEHR • LinkEHR	• OLAP • XML • RESTful Web Services. • JavaEE distribution • Spring Framework	• The designed archetype terminologies perform each of the necessary operations like modelling, extraction, transformations, loading & Query.	Authors did not highlight the issues related to structure of information.

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7.	• An ontology based flexible approach for automatic transformation of clinical model into OpenEHR archetype is proposed. • For transformation purpose, authors implemented web ontology language (OWL) • Authors also make use of reusable transformation templates.	• OpenEHR archetypes	• Ontology pre-processing language version 2 (OPPL 2) for generating axioms is Implemented	• Improve the mean time of model- to-model mapping. • Highly Scalable.	NA
8.	• Authors proposed a graphical retrieval method to identify clinical information model (CIMs) online to represent EHR data. • Authors implemented Bayesian network and CKM or Clinical Information resources to create new OpenEHR archetype to support semantic interoperability.	• OpenEHR	• XML	• Robustness. • Improves the semantic interoperability of EHRs	• The Proposed study lacks the calculation of the semantic relevance of synonyms or homonyms for network and query modelling. • Inaccurate results were generated
9	• Authors aimed to describe a summary representation of Obscare workflow and to check whether archetypes in the OpenEHR CKM repository can represent Obscare clinical concepts.	• OpenEHR	• Business Process model and Notation (BPMN)	• Improve data Quality	• In Obscare, the presence of incomplete variables and doubtful record as well

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	It includes the following phases; a) Obscare form selection. b) Description of the workflow care process. c) Detailed data extraction, and d) Clinical Knowledge model (CKM) model analysis.				creating a standard problem in it.
10.	• Authors modelled an EMR prototype for infants affected by cerebral palsy (CP). • Dual model approach with semantic web technologies is implemented. The methodological process involves three main concepts which are; a) OWL- DL based archetype Expressions. b) Creating an ontological source to annotate EMR archetypes. c) Creating archetypes annotations to enhance data extraction.	• OpenEHR • ISO/ 13606	• Argo- UM • SOAP • Web Ontology Language (OWL)	• The insertion of semantic relations by adding new semantic concepts. • Supply the knowledge base with the additional checking rules. • It provides better quality of care and ensures semantic interoperability between all involved therapy's Information systems.	• NA
11	• Authors proposed a fuzzy interoperable framework for Distributed EHR Systems. It consists of following layer;	• Open EHR • HL RIM • DB2 OWL. • ADL2 OntoModule	• SparkQL • XML • SQL • UML	• Heterogeneous data can be aggregated while maintain the semantic,	NA

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	a) At lower layer which includes ontologies used to save EHR healthcare information. b) At middle layer, data collected from lower layer is converted into global ontologies by various mapping algorithms and experts. c) At highest level, graphical user interface is provided.			by the framework. • It Improve the semantic interoperability between the various EHRs.	
[12]	• Authors in this study designed an interoperable concept which enables an easy integration of the Clinical decision support system (CDSSS) across different institutions, by using Open EHR archetypes, terminologies , binding and AQL	• OpenEHR OpenEHR Clinical Knowledge Manager (CKM). • HaMSTR (Hannore Medical School Translation Research). Open EHR Repository.	• CommonKADS modeling method for knowledge creation. • Agent based modelling. • Microsoft SQL Server • Archetype Query Language (AQL). • Altoya Map Force 2014. • Java & Eclipse JavaEE.	• High Reusability rate. • Better performance • Fast, trusted and having high detection of SIRS. • Data and others facts can be added dynamically into the • Knowledge base.	• NA
[13]	• Authors presented a mobile tethered personal health record (PHR) architecture with using Personal Health	• OpenEMR • OpenEHR	• UML • XML • JASON	• Proposed framework has promised flexibility.	• Authors did not address the issues

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	Record System (PHR-S) & Functional Model (FM) for Functional Interoperability.	• HL-7 FHIRfor Structure Interoperability. • SNOMED &RxNorm for Semantic Interoperability.		• Other legacy system can be integrated into this framework. • Highly beneficial for biomedical and healthcare research community to achieve semantic Interoperability.	related to privacy and security of patient's data.
[14]	• Authors designed a distributed model, named OmniPHR, to integrate PHRs from various hospitals. a) Blockchain technology is implemented to divide the patient's health related data into data blocks such as laboratory data, drug related data, etc. b) Proposed incorporates model also concept of paging.	• OpenEHR	• Blockchai • Routing Overlay • Chord Algorithms . • OMnet++ • OverSim Framework.	• Scalability & high Elasticity. • High Performance • Improves scalability. • With the help of this framework patient's access to their personal health related data. •	• Proposed framework did not address the issue related security and privacy of patient's health information.
[15]	• A Framework based on data transformation and reasoning services intended for clinical data and knowledge is developed. • Authors Implemented dual model approach i.e. OpenEHR and ISO/ 13606 to improve the semantic interoperability.	• OpenEHR • ISO/ 13606 • LinkEHR and • SWITmapping tools. • OWL.	• J2EE • Neo4J • REST API • Cypher. • XML	• Due to simple design, new mappings can be easily added to define new transformations and workflows. • User Friendly GUI. • Improves semantic	• Lack of control mechanism . • Another shortcoming is persistence of workflows. • Does not support

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	Main components of Framework is; a) Integrated representation. b) Storage and exploitation of mappings. The overall objective of this approach is to maximize the reuse of information artifacts and mappings in the design and development of different transformation workflows using EHR.			• Interoperability	workflow languages.
[16]	• Authors in this study designed a methodology which is based on OpenEHR archetype and software agents to deal with interoperability between legacy systems. • Authors also designed a system, as a case study, that supports the preparation of a cardiac surgery by reusing Legacy information Systems. • Dual modeling approach is applied. At first level, a common Reference Model (RM) is defined and at second level archetypes expressed in the Archetype Definition Language (AQL).	• OpenEHR • CKM • SNOMED-CT	• XML	• Reusable and flexible domain artifacts. • Specific applications can be build reusing artifacts. • Improves semantic interoperability. • Proposed methodology can be employed in other application domains. • Very useful for various stakeholders.	• Security and confidentiality issues were not addressed during transformation of patient data in a healthcare environment. • Less Scalable.
[17]	• Authors in this study proposed a model to semantically represent and linked all the components of	• SNOMED-CT • OWL (Web Ontology Language)	• SOA • RESTful web services.	• Improves syntactic as well as semantic interoperability	• Adaptation of Clinical Decision Support

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	Clinical Decision Support System (CDSS) using web service definition ontology.		• XML	arises in various clinical decision support system	System at Local level is still a barrier to share their Clinical Decision Support System (CDS) capabilities. • More Qualitative evaluation needed to verify the accuracy and reliability of the proposed model.
[18]	• Authors developed a multi-professional information model for decision- making process in primary care in Brazil. For this, authors applied Delphi method to perform consensual analysis. The Proposed model comprised of following three stages: a) Expert panel selection b) Preliminary model development. c) Delphi method for content validation.	• OpenEHR • SNOMED-CT	• Mind Maps	• Support for requirements for building electronic health records information system architecture. • It helps IT specialist in business modelling for EHR products.	• Need Verification.

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[19]	Authors developed information 13606 model as a specification development of graphical user interface based on archetype medical data.	• ISO 13606	• XML • XSL • C#	• Able to process several archetypes at a time. • Able to define reusable graphical representation for EHRs. • Able to target stakeholders by providing them flexible and adjustable graphical user interface. • Preserves the advantage of the state- of-the- art technologies. • High Performance. • Provide efficient modelling facilities. • Highly user interactive. • Improves semantic interoperability.	• Authors did not perform compariso n analysis for performan ce evaluation. • Less adoption at local as well national level.
[20]	Authors in this study proposed a method for clinical model comparisons. • Lin similarity estimates and Sokal and Sneath similarity implemented together with two aggregation techniques	• SNOMED-CT • Lin/ALLAVG, Lin/BestAVG, SoSn/AllAVG and SoS/ BestAVG	• Matlab Hierarchica l. • Clustering . • Dendogra ms.	• Better performance. • Dendograms based on intrinsic similarity estimation and	• Introduced some structural issues.

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	(average and best- match-average respectively.) • The purpose behind is to give an overview of multiple clinical models whether these modelsate local templates or standardized information Models.			best- pair average techniques is capable of grouping diverse templates in order to improve the semantic interoperability.	
[21]	Objective of this paper of this research is to use the HL7 metamodel in the Model Driven Engineering (MDE) context. • Authors performed and practically implemented the comparison of all modelling tools to identify the best tool deal with technology transfer issues.	• AQL • Archetype Modeling Language. • OpenEHR archetypes • Navigational techniques: CDA (Clinical Document Architecture. • HL7	• Model Driven Engineering (MDE). • UML • SOA	• Reduce the development time and help to identify the possible errors inconsistencies in early phases of development. • This proposed concept will help the software engineers to design health information systems with solid support. • Authors find that there are elements in the HL7 metamodel that do not correspond to	• Work mostly on requirement and analysis part.

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				elements of the UML metamodels. UML metamodels through stereotypes anticipate this issue. •	
[22]	Interoperability smart lane for electronic health record (islEHR). which comprises of three modules 1) a data fetching APIs 2) a data integration service 3) a RESTful API •	• RESTful API	• Archetype Modeling • Artificial Intelligence	• High accuracy • Data transfers rate was very among EHRs. • Reliable	• Very less sample size.

Challenges:

- Sharing and reusing a broader archetype is difficult. To envisage this, collaborative modelling can also be used or incorporated. [1]
- There has been almost no research on NoSQL solutions in archetype-based system development.[2]
- From an architectural standpoint, implementing an entire archetype for the EEGBase portal is a challenge. [5]
- Information modelling must be viewed as a separate stage. [6]
- There is a need to create an end-user tool that supports the process and allows users to configure their own integration templates. [7].
- The transformation template is still an unexplored area, so researchers must work on it to improve semantic interoperability issues. [7]
- There is indeed a paucity of research evidence to support the use of the OpenEHR archetype to represent maternal health clinical EHR data. [9]
- Hence the need to propose or develop a tool to assist or guide the implementation of search engines to solve semantic queries [12]
- The interoperability and reusability issues in medical healthcare have already been studied and addressed in various areas of software engineering and artificial intelligence. However, the re-use of software components offers a robust methodology for addressing issues pertaining to semantic and syntactic interoperability. [13]
- No previous research has attempted to use HL7 in the MDE context by establishing a correspondence between both HL7 and UML metamodel elements. Practitioners can directly implement UML and work automatically on HL7 metamodels. [17]

- Open health standards and global terminology expertise have not yet achieved widespread adoption in the market; instead, they are primarily prevalent within the academic community, such as educational institutions, and large software providers.[23]

IV. Conclusion

The review of various methodologies, approaches, and models in the realm of semantic interoperable archetype models within Electronic Health Record (EHR) systems reveals a dynamic landscape. These approaches hold the promise of significantly enhancing the quality and efficiency of healthcare data management, ensuring meaningful data exchange, and fostering semantic interoperability. The use of OpenEHR, along with other standards and terminologies, offers a robust foundation for these endeavors.

Many of the proposed approaches exhibit distinct advantages. They improve the semantic interoperability of EHR systems, ensuring data is both understood and consistent across various healthcare settings. Additionally, they enhance data quality, support decision-making processes, and have the potential to facilitate research and analytics within the healthcare domain.

However, several limitations and challenges have also been identified. These include issues related to security and privacy, scalability, and the persistence of structural and semantic inconsistencies. Some proposed methods may lack the qualitative evaluation necessary to verify their accuracy and reliability, while others may struggle to adapt to local-level implementations of Clinical Decision Support Systems (CDSS).

V. Discussion

The findings from this comprehensive review highlight the vital role that semantic interoperable archetype models play in overcoming the challenges of heterogeneous data in EHR systems. These models provide a standardized framework that ensures a common language for healthcare data, making it comprehensible and consistent across different healthcare specialties and institutions. They bridge the semantic divide, enabling healthcare data to be exchanged seamlessly, supporting clinical decision-making and enhancing the quality of care.

The diversity of approaches and methods discussed in the reviewed literature underscores the ongoing innovation in the field. However, there is also a need for standardized evaluation criteria and comparative studies to assess the performance and effectiveness of these approaches comprehensively. Addressing issues such as security and privacy, scalability, and the persistence of structural inconsistencies is crucial in ensuring the successful implementation of semantic interoperable archetype models. As technology and standards continue to evolve, it is imperative that researchers, practitioners, and healthcare stakeholders work together to address the challenges and unlock the full potential of semantic interoperability in healthcare.

References

1. Min, L., Tian, Q., Lu, X., An, J., & Duan, H. (2018). An openEHR based approach to improve the semantic interoperability of clinical data registry. BMC Medical Informatics and Decision Making, 18(1), 49-56. https://doi.org/10.1186/s12911-018-0596-8
2. Kalogiannis, S., Deltouzos, K., Zacharaki, E. I., Vasilakis, A., Moustakas, K., Ellul, J., & Megalooikonomou, V. (2019). Integrating an openEHR-based personalized virtual model for the ageing population within HBase. BMC Medical Informatics and Decision Making, 19(1), 1-15. https://doi.org/10.1186/s12911-019-0745-8
3. Santos, M. R., de Sá, T. Q. V., da Silva, F. E., dos Santos Junior, M. R., Maia, T. A., & Reis, Z. S. N. (2017). Health information exchange for continuity of maternal and neonatal care supporting: a proof-of-concept based on ISO standard. Applied Clinical Informatics, 8(4), 1082-1094. DOI: 10.4338/ACI-2017-06-RA-0106
4. Kopanitsa, G. (2017). Integration of hospital information and clinical decision support systems to enable the reuse of electronic health record data. Methods of Information in Medicine, 56(3), 238-247. https://doi.org/10.3414/ME16-01-0057
5. Papež, V., & Mouček, R. (2017). Applying an archetype-Based approach to electroencephalography/event-related Potential experiments in the eegBase resource. Frontiers in Neuroinformatics, 11, 24. https://doi.org/10.3389/fninf.2017.00024

6. Marco-Ruiz, L., Moner, D., Maldonado, J. A., Kolstrup, N., & Bellika, J. G. (2015). Archetype-based data warehouse environment to enable the reuse of electronic health record data. International Journal of Medical Informatics, 84(9), 702-714. https://doi.org/10.1016/j.ijmedinf.2015.05.016
7. Legaz-García, M. del C., Menárguez-Tortosa, M., Fernández-Breis, J. T., Chute, C. G., & Tao, C. (2015). Transformation of standardized clinical models based on OWL technologies: from CEM to OpenEHR archetypes. Journal of the American Medical Informatics Association, 22(3), 536-544. https://doi.org/10.1093/jamia/ocu027
8. Yang, L., Huang, X., & Li, J. (2019). Discovering clinical information models online to promote interoperability of electronic health records: a feasibility study of OpenEHR. Journal of Medical Internet Research, 21(5), e13504. doi:10.2196/13504
9. Alves, D. S., Maranhão, P. A., Pereira, A. M., Bacelar-Silva, G. M., Silva-Costa, T., Beale, T. W., & Cruz-Correia, R. J. (2019). Can openEHR represent the clinical concepts of an obstetric-specific EHR - ObsCare Software? In MEDINFO 2019: Health and Wellbeing e-Networks for All (pp. 773-777). IOS Press. 10.3233/SHTI190328
10. Ellouze, A. S., Bouaziz, R., & Ghorbel, H. (2016). Integrating semantic dimension into openEHR archetypes for the management of cerebral palsy electronic medical records. Journal of Biomedical Informatics, 63, 307-324. https://doi.org/10.1016/j.jbi.2016.08.018
11. Adel, E., El-Sappagh, S., Barakat, S., & Elmogy, M. (2019). A unified fuzzy ontology for distributed electronic health record semantic interoperability. In U-Healthcare Monitoring Systems (pp. 353-395). Academic Press. https://doi.org/10.1016/B978-0-12-815370-3.00014
12. Wulff, A., Haarbrandt, B., Tute, E., Marschollek, M., Beerbaum, P., & Jack, T. (2018). An interoperable clinical decision-support system for early detection of SIRS in pediatric intensive care using OpenEHR. Artificial Intelligence in Medicine, 89, 10-23. https://doi.org/10.1016/j.artmed.2018.04.012
13. Saripalle, R., Runyan, C., & Russell, M. (2019). Using HL7 FHIR to achieve interoperability in patient health record. Journal of Biomedical Informatics, 94, 103188. https://doi.org/10.1016/j.jbi.2019.103188
14. Roehrs, A., da Costa, C. A., & Righi, R. da R. (2017). OmniPHR: A distributed architecture model to integrate personal health records. Journal of Biomedical Informatics, 71, 70-81. https://doi.org/10.1016/j.jbi.2017.05.012
15. Maldonado, J. A., Marcos, M., Fernández-Breis, J. T., Giménez-Solano, V. M., Legaz-Garcia, M. del C., & Martínez-Salvador, B. (2020). CLIN-IK-LINKS: A platform for the design and execution of clinical data transformation and reasoning workflows. Computer Methods and Programs in Biomedicine, 197, 105616. https://doi.org/10.1016/j.cmpb.2020.105616
16. de Moraes, J. L. C., de Souza, W. L., Pires, L. F., & do Prado, A. F. (2016). A methodology based on openEHR archetypes and software agents for developing e-health applications reusing legacy systems. Computer Methods and Programs in Biomedicine, 134, 267-287. https://doi.org/10.1016/j.cmpb.2016.07.013
17. Marco-Ruiz, L., Pedrinaci, C., Maldonado, J. A., Panziera, L., Chen, R., & Bellika, J. G. (2016). Publication, discovery and interoperability of clinical decision support systems: a linked data approach. Journal of Biomedical Informatics, 62, 243-264. https://doi.org/10.1016/j.jbi.2016.07.011
18. Braga, R. D., Lucena, F. N. de, & Ribeiro-Rotta, R. F. (2016). A multiprofessional information model for Brazilian primary care: defining a consensus model towards an interoperable electronic health record. International Journal of Medical Informatics, 90, 48-57. https://doi.org/10.1016/j.ijmedinf.2016.03.004
19. Kopanitsa, G., Veseli, H., & Yampolsky, V. (2015). Development, implementation, and evaluation of an information model for archetype-based user-responsive medical data visualization. Journal of Biomedical Informatics, 55, 196-205. https://doi.org/10.1016/j.jbi.2015.04.009
20. Gøeg, K. R., Cornet, R., & Andersen, S. K. (2015). Clustering clinical models from local electronic health records based on semantic similarity. Journal of Biomedical Informatics, 54, 294-304. https://doi.org/10.1016/j.jbi.2014.12.015
21. Martinez-García, A., García-García, J. A., Escalona, M. J., & Parra-Calderón, C. L. (2015). Working with the HL7 metamodel in a Model Driven Engineering context. Journal of Biomedical Informatics, 57, 415-424. https://doi.org/10.1016/j.jbi.2015.09.001
22. Najjar, A., Amro, B., & Macedo, M. (2022). islEHR, a model for electronic health records interoperability. Bio-Algorithms and Med-Systems, 18(1), 39-54. http://doi.org/10.1515/bams-2021-0117
23. de Mello, B. H., Rigo, S. J., da Costa, C. A., da Rosa Righi, R., Donida, B., Bez, M. R., & Schunke, L. C. (2022). Semantic interoperability in health records standards: A systematic literature review. Health and Technology, 12(2), 255-272. https://doi.org/10.1007/s12553-022-00639-w