Interoperability Challenges in Healthcare Blockchain System - A Systematic Review

Faheem Reegu[1], Salwani Mohd Daud[2], Shadab Alam[3*]

[1, 2] Razak faculty of technology and Informatics, Universiti Teknologi Malaysia, Malaysia
[3] College of Computer Science & IT, Jazan University, Jazan, KSA
Email: [1]farfaheem6211@gmail.com, [2]salwani.kl@utm.my, [3*]snafis@jazanu.edu.sa

ABSTRACT

EHR is the digital record of the medical history of the patient. It has solved many issues related to data handling and its security. A detailed study is required to implement this technology under modern technology and standards to minimize errors in integration. Present solutions lack interoperability and blockchain;therefore, theymust undergo further discussion and research related to it. This research aims to examine the interoperability challenges and issues of blockchain EHR frameworks as per the national and international standards of EHR. It will follow the interoperability standards in the EHR framework in terms of medical data distribution, sharing, and data dependability. The research is based on a systematic review of previous researches; 156 articles were excluded as they were based purely on blockchain and had little or no part of EHR, and 11 articles were selected based on the keywords selected in this research. Innovative interoperability framework and blockchain-based framework found to be successful in solving the current challenges in EHR. However, the issues of EHR can be resolved by bringing advancement in EHR. The research has contributed to highlighting the related challenges and solution in EHR implementation and presented a solution that will help to manage the data, security of information related to the patient and the benefits of blockchain and interoperability of EHR

1. Introduction

Blockchain technology launched in 2009[1]; it is about storing information into ledgers and decentralized into a way across all computing devices within the company that is part of the blockchain infrastructure[2]. The infrastructure is based on peer-to-peer and operates by two sides; the users of the network and the blockchain miners who facilitate the transactions in a distributed ledger [3]. There are various security issues related to any online system minimized using encryption and authentication techniques, but due to centralized storage and inherent weaknesses cannot be fully resolved [4][5]. The ledger prepared by the blockchain in a decentralized network is created through a cryptographic process that is computed by all the data miners within the network. This technology additionally includes reliable storage capabilities for the data, and because of the advanced features, its services are secure, traceable, and non-repudiate[6].

Furthermore, the data is stored in a decentralized public manner while respecting the privacy of the data so that there is no unauthorized access[7]. However, the use of blockchain proves to be challenging for organizations[8]. The advent of substantial transaction volumes in the healthcare industry has inspired a lot of research into scaling blockchain for healthcare[9]. For example, key management and engagement questions, including anonymity and privacy on a blockchain,

would also need to be considered when developing an anonymous blockchain[10]. Moreover, the privacy issue is another challenge of interoperability, and last is the scalability challenge [11][12]. The benefits of EHR can deliver improvement based onthe quality of care and minimization of the applied cost [13]. Although, the designed system mostly remains unable to interoperate properly because of various reason. The absence of interoperability amongst several used systems may result in a reduced level in terms of quality of patient care and loss of economic resources [13]. The merits of the EHR adoption in clinics and hospitals endeavour for a unified distribution and incorporation of patient data by means of hospital procedure workflows. However, medical organizations are worried about the limitations of the IT set-up using software and hardware safety measures to protect patients' data, which can hamper EHR interoperability. Chaim (2019) investigated the constriction of safety measures to defend data of patients that could lead to potentially higher interoperability difficulties in the EHR systems installed in the hospitals [14]. Mukwaya (2020) investigated how the requirements of data in the installed EHR systems, implementation, IT platforms, and integration of different proposed models and suggestions have been assessed for catering interoperability [15]. Advanced healthcare struggling for precision medicine, modified healthcare will offer an enhanced and modernized therapeutic experience for every patient[16].

The deficiency of standardization and regulation of sharing files endures creating EHR interoperability that is a critical issue to be considered by healthcare administrations. Divergence and discrepancy in the usage of standards in health IT renders several administrations powerless for swapping records among dissimilar EHR solutions [17]. Practices of Hospitals, medical administrations, and clinicians are required to select a method that can satisfy their requirements. Heterogeneity in the EHR system and EHRs present additional complications and obstruct the sharing of information among health care organizations and medical professionals[18]. The issues of semantics, the alteration amongst restricted and unrestrained software systems, and determining confidentiality and security during the information sharing increases the struggle of attaining interoperability [19][20].

Blockchain is being used worldwide to resolve the security problems of data inherent in the process of data centralization of records in conventional EHR frameworks and have a distinct appeal to health data. Several existing blockchain-based EHR models have brought security resolutions for important security aspects of record alteration, access control, authentication, and latency[21]. However, the existing EHR framework is not developed to provide multi-platform and multi-institutional support[22]. In addition, current solutions lack the interoperability aspects that require further discussion and research. This particular research examines the interoperability challenges and issues of blockchain EHR frameworks as per the national and international standards of EHR. Furthermore, it will follow the interoperability standards in the EHR framework in terms of medical data distribution, sharing, and data dependability.

Since blockchain technology is becoming a common technology in the current business environment, its use is convenient for businesses as data is protected and processed in a decentralized manner without any threat to privacy. Although there has been extensive research on blockchain technology and its benefits, researchers have also highlighted few interoperability challenges in using blockchain technology in healthcare[23]. The research will help healthcare professionals and institutions to address the challenges by identifying them and providing recommendations for better use and implementation of blockchain.

2. Literature Review

2.1 The Current State of Interoperability and EHR

Interoperability in healthcare reflects the secure and seamless exchange of information electronically between authorized users of such information so that any unauthorized personnel cannot use such information or access it. Healthcare interoperability is complicated because it is about the health data of the patient[24]. There are many people involved in data processing, such as providers, consumers, and payers who may use the data. The National Coordinator of Health Information Technology (ONC) released what it highlighted as the roadmap to enable people and organizations to share health data with any provider safely [13]. In doing so, the ONC called all health IT stakeholders to design policies and approaches to achieve the ability to share the data without any fear of loss or theft. As a result, the investment made in the blockchain is much higher. At the same time, it has been reported that providers are yet to see a significant enhancement in the value of their investment of time, money, and effort[25].

Linn and Koo (2016) stated that interoperability in the blockchain is not just about sending the records. Still, most hospitals can now send out health data records to community-based physicians[26]. However, only 60% of hospitals can use and integrate incoming data into their EHRs[16]. Abu-Elezz et al. (2020) stated that currently, both federal and state governments worldwide are working actively to improve interoperability and have various complementary regulations in practice that drive towards a common vision. However, few rules and regulations have been created and implemented for interoperability requirements, and the majority of the providers and vendors are just doing a minimum due to other priorities[27].

De La (2017) analyzed for the identification of the existing state of knowledge related to medical information system implementation in chief care. For the analysis of the EHRs system, De La (2017) used diverse resources, typically those connected to the research of EHRs systems in diverse areas   [28]. The outcomes of this study provided the clue to the chief idea, the requirement for interoperability in between diverse systems.

2.2 Challenges to Interoperability in EHR

Kruse (2018) assess the link between EHR use in population health based on facilitators and challenges in its adoption (Kruse et al., 2018). Overall, 26 factors identified,of which 37 per cent were challenges and 63 per cent were facilitators. Seventy per cent of the facilitators comprised of efficiency in EHR 33 times increased, quality and data management elevated 19 times. Whereas 70 per cent of the barriers comprised in missing information occurring around 24 times and interoperability occurred 13 times, loss of productivity by 12 times and too complex technology occurred ten times[29].

According to Reisman (2017), the main issues in EHR interoperability is not a technological barrier but a cultural. As compare to other diligences, interoperability in medical care needs the narrow coordination and complete collaboration of numerous shareholders comprised of patients, legislators, software vendors, IT professionals and providers, Hitherto the U.S. medical care system of delivery lasts to have a culture distinct by fragmented processes, silos, and contrasting shareholders, and where information has developed as more of competitive advantage and commodity [30]

Blobel (2018) conducted a study to discuss different types of EHR, EHR standards and

implementation by considering various requirements, architecture, solutions and specifications (Blobel, 2018). The study aims to meet the challenges of interoperability by advancing EHR and PHRS. Results were based on comparing EHR standards and specifications with altering requirements, weaknesses, and modernizing EHR embedded in the modernized infrastructure. It is recommended that data models at the level of the business domain must be verified [31]

According to Evans (2016), the advancement in technology has made the hardware easily available, compact and affordable. Similarly, EHR is being revolutionized, and most of the EHRs available in medical and academic facilities are replaced with new ones. Moreover, its use is becoming common, and health care professionals are ready to learn and practice in an EHR-mediated globe. However, practical issues have been outshined by bureaucratic, social, professionals, political, and particularly ethical disputes along with the requirement for amenableness with value, standards and data security[32]. There have been massive progressions that have occupied. Still, many of the initial prospects for EHRs have not been understood and present EHRs up till now is not meeting the requirements of the modern, rapidly altering healthcare surroundings. The latest advancement in technology initiates the present use of EHR. The new changes in EHR will help provide international standards for the application of interoperability, including social, environmental, behavioural, health, and economic data. The data can be used in interpreting, communicating and acting efficiently on complex health-related information to maintain accuracy in the medicinal field and learning medical system[33].

Suess et al. (2019) carried out a retrospective cohort analysis at a Lancaster, Pennsylvania facility. Based on PCA therapy obtained prior to or after PCA-EHR interoperability, subjects were assigned to a pre-auto-documentation category with a sample size of 55 or a post-auto-documentation group with a sample size of 58. The number of patient attempts, the overall capability of infused, and the number of doses issued for pre-auto-documentation and post-auto-documentation classes were all included in the PCA therapy registration. In addition, for the class of post-auto-documentation, the full dose was registered. The primary outcome was used to determine the overall chart-field achievement score. Stratified grades measured discrete map achievement percentages dependent on secondary results [34].

3. Methodology

3.1 Systematic Review Execution

The systematic review refers to reviewingthe most relevant past papers on the topic to determine and understand what has been found regarding the topic. The review is conducted following six different stages; 1) developing a research question, 2) procedures of the research, 3) reviewing relevant articles, 4) keywords based on abstract, 5) extraction of relevant data, and 6) mapping process. Each of the steps in conducting the systematic review has been explained as under;

a. Identifying the Research Question

Developing and understanding the research question is an important step within research so that steps can be taken to address such a question. The research procedures are also based on the research questions; therefore, it is important first to design the research questions and then accordingly decide on the research procedures. Following are the research questions associated with blockchain and interoperable standards for EHR;

- What is the current state of Interoperability and EHR?
  The research question of the study is significant in understanding the present state of interoperability and EHR in the healthcare system. To address this, current research studies

need to be evaluated that will aid in overcoming the issues related to it. Consequently, solutions to the current issues can be provided.

- What can be the barriers to interoperability?
  The research aims to understand barriers to interoperability in different areas like technical barriers, financial barriers, IT usability barriers, reporting barriers, and administrative barriers. The barriers are needed to be categorized for a better understanding based on previous researches

- What are the blockchain-based solutions to the barriers to interoperability identified?
  Block-chain can modernize the method of EHR that is deposited and shared by delivering a secure approach for medical data, exchanging medical data in the field of healthcare productiveness, and safeguarding it through a dispersed peer-to-peer linkage. Several studies have provided solutions based on blockchain techniques. Many solutions have been proposed, but unfortunately, very few solutions turned to success in the form of a working prototype. Hence, implementing the proposed solutions is difficult due to several barriers. In this study, these barriers will be focused on minimizing issues in implementing the solution.

- Are these solutions currently being implemented inEHR?
  The research is based on identifying different solutions by understanding the results and methodologies of previous researches. Those proposed solutions will act as a guideline for implementing new ideas and technologies related to implementing EHR. Moreover, numerous researches have contributed by providing solutions with multiple techniques that will also help in predicting future issues and the relevant solutions.

3.2 Procedures of the Research

- **Search Strategy**

Searching of the relevant article was based on a keywords searching strategy. The keywords including EHR, blockchain, interoperability and EHR standards were written on Google scholar and Pubmed, and the range of the years selected was 2000 to 2020.

- **Inclusion-Exclusion Criteria**

The selections of relevant articles were based on the aim of the study. 156 articles were excluded as they were based purely on blockchain and had little or no part of EHR. Overall, 11 articles were found to be relevant and used for data extraction (Table 1).

- **Reviewing relevant articles**

The selected articles were screened based on provided citation by the databases.

Table 1. Inclusion and Exclusion Criteria

Criteria	Details
Exclusion	Not cited in the paper
	Published between 2000 to 2015
	Article duplication from various sources

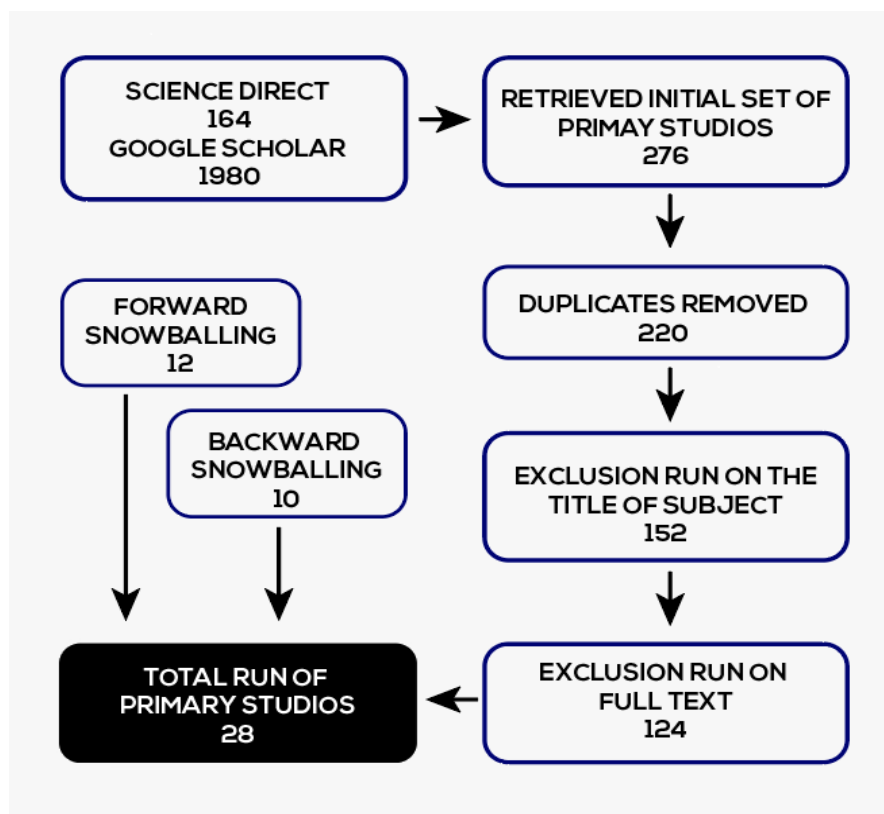|	Titles do not include the relevant keywords
Exclusion	Cited in the paper
	Published from 2015-2020
	Abstract, conclusion and conclusion relevant to the selected keywords.

Figure 1. Flowchart of inclusion and exclusion

- **Keywords based on abstract**

In every research paper, keywords are presented at the end of the abstract. This study has focused on the keywords of the papers selected in this study to include all the necessary words in the paper. The keywords used in this study are Healthcare, EHR, blockchain, interoperability and EHR standards.

- **Extraction of relevant data and Mapping process**

Subsequently, around 46 codes and 400 quotations are assembled from the outcomes. Manually, the codes are coded for the categorization of quotations. The code mapping is conducted onto the selected network in terms of a mapping process. In the given process in this paper, the link between the codes is established.

4. Findings and Discussion

4.1 Summary of challenges

In recent years, it has been observed that the healthcare industry is adopting EHR; however, several low-income countries still need to adopt EHR in their healthcare industry. In managing data, several issues are observed like data management, data security, the privacy of patients' information and many other issues, as mentioned in Table 4

4.2 Summary of solutions

Table 3 and 4 illustrate current challenges in managing patient data and the adoption of EHR in the healthcare industry.

- **Blockchain-based framework**

Block-chain based framework willhelp overcome the challenges of data security, privacy, high volume data and data sharing. The need for blockchain is increasing with time; therefore, the issues must be considered to increase the security of patients' records and manage their data efficiently. Furthermore, implementing Blockchain technology with the consideration of national and international standards will also aid the healthcare professionals to work effectively and save their time because its implementation will speed up the whole process of patient data management.

- **Innovative interoperability framework**

An innovative interoperability framework helps to share data electronically among different EHR systems. It assists in data sharing; hence, people can share data and discuss it easily with other healthcare professionals. It will also increase building knowledge of new medication and make the data available at the right time to the right person.

- **Advancement in EHR and adoption**

EHR adoption in several countries found to be difficult due to its architecture, standards and cost. Therefore, it is required to make advancements in EHR to be adopted throughout the world and help the patients and healthcare professionals manage data easily and provide the best treatment to the patients at the right time.

Table 2. Model of a method for EHR implementation

S. No.	Method/Model	Summary
1	Review of Health policies and EHR development in Kenya [10]	Delivered a guideline for challenges in implementing EHR across Africa
2.	Meta-Analysis guidelines and systematic review [11]	Identified the use and application of blockchain-based technology
3.	Use of public blockchain [12]	Controlled access to public health-related data

4.	Review of blockchain technology [13]	Identified the benefits and threats of blockchain
5.	Review of EHR adoption [14]	Identified reasons for slow implementation of EHR in healthcare
6.	Precision dosing ontology framework [15]	Investigated necessities in the EHR system, IT related area, incorporation and implementation of Model Imposed Precision Dosing (MIPD)
7	Review for adopting security techniques in EHR implementation [16]	To identify and classify advanced techniques related to security
8	Advancement in EHR [19]	Identified new features in the EHR
9	Innovative interoperability framework [21]	Effective and uniform access to, and operational usage of, the vast amount of health data stored in EHR networks installed and retained at regional and/or national levels throughout Europe.
10	PCA smart pump [22]	Charting of PCA therapy
11	Blockchain-based framework [23]	For mystification and control of knowledge, smart contracts are used in an Ethereum-based blockchain, with advanced cryptographic methodology implemented for added security.

Table 3. Solutions to the issues in EHR

S. No.	Solution	Category
1	Review of Health policies and EHR development in Kenya [10]	Optimizing the implementation process of EHR
2	Meta-Analysis guidelines and systematic review [11]	Addressing current challenges of blockchain-based health information technology
3	Use of public blockchain [12]	Engagement of the millions of people to share data
4.	Review of blockchain technology [13]	benefits and threats of blockchain
5.	Review of EHR adoption [14]	Simulating EHR adoption
6.	Precision dosing ontology framework [15]	Providing better therapeutic experience
7.	Review for adopting security techniques in EHR implementation [16]	Categorizing security techniques and measures.
8.	Advancement in EHR [19]	Identified benefits of new features and recommended training to reduce medical errors
9	Innovative interoperability framework [21]	Enlightening benefits of interoperability structure related to EHR
10	PCA smart pump [22]	substantial advances the accomplishment of opioid management chart-fields

11	Blockchain-based framework [23]	Addressed safety and security concerns and accessibility of EHR

Table 4. Category of solutions

Challenges	Solution
1. Security issues 2. High Volume of data 3. Quality of healthcare outcomes 4. Inefficient consensus algorithms 5. privacy vulnerabilities	Block-chain-based framework
1. The increasing wealth of medical information 2. Lack of legal and technical standards 3. Lack of using effective new medications in low-income countries 4. Restricted access to effective new medications 5. Data sharing	Innovative interoperability framework
1. Medical errors 2. inadequate data collection systems in low-income countries 3. paper medical record	Advancement in EHR and adoption

Several studies have been conducted related to EHR, interoperability and blockchain-based methods. As a result, there have been huge progressions in EHR and its implementation in various regions. Nevertheless, most of the previous expectations are still required to be studied further and present several new strategies in EHRs implementation. However, the identified benefits of EHR from previous research have shown a considerable improvement in encountering the present speedily altering environment in healthcare. Therefore, advancing EHR technology would aid to deliver international standards for interoperable applications based on social, health, behavioural, economic, and environmental data for interpreting, communicating, and acting logically upon multifaceted healthcare data to nurture health system and precision medicine.

Previous researches have shown that EHR is the digital record of the medical history of the patient. It has solved many issues related to data handling and its security. There are several benefits of interoperability and blockchain-based methods, which increases its importance in the health care industry. It also helps make communication easy among different healthcare departments without causing issues in the safety and security of the patient data. Studies also suggested that proper training must be given to the staff members to implement new techniques and using EHR efficiently. Researches have made a significant contribution to classifying and categorizing associated data and security techniques, measures, advantages and disadvantages of EHR. It has also found that interpreting the data from EHR is difficult for some people; therefore, improvement is required in this area so that information can be easily interpreted. The advancement in EHR will also help contribute to the research area of healthcare and patient care and security.

The goal of every healthcare department is to provide their patient with the best service, manage

their data, provide the best treatment plan and secure their data. Therefore, it is required that EHR be integrated into the healthcare industry andefficiently used by the relevant staff member. Researches have proven that EHR successfully provides up-to-date information about the patients, increasing the industry's productivity, minimizing the time and helps the relevant staff members maintain a balance between work and life. In addition, patient data can be easily transferred and stored. Moreover, researchers must focus on this area to overcome the current issues in EHR and update it by using different models and framework. It must be kept in mind that before its implementation, make sure that it is well-designed and updated with new technology to avoid hacking, and staff must be trained to avoid any issue related to consistency and accuracy.

By providing a stable solution for medical data sharing in healthcare productivity through safeguarding it via a dispersed peer-to-peer linkage, blockchain may improve the process through which electronic health records of patients are exchanged and stored. The previous study has yielded a slew of solutions for leveraging blockchain technologies to improve the current shortcomings of medical systems. Hyperledger Caliper, Composer, Hyperledger Fabric, Wireshark capture engine, and Docker Container are examples of methods and frameworks used to test the output of these structures. Mayer et al. (2020) further propose an "Access Control Policy Algorithm" for improving the usability of knowledge amongst medical professionals and assisting in the modelling of environments for using the "Hyperledger-driven electronic healthcare record (EHR) sharing scheme" based on the concept of a chain-code. The research has illustrated the problems and alternatives of blockchain in EHR by comparing it to EHR norms [12]. It can effectively store and distribute by providing nonviolent channels for health knowledge transmitted from medical data throughout the healthcare industry by securing it through a decentralized peer-to-peer network.

The research has helped to identify the problems and concerns with EHR interoperability. Recent research has shown a surge of momentum to improve patients' ability to view their own health records. Even then, there has been some debate on whether or not patients can have access to their medical history and results.

5. Conclusion

EHR is the digital record of the medical history of the patient. It has solved many issues related to data handling and its security. A detailed study is required to implement this technology under modern technology and standards to minimize errors in integration. The deficiency of standardization and regulation of sharing files endures to create EHR interoperability, and issues in implementing blockchain method is an important issue that has to be considered by healthcare administrations. EHR that will be used in the healthcare department must be integrated by any professional so that errors can be reduced and hacking chances can be minimized. Standards related to EHR must be implemented to be done effectively under specific rules and regulations. The challenges and issues that are reviewed in this research are based on blockchain and interoperability of EHR. The tables represented in this research compiled the models and methods from previous research to resolve these issues. A total of 11 methods and related solutions are identified in this report. It will help study the associated challenges and solution in EHR implementation and help manage the data and maintain information related to the patient. Innovative interoperability framework and blockchain-based framework found to be successful in enlightening its benefits. However, further research is required to evaluate its implementation rate and how much the previous research successfully overcameits issues. Researchers are still

working on the identification of new features of EHR and bringing innovation to this. Researchers can take help from this report for evaluating the benefits of blockchain and interoperability of EHR.

References

[1]   S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008.

[2]   Reegu Faheem, Zada Khan Wazir, Mohd Daud Salwani, Arshad Quratulain, and Armi Nasrullah, "A Reliable Public Safety Framework for Industrial Internet of Things (IIoT)," *Proceeding - 2020 Int. Conf. Radar, Antenna, Microwave, Electron. Telecommun. ICRAMET 2020*, pp. 189–193, Nov. 2020, doi: 10.1109/ICRAMET51080.2020.9298690.

[3]   P. Zhang, J. White, D. C. Schmidt, and G. Lenz, "Applying Software Patterns to Address Interoperability in Blockchain-based Healthcare Apps," 2017.

[4]   M. U. Bokhari and S. Alam, "BSF-128: a new synchronous stream cipher design," in *Proceeding of international conference on emerging trends in engineering and technology*, 2013, pp. 541–545.

[5]   I. Alshourbaji *et al.*, "An Approach To Weigh Cybersecurity Awareness Questions In Academic Institutions Based On Principle Component Analysis: A Case Study Of Saudi Arabia Digital forensic project View project Factors motivating inside threat attacks View project An Approach To ," *Indep. Res. Soc. Media. Areas Incl. Res. ethics*, 2021.

[6]   S. T. Siddiqui, R. Ahmad, M. Shuaib, and S. Alam, "Blockchain Security Threats, Attacks and Countermeasures," in *Advances in Intelligent Systems and Computing*, 2020, vol. 1097, pp. 51–62, doi: 10.1007/978-981-15-1518-7_5.

[7]   M. Shuaib, S. Alam, S. Daud, and S. Ahmad, "Blockchain-Based Initiatives in Social Security Sector," in *EAI 2nd International Conference on ICT for Digital, Smart, and Sustainable Development (ICIDSSD)*, 2021, p. 8, doi: 10.4108/eai.27-2-2020.2303256.

[8]   M. Shuaib, S. Alam, M. Shahnawaz Nasir, and M. Shabbir Alam, "Immunity Credentials using Self-Sovereign Identity for combating COVID-19 Pandemic," *Mater. Today Proc.*, Mar. 2021, doi: 10.1016/j.matpr.2021.03.096.

[9]   A. Raghuvanshi, U. Kumar Singh, M. Shuaib, and S. Alam, "An investigation of various applications and related security challenges of Internet of things," *Mater. Today Proc.*, Mar. 2021, doi: 10.1016/j.matpr.2021.01.821.

[10]   M. Shuaib, S. M. Daud, S. Alam, and W. Z. Khan, "Blockchain-based framework for secure and reliable land registry system," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 5, pp. 2560–2571, Oct. 2020, doi: 10.12928/TELKOMNIKA.v18i5.15787.

[11]   W. J. Gordon and C. Catalini, "Blockchain Technology for Healthcare: Facilitating the Transition to Patient-Driven Interoperability," *Comput. Struct. Biotechnol. J.*, vol. 16, pp. 224–230, 2018, doi: 10.1016/j.csbj.2018.06.003.

[12]   F. A. Reegu, M. O. Al-Khateeb, W. A. Zogaan, M. R. Al-Mousa, S. Alam, and I. Al-Shourbaji, "Blockchain-Based Framework for Interoperable Electronic Health Record," *Ann. Rom. Soc. Cell Biol.*, vol. 25, pp. 6486–6495, Mar. 2021.

[13]   M. Ciampi, A. Esposito, R. Guarasci, and G. De Pietro, *Towards Interoperability of EHR Systems:*

The Case of Italy. 2018.

[14]   R. M. Chaim, E. C. Oliveira, and A. P. F. Araujo, "Technical specifications of a service-oriented architecture for semantic interoperability of EHR - Electronic health records," Jul. 2017, doi: 10.23919/CISTI.2017.7975923.

[15]   J. N. Mukwaya, "An Investigation of Semantic Interoperability with EHR systems for Precision Dosing JOVIA NAMUGERWA MUKWAYA KTH ROYAL INSTITUTE OF TECHNOLOGY SCHOOL OF ENGINEERING SCIENCES IN CHEMISTRY, BIOTECHNOLOGY AND HEALTH," 2020.

[16]   F. A. Reegu, S. M. Daud, S. Alam, and M. Shuaib, "Blockchain-based Electronic Health Record System for efficient Covid-19 Pandemic Management," 2021, doi: 10.20944/preprints202104.0771.v1.

[17]   M. Shuaib, S. Alam, M. Shabbir Alam, and M. Shahnawaz Nasir, "Compliance with HIPAA and GDPR in blockchain-based electronic health record," *Mater. Today Proc.*, 2021, doi: https://doi.org/10.1016/j.matpr.2021.03.059.

[18]   X. Zhang and S. Poslad, "Blockchain Support for Flexible Queries with Granular Access Control to Electronic Medical Records (EMR)," *IEEE Int. Conf. Commun.*, vol. 2018-May, 2018, doi: 10.1109/ICC.2018.8422883.

[19]   S. Bhartiya, D. Mehrotra, and A. Girdhar, "Issues in achieving complete interoperability while sharing electronic health records," *Procedia Comput. Sci.*, vol. 78, pp. 192–198, 2016.

[20]   S. Mehta, K. Grant, and A. Ackery, "Future of blockchain in healthcare: potential to improve the accessibility, security and interoperability of electronic health records," *BMJ Heal. Care Inf.*, vol. 27, p. 100217, 2020, doi: 10.1136/bmjhci-2020-100217.

[21]   M. U. Bokhari, S. Alam, and S. H. Hasan, "A Detailed Analysis of Grain family of Stream Ciphers.," *Int. J. Comput. Netw. Inf. Secur.*, vol. 6, no. 6, 2014.

[22]   A. Ekblaw, A. Azaria, J. D. Halamka, A. Lippman, and T. Vieira, "A Case Study for Blockchain in Healthcare: 'MedRec' prototype for electronic health records and medical research data White Paper MedRec: Using Blockchain for Medical Data Access and Permission Management IEEE Original Authors," 2016.

[23]   T. McGhin, K. K. R. Choo, C. Z. Liu, and D. He, "Blockchain in healthcare applications: Research challenges and opportunities," *Journal of Network and Computer Applications*, vol. 135. pp. 62–75, Jun. 2019, doi: 10.1016/j.jnca.2019.02.027.

[24]   N. Muinga *et al.*, "Implementing an Open Source Electronic Health Record System in Kenyan Health Care Facilities: Case Study.," *JMIR Med. informatics*, vol. 6, no. 2, p. e22, Apr. 2018, doi: 10.2196/medinform.8403.

[25]   M. Shuaib, S. Alam, M. Shabbir Alam, and M. Shahnawaz Nasir, "Self-sovereign identity for healthcare using blockchain," *Mater. Today Proc.*, Mar. 2021, doi: 10.1016/j.matpr.2021.03.083.

[26]   L. A. Linn, "Blockchain For Health Data and Its Potential Use in   Health IT   and   Health Care   Related Research," *truevaluemetrics*, 2015. .

[27]   I. Abu-elezz, A. Hassan, A. Nazeemudeen, M. Househ, and A. Abd-alrazaq, "The benefits and threats of blockchain technology in healthcare: A scoping review," *International Journal of Medical Informatics*, vol. 142. Elsevier Ireland Ltd, p. 104246, Oct. 2020, doi:

10.1016/j.ijmedinf.2020.104246.

[28]   I. De La Torre, S. González, and M. López-Coronado, "Analysis of the EHR systems in spanish primary public health system: The lack of interoperability," *J. Med. Syst.*, vol. 36, no. 5, pp. 3273–3281, Oct. 2012, doi: 10.1007/s10916-011-9818-7.

[29]   C. S. Kruse, B. Smith, H. Vanderlinden, and A. Nealand, "Security Techniques for the Electronic Health Records," *J. Med. Syst.*, vol. 41, no. 8, 2017, doi: 10.1007/s10916-017-0778-4.

[30]   M. Reisman, "EHRs: The challenge of making electronic data usable and interoperable," *P T*, vol. 42, no. 9, pp. 572–575, 2017.

[31]   B. Blobel, "Interoperable EHR Systems - Challenges, Standards and Solutions," *Eur. J. Biomed. Informatics*, vol. 14, no. 2, 2018, doi: 10.24105/ejbi.2018.14.2.3.

[32]   H. van der Linden, D. Kalra, A. Hasman, and J. Talmon, "Inter-organizational future proof EHR systems. A review of the security and privacy related issues," *International Journal of Medical Informatics*, vol. 78, no. 3. Elsevier, pp. 141–160, Mar. 2009, doi: 10.1016/j.ijmedinf.2008.06.013.

[33]   J. Dennis-Wall, S. Bajracharya, and T. Nguyen, "How Virtual Trials Support Patient-Centricity Revolutionizing Clinical Research: How Virtual Trials Support Patient-Centricity."

[34]   E. F. Jesus, V. R. L. Chicarino, C. V. N. De Albuquerque, and A. A. D. A. Rocha, "A Survey of How to Use Blockchain to Secure Internet of Things and the Stalker Attack," *Secur. Commun. Networks*, vol. 2018, 2018, doi: 10.1155/2018/9675050.