



## A Consensus-Driven Architecture for Privacy-Preserving Healthcare Data Management Exchange Using Blockchain

Nada Ratkovic

*Faculty of Economics, Business and Tourism, University of Split, Split, Croatia*

### ARTICLE INFO

#### Keywords:

Blockchain Technology,  
Data security, Data  
Management, Healthcare  
sector

Received: Jan, 29, 2025

Accepted: Mar, 11, 2025

Published: Jun, 25, 2025

### ABSTRACT

With the growing use of digital data in healthcare systems, the issue of data security, integrity, and interoperability has become critical. The blockchain technology has come out as a promising solution to such challenges. The present systematic review represents an in-depth analysis of the existing literature on the topic of blockchain use in healthcare data management. It starts by defining the basic concepts of blockchain technology as well as its possible applications in improving data security, immutability, and decentralized control in healthcare settings. The review then methodically classifies and examines the recent scholarly articles, case studies, and real-world initiatives of blockchain implementations in healthcare. The review presents existing challenges, areas of opportunity, and prevailing trends based on a critical synthesis of the literature. It emphasizes the role of blockchain in revolutionizing healthcare data practices through creating patient-centric solutions that are secure and transparent. This review informs researchers, healthcare practitioners, and policymakers on the present situation, the practical implications, and the future on the application of blockchain technology in the digital transformation of healthcare. With the development of the sector, blockchain has a significant role in determining the future of healthcare data management and delivery.

### 1. INTRODUCTION

Healthcare organizations throughout the world face a paradoxical dilemma in the age of digital transformation: the exponential growth of health data combined with ongoing worries about data security, integrity, and interoperability (Odeh et al., 2022). The enormous volumes of private patient data created and maintained digitally necessitate creative solutions that guarantee accessibility and privacy. Blockchain technology is originally designed to work with cryptocurrencies, but now it has turned into a game-changer in the healthcare sector as it offers a clear, secure, and decentralized platform on which data management is conducted. This systematic review aims to provide a critical and up-to-date study of a fast-evolving subject of

"Blockchain for Healthcare Data Management." It is impossible to emphasize the significance of a good and safe healthcare data management system (Mohanta et al., 2018). They are very likely to make errors, easily hacked, and often face a problem of interoperability when patient information is not easily exchanged between different healthcare systems and care providers. These issues hinder the provision of quality and informed healthcare besides putting patient privacy at risk (Shrimali and Patel, 2021).

The blockchain technology has emerged as a solution to the data issues afflicting the healthcare sector. It became popular first as the foundation of cryptocurrencies, such as Bitcoin. Blockchain is a decentralized registry framework based on

cryptographic mechanisms to ensure immutability, transparency, and security by storing data with the help of a network of nodes (Girardi et al., 2020). Due to these attributes, it is particularly desirable to healthcare data management, where interoperability, trust, and data integrity are essential. This systematic review aims to analyze the current state of the blockchain-based healthcare data management research and practice. It also seeks to give a clear insight into the key themes, challenges, and opportunities that blockchain technology presents to the healthcare sector through an organized assessment of the existing research body. The final aim of this review is to assist researchers, and healthcare professionals to recognize how blockchain can be adopted to resolve the multifaceted data management issues within the healthcare sector. Moreover, the aim of this review is to determine new uses, new trends, and research directions. In the following sections, we will discuss the most important concepts of blockchain technology, its applications, and their relevance to patient-centered care models, interoperability, and the security of healthcare information. Moreover, we will consider challenges and barriers associated with the adoption of blockchain technology in the healthcare sector, preconditioning a profound and insightful analysis of the existing state of affairs. The concept of blockchain can transform the entire healthcare data management process in the digital era. It will ensure data access, privacy and integrity and usher in a new age of both trust and innovativeness in healthcare provision.

### *1.1. Contributions to the Healthcare Industry*

The study results determine the revolutionary power of blockchain technology in healthcare data management, where it offers superior security, transparency, and patient empowerment, solving decades-old problems in the healthcare industry. This field of research and innovation will still affect healthcare data management. It was known that research demonstrated the ability to protect unauthorized access, tampering, and data breaches in such a way that patient records are confidential and unchanged (Mettler and Hsg, 2016). Nonetheless, blockchain makes it easier to interoperate data because healthcare records are represented in a uniform format. It allows patient data to be easily shared among other healthcare

providers so that service coordination is enhanced and medical errors are minimized.

Blockchain smart contracts allow patients to gain more control over their data. There has been research done to create consent management systems in which patients can give or withdraw their access to healthcare records, increasing their privacy and data autonomy.

The immutable ledger of the blockchain technology ensures the creation of an exhaustive audit trail of data access and modifications. Researchers have explored how traceability can be used to track the flow of health data, enable accountability, and comply with legal requirements like GDPR and HIPAA. It is important to ensure that pharmaceutical products are legitimate as well as secure. With the help of blockchain technology, medication supply chains will become transparent and immutable, reducing the risk of counterfeit drugs and enhancing patient safety.

Credentialing systems which are based on blockchain will help reduce the administrative load and also fast-track the verification process. Research has been conducted on how to use blockchain technology to develop verifiable and tamper-proof credentials of medical professionals, including nurses and doctors.

To blockchain technology, patients can keep their health-related information under their control. Studies have also examined new business models which have the potential to completely transform the process of monetizing patient data in the health sector by enabling patients to choose whether or not to reveal their data in return of incentives or compensation. The automation and decentralization of administrative functions made possible by blockchain technology can reduce the administrative expenses of the healthcare sector. It has also been demonstrated that blockchain technology allows faster insurance verification, billing, and claims processing.

## 2. LITERATURE REVIEW

Blockchain technology has been increasingly being understood for its security-boosting capabilities for healthcare data. Allouche et al. (2021) in their paper Blockchain for Secure and Privacy-Preserving Sharing of PHR in Cloud Computing showed the potential of blockchain in securing the integrity and confidentiality of PHR stored in cloud-based systems. Overall, their work

underscores the importance of cryptographic mechanisms and decentralised storage systems in protecting against unauthorised access and data tampering. Further, another key challenge that exists in healthcare is dealing with patient consent, which Nazir et al. (2018) addressed by implementing blockchain-based access control mechanisms. By using smart contracts, their platform can provide granular access control, allowing patients to have more control over who can access their data while ensuring compliance with data privacy regulations.

In addition to facilitating secure access to data, the immutability and transparency of blockchain technology have been considered as solutions for healthcare accountability and regulatory compliance. Khan et al. (2023) said that blockchain reflected autonomy of patients, because it can't be altered without a notification or warning, that in turn would lead to better privacy protection. Similarly, other proposals such as Macrinici et al. (2018) and Khubrani (2021) proposed blockchain-based audit trail systems to allow us to observe data usage and data changes, so as to give assurance on compliance with the data protection regulation. Besides clinical care, Kuo et al. (2020) reviewed the application of blockchain in clinical research where safe data sharing can speed up drug discovery, and increase reveal of clinical trials. These studies together reveal blockchain's importance to maintain both data integrity and regulatory accountability in the various domains of healthcare.

The pharmaceutical industry has also seen benefits from blockchain's ability to provide product authenticity and supply chain security. Writing in the Journal of the Academy of Global Health Information Technology, Khubrani (2021) and Odeh et al. (2022) highlighted the use of blockchain to reduce the circulation of counterfeit drugs by using an immutable ledger to track the supply chain. This capability not only ensures patient safety but also bolsters trust in pharmaceutical distribution networks. Furthermore, blockchain solutions have simplified an otherwise labor-intensive and time-consuming process known as healthcare credentialing. Huang and Foysal (2021) and Khubrani (2021) proposed blockchain

### 3. RESEARCH DESIGN

This section describes the methodological

credentialing systems that can facilitate secure and standardized verification of healthcare professionals while reducing administrative burdens and ensuring workforce reliability. In addition, blockchain has created new business models for patient data management. Lakhan et al. (2021) suggested that patients could commercialize their health data and maintain full ownership, thus changing ownership structures and enabling appropriate utilization of such data in an ethical manner.

More recently, blockchain has been described as a transformative technology that can help solve the longstanding problems associated with managing health care data, in particular the challenge of security, interoperability, and patient privacy. Annam et al. (2023) focused on privacy protection mechanism of cloud-based PHRs with blockchain, while Almalki et al. (2022) demonstrated that blockchain can enhance the interoperability with easy data transportation among providers. Khan et al. (2023) further extended blockchain-based access control systems that provide ownership and decision-making to the patients. Together, these academic contributions show the various ways in which blockchain can be applied in healthcare (such as secure data storage and sharing, credentialing, and supply chain management) and form the basis for further research and development in this area

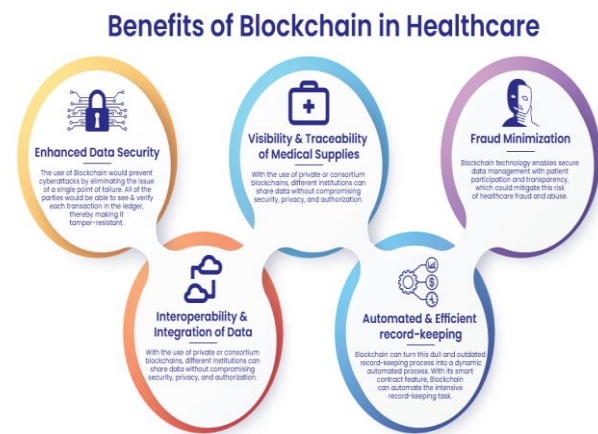


Figure 1: Benefits of Blockchain Technology in Healthcare

approach taken for the study. The research was carried out following the systematic literature review (SLR) process, which includes eight

sequential steps: planning and defining research problem, searching the literature, collecting relevant data, appraising the quality of the studies, synthesising and analysing the findings, interpreting the results, presenting the evidence, and updating the review where needed. This formalized approach has been widely applied to similar scientific studies since it was presented by Thome et al. (2016).

In the early planning and formulation stage, a Rapid Review (RR) was carried out to decide whether a new review was justified, namely, by searching for existing SLRs on the topic (Thome et

al., 2016). Based on the SLR procedure, three research questions were formulated as shown in Section 1. In order to guide the literature search, two broad keyword clusters, namely, Blockchain Technology and Healthcare Data Management, were created which capture the phenomenon being examined. These clusters were further expanded and classified, to extract relevant keywords, in order to retrieve studies that were specifically related to the implementation of the blockchain technology within healthcare data management, both in isolation and in synergy with other digital solutions.

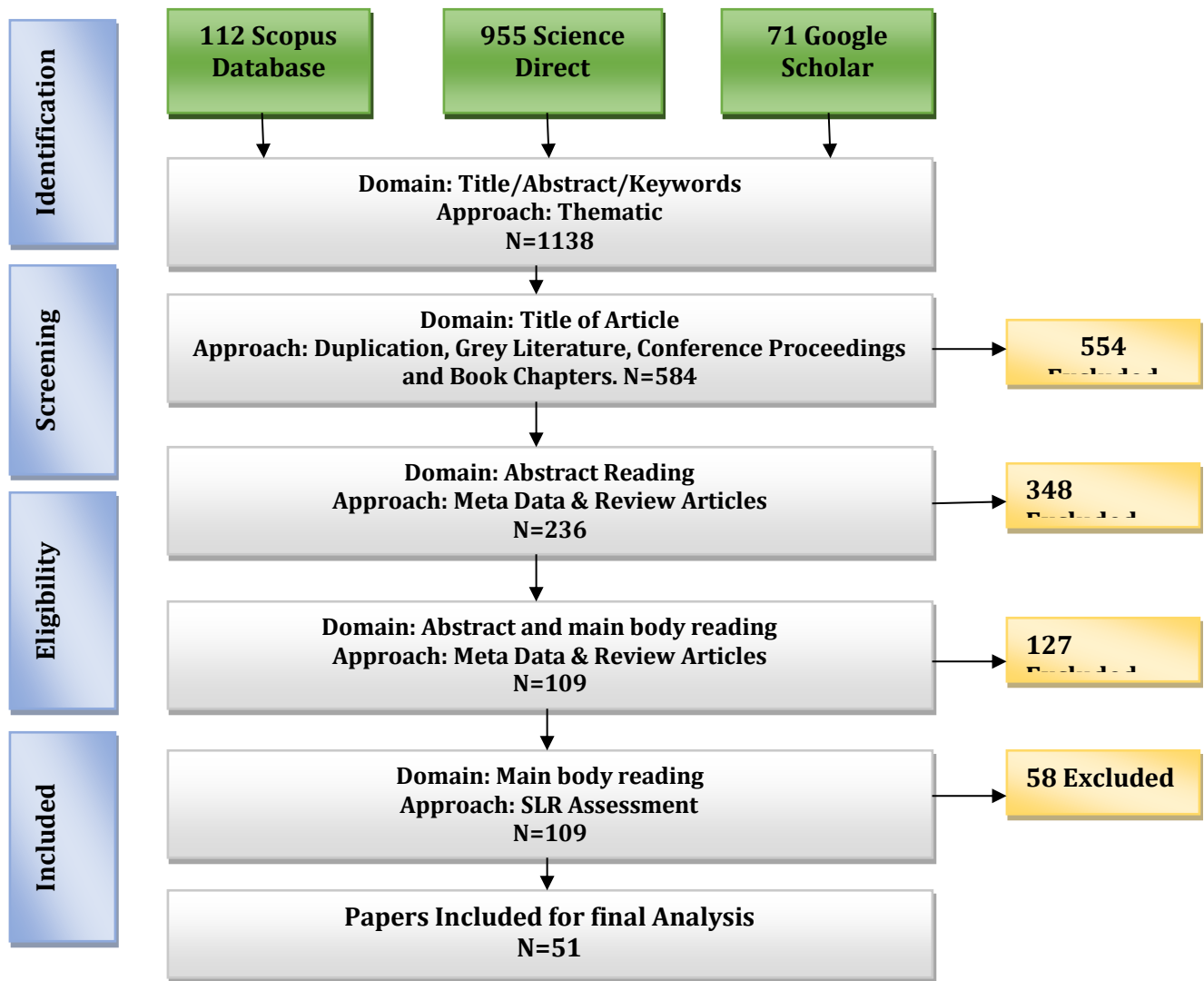


Figure 2: Literature Research Protocol

This search turned up 1138 items in total, comprising 112 papers from Scopus, 955

publications from Science Direct, and 71 articles from Google Scholar. By eliminating duplicates, restricting studies to the English language, and

only incorporating peer-reviewed publications or conferences, the original database results were combined.

Table 1: Overall SLR Assessment Criteria

| Search String Input (Databases – Advanced Search)  | Quality Assessment Dimensions | Quality Assessment Questions ( <i>Adapted from Dybå &amp; Dingsøyr, 2008</i> )  | Eligibility Questions (Full-Text Review Stage)   | Screening |
|--|-------------------------------|---|--|-----------|
| “Blockchain”, “Data Security”, “Data Management”, “Communication”, “Patient Records”, “Electronic Data”, “Healthcare Digitalization”, “Digital Health”, “Patient Data Management”, “Security”, “Privacy”, “Data Confidentiality”, “Digital Diagnosis”. | Accuracy of the Study         | - Has the study applied a rigorous and suitable research methodology? - Are the research objectives clearly defined and aligned with the methods used?                                    | - Is this a technical research paper addressing computational performance, security mechanisms, or design issues of blockchain systems?  |           |
|  | Credibility of the Study      | - Does the study provide reliable evidence (e.g., empirical data, case studies, or validated frameworks)? - Are findings presented transparently and supported by data or prior research? | - Is this a review or informative paper that systematically synthesizes secondary research? - Does the article conclude by explicitly proposing blockchain technology (BCT) as a healthcare solution?  |           |
|  | Relevance of the Study        | - Does the study contribute to the understanding of blockchain adoption in healthcare? - Are implications for healthcare digitalization, data management, or security clearly addressed?  | - Does the paper explicitly focus on blockchain integration within healthcare systems (e.g., electronic patient records, data privacy, healthcare digitalization)? - Are the findings useful for both academic researchers and healthcare practitioners? |           |

#### 4. RESULTS OF SYSTEMATIC LITERATURE REVIEW (SLR)

##### 4.1. Bibliometric Analysis

The bibliometric analysis for the chosen publications is summarized in Figure 3. To evaluate the trends in the number of studies on the subject, Figure 3 shows the distribution of publications by year. In conclusion, no research had been found on the topic before to 2010, which makes sense considering that the healthcare industry was the first to contemplate using BCT. Research publications have increased annually till 2020. It should be noted that we chose 25 papers from 2022 (the most recent search was completed in 2023), suggesting that interest in the topic has been growing among academics, researchers and professionals.

Despite a promising the future arise; it is important to recognize that enabling technologies integrated with the BCT are displayed in Figure 4. The results showed that 29% of studies treated blockchain integration with internet of things technology. This makes logical because BCT is still in its early stages, and scientists are still trying to fully grasp the technology in healthcare sector as well. The majority of the studies included a variety of 4.0 enabling technologies, indicating that researchers generally agree that the blockchain technology can gain new advantages from the smooth integration of two domains. These results are expected considering the two's compatibility and the complementary features provided by BCT.

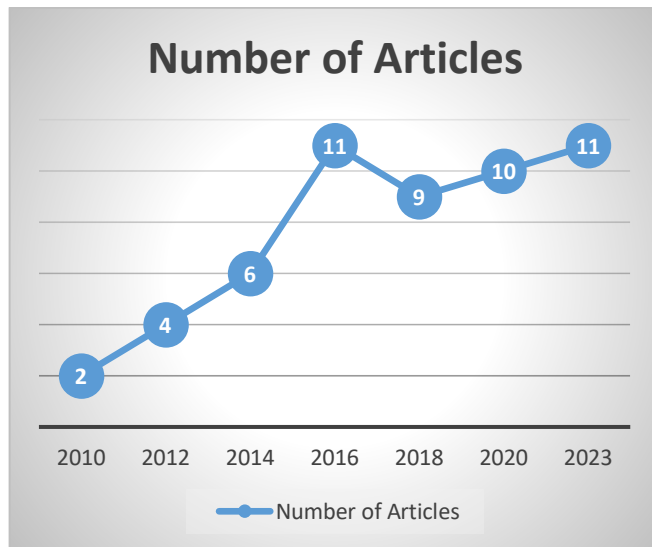


Figure 3: Year of Publications

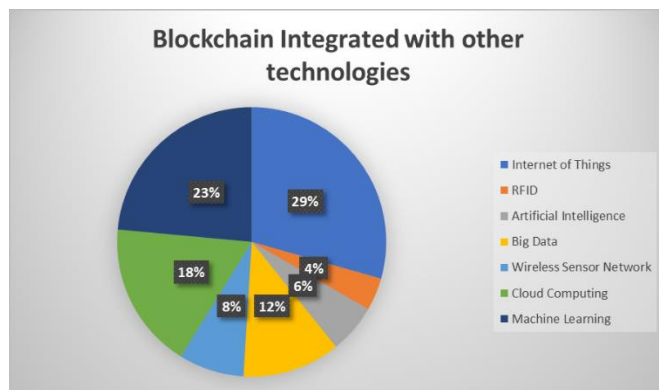


Figure 4: Technologies integration with Blockchain

## 5. DISCUSSION

### 5.1. Applications of Blockchain Technology in Healthcare Data Management

In order to answer the research questions, this study conducted an extensive review of the literature around healthcare data management and blockchain technology. The research highlights how blockchain can play a significant role in improving the security, privacy, and interoperability of healthcare data, while overcoming long-standing challenges in healthcare data governance. Its uses are varied and cover many key areas of healthcare delivery and management.

- *Secure Electronic Health Records (EHRs)*

Blockchain can be used to create tamper-proof systems for handling electronic health records. By encrypting patient data and linking it to a decentralized ledger, blockchain not only ensures the confidentiality of medical data but also its

integrity. The infrastructure enables records among healthcare providers to be shared securely while safeguarding patient privacy (Saeed et al. 2022).

- *Data Interoperability and Exchange*

One of the key challenges in healthcare systems is data siloing, where different institutions use different formats and standards for their data. Blockchain provides a standardized and secure way to exchange information, which improves interoperability between different systems. This capability not only results in better coordination of care but also leads to better outcomes for patients through the seamless flow of information (Almalki et al., 2022).

- *Clinical Trials and Research*

Blockchain-based solutions can play a crucial role in enhancing transparency and traceability in clinical research. Smart contracts can be used to automate trial protocols, ensuring that data is reported accurately and reducing the risk of manipulation or fraud. These capabilities provide researchers with access to both secure and unforgeable data on a real-time basis, expediting research and in turn increasing the fidelity of clinical trial results (Huang and Foysal 2021).

- *Pharmaceutical Supply Chain Management*

Blockchain applications can also be extended to pharmaceutical logistics, providing end-to-end visibility of the supply chain. Immutability of the production, shipping, and distribution process means stakeholders can track drug movements, and anti-counterfeit measures can be put in place more efficiently along with more efficient recalls. This helps to ensure better product authenticity, patient safety, and regulatory compliance (Ghosh et al., 2023).

- *Patient-Generated Data and Health Records*

In addition to institutional use, blockchain allows patients to be active in the management of their health data. Patients can add information from wearables, lifestyle tracking, and self-reporting into their medical records while preserving data integrity and having more control over access and consent. This patient-first practice allows for personalized healthcare and helps create trust between patients and providers (Odeh et al., 2022). A review of the literature highlights blockchain's transformative impact on healthcare data management, particularly in terms of enhancing security, transparency, and efficiency. However,

successful adoption must be carefully aligned to the sector's organizational, technical and regulatory context. While cryptocurrency's decentralized and cryptographic nature makes it resistant to breaches and unauthorized access, blockchain is vulnerable to scalability, governance, and compliance challenges. In any case, it is clear that continued development in standards and technology will be key to future adoptions, as well as policies that will enable secure interoperability and manage ethical implications related to data ownership.

In addition, the inherent immutability of blockchain has the potential to ensure data integrity, which is a key prerequisite for accurate diagnosis, treatment, and research. The concept of smart contracts takes its applications even further, enabling automation of processes such as data-sharing agreements, insurance claims, and billing - which can eliminate errors, while also saving administrative time. In clinical research, blockchain can provide an accurate audit trail to increase transparency and allow scientists to collaborate. In addition, its traceability features are useful in pharmaceutical supply chains to reduce the risk of counterfeit drugs and to verify the authenticity of prescriptions or medications. Taken together, these contributions offer a clear view that blockchain is poised to play an increasingly important role in healthcare, transforming how data is secured, distributed, and managed across the sector.

## 6. CONCLUSION

As research continues, the authors suggest that there is growing interest in the transformative potential of blockchain within healthcare, and specifically in its ability to tackle longstanding issues of data security, integrity and interoperability. For example, the literature shows a wide agreement that blockchain can help in solving some serious problems such as violations of privacy, data breaches, and the lack of a reliable and standardized exchange of health information. By providing a decentralized, immutable, and tamper-resistant infrastructure, blockchain creates an exciting new foundation for rethinking how healthcare data is stored, accessed, and shared. This technology can contribute to enhancing trust, transparency and accountability throughout the healthcare ecosystem, by facilitating secure patient centric and auditable

data flow.

Furthermore, there are many applications of blockchain in the healthcare industry from secure patient data management and electronic health records (EHRs) to clinical trial transparency to pharmaceutical supply chain monitoring and insurance billing and claims processing. This adaptability highlights the fact that blockchain is not a one-size-fits-all or static solution, but rather an adaptable technology that can be customized to suit the specific needs of various stakeholders, including patients, healthcare providers, regulators, and insurers. These applications are some of the best examples of blockchain as an enabling technology that can be aligned with the specific challenges faced in the sector while providing robust security and transparency.

In the future, blockchain has the potential to act as a building block for a more efficient, secure, and collaborative healthcare ecosystem. But realizing this vision involves overcoming several intractable problems. Innovators are facing significant challenges in scalability, regulatory compliance, interoperability with legacy healthcare systems, and the development of technical and governance standards. The integration of blockchain into healthcare will require the creation of favorable policies, cost-effective integration models and interoperable platforms. In addition, it will be important to facilitate cross-sectoral collaboration to ensure that progress is made within an ethical, legal and organisational framework.

- *Challenges, Limitations, and Future Research*

As promising as it is, blockchain adoption in healthcare is still hindered by technical, economic, and regulatory challenges. Scalability challenges, lack of standardization and interoperability across blockchain platforms, and difficulty in developing standardized workflows remain obstacles to widespread implementation. Furthermore, an efficient approach to the implementation of blockchain with various types of health information systems is imperative to avoid unnecessary expenditures for healthcare organizations. Future research should therefore be more application-oriented and based on real-world case studies, while placing greater importance on the development of internationally recognized standards to enable integration. Ultimately, the successful adoption of blockchain in healthcare will

require a concerted effort from researchers, healthcare professionals, policymakers, and technology developers to break down barriers and realize its full potential for revolutionizing healthcare data management.

## REFERENCES

- Allouche, M., Mitrea, M., Moreaux, A., Kim, S.-K., 2021. Automatic Smart Contract generation for Internet of Media Things. *ICT Express* 7, 274–277.
- Almalki, J., Al Shehri, W., Mehmood, R., Alsaif, K., Alshahrani, S.M., Jannah, N., Khan, N.A., 2022. Enabling Blockchain with IoMT Devices for Healthcare. *Information* 13, 448.
- Anaam, E., Hasan, M.K., Ghazal, T.M., Haw, S.C., Alzoubi, H.M., Alshurideh, M.T., 2023. How Private Blockchain Technology Secure IoT Data Record. 2023 IEEE 2nd Int. Conf. AI Cybersecurity, ICAIC 2023 2023, 2023.
- Ghazal, T.M., Alshurideh, M.T., Alzoubi, H.M., 2021. Blockchain-Enabled Internet of Things (IoT) Platforms for Pharmaceutical and Biomedical Research, in: *The International Conference on Artificial Intelligence and Computer Vision*. pp. 589–600.
- Ghosh, P.K., Chakraborty, A., Hasan, M., Rashid, K., Siddique, A.H., 2023. Blockchain Application in Healthcare Systems: A Review. *Systems* 11.
- Girardi, F., De Gennaro, G., Colizzi, L., Convertini, N., 2020. Improving the healthcare effectiveness: The possible role of EHR, IoMT and Blockchain. *Electron.* 9.
- Huang, G., Foysal, A. Al, 2021. Blockchain in Healthcare. *Technol. Invest.* 12, 168–181.
- Khan, Z.A., Amjad, S., Ahmed, F., Almasoud, A.M., Imran, M., Javaid, N., 2023. A Blockchain-Based Deep-Learning-Driven Architecture for Quality Routing in Wireless Sensor Networks. *IEEE Access* 11, 31036–31051.
- Khubrani, M.M., 2021. A Framework for Blockchain-based Smart Health System. *Turkish J. Comput. Math. Educ.* 12, 2609–2614.
- Lakhan, A., Mohammed, M.A., Rashid, A.N., Kadry, S., Panityakul, T., Abdulkareem, K.H., Thinnukool, O., 2021. Smart-contract aware ethereum and client-fog-cloud healthcare system. *Sensors* 21.
- Macrinici, D., Cartofoeanu, C., Gao, S., 2018. Smart contract applications within blockchain technology: A systematic mapping study. *Telemat. Informatics* 35, 2337–2354.
- Mettler, M., Hsg, M.A., 2016. 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services, Healthcom 2016. 2016 IEEE 18th Int. Conf. e-Health Networking, Appl. Serv. Heal. 2016 16–18.
- Mohanta, B.K., Panda, S.S., Jena, D., 2018. An Overview of Smart Contract and Use Cases in Blockchain Technology, in: *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. pp. 1–4.
- Nguyen, C. V, Nguyen, M.T., Le, T.T.H., Tran, T.A., Nguyen, D.T., 2021. Blockchain Technology in Wireless Sensor Network : Benefits X, 1–4.
- Odeh, A., Keshta, I., Al-Haija, Q.A., 2022. Analysis of Blockchain in the Healthcare Sector: Application and Issues. *Symmetry (Basel)*. 14.
- Saeed, H., Malik, H., Bashir, U., Ahmad, A., Riaz, S., Ilyas, M., Bukhari, W.A., Khan, M.I.A., 2022. Blockchain technology in healthcare: A systematic review, *PLoS ONE*.
- Shrimali, B., Patel, H.B., 2021. Blockchain state-of-the-art: architecture, use cases, consensus, challenges and opportunities. *J. King Saud Univ. - Comput. Inf. Sci.*
- Thomé, A.M., Scavarda, L., Scavarda, A., 2016. Conducting systematic literature review in operations management. *Prod. Plan. Control* 27, 1–13.