Blockchain Technology in Healthcare: A Systematic Review with a Focus on Sri Lanka

R. Vaishali and G. Vijayakanthan

Abstract *This review systematically explores the application of blockchain technology (BT) in healthcare, highlighting its challenges and potential solutions. A literature search was conducted across databases such as PubMed, IEEE Xplore, and Scopus, covering studies published in 2023 and 2024. Eligibility criteria included peer-reviewed articles that provide empirical data, theoretical insights, or practical implementations of BT in healthcare, resulting in the selection of 27 studies. Key technical challenges identified are storage maintenance, security, throughput, and scalability, while non-technical challenges involve social acceptance, regulatory compliance, and lack of standards. Proposed solutions include hybrid storage models, advanced access control, novel consensus algorithms, and layer-2 scaling techniques. The review also discusses BT's application in Sri Lanka, emphasizing its potential to enhance Electronic Health Record (EHR) systems, pharmaceutical supply chain tracking, telemedicine platforms, clinical trial management, and medical credential verification. The findings suggest that while BT offers significant benefits for secure and efficient healthcare data management, its implementation requires overcoming both technical and regulatory barriers. Future research directions include integrating BT with Artificial Intelligence (AI) and the Internet of Things (IoT), leveraging smart contracts, and developing patient-centered health record systems. This review underscores BT's potential as a transformative tool in healthcare, offering insights into its applications and providing a basis for future studies.*

***Index Terms*— Blockchain, Electronic Health Record, Healthcare, Security**

I. Introduction

IN the rapidly evolving landscape of healthcare, data management, security, and privacy remain critical challenges. The healthcare system, encompassing primary service providers such as doctors, nurses, technicians, and hospital administrators, emergency services, and health service users, particularly patients, is becoming increasingly digitized [1]. This digitization has advanced the recognition of issues related to secure storage, access to patients' medical records, ownership, and data from associated sources [2]. For instance, in 2017 alone, over 300 security and privacy breaches were reported, affecting up to 37 million records between 2010 and 2017 [3], [4]. These breaches emphasize the critical need for more secure and efficient methods of managing healthcare data.

R. Vaishali is with Department of Physical Science, Faculty of Applied Science, University of Vavuniya, Sri Lanka. (Email: rvaishali@vau.ac.lk)

G. Vijayakanthan is with Department of Physical Science, Faculty of Applied Science, University of Vavuniya, Sri Lanka. (Email: g.vijayakanthan@vau.ac.lk)

Blockchain technology, a decentralized and distributed digital ledger, has emerged as a promising solution to these challenges. Initially developed for cryptocurrencies, blockchain has evolved through various phases, from smart contracts in industries like real estate and finance to applications in non-financial sectors, including government, culture, and healthcare [5]. The technology's unique features, such as data immutability, cryptographic security, and consensus algorithms, enable it to address critical issues in healthcare, such as secure sharing of health records and compliance with data privacy laws [6].

The healthcare sector in Sri Lanka, like many other countries, faces significant challenges in data management, including high maintenance costs, complex data structures, and the need for efficient information exchange among various healthcare domains. Traditional EHR systems, maintained by third parties, often fail to meet the privacy and security needs of stakeholders, resulting in a lack of transparency and trust [7], [8]. Blockchain technology offers a solution by providing a decentralized, secure platform for storing, sharing, and managing health data. This technology can enhance data integrity, reduce the risk of human error, and ensure that patients retain control over

ISSN: 2961-5992

Despite the potential benefits, the adoption of blockchain in healthcare is still in its early stages, particularly in Sri Lanka. Numerous obstacles to its widespread implementation include regulatory barriers, a lack of awareness among users, and the need for substantial investments. Moreover, there are no studies carried out in Sri Lanka for the application of blockchain technology in healthcare, and there is a lack of comprehensive reviews that synthesize existing knowledge and highlight specific areas for future research.

This systematic review aims to address this gap by providing a thorough examination of the current state of blockchain technology in the healthcare sector, with a particular focus on its future contribution in Sri Lanka. By analyzing existing studies, identifying research gaps, and proposing directions for future research, this review seeks to offer valuable insights into the potential of blockchain to transform healthcare in Sri Lanka. The study is organized as follows: Section 2 describes the background study, Section 3 explains the research methodology, Section 4 presents and discusses the findings from the literature review, and Section 5 concludes the study with recommendations for future research and practical implications for the healthcare sector in Sri Lanka.

II. Background

A. What is Blockchain

Blockchain is a specific type of decentralized distributed ledger technology (DDLT) where each participant operates as a node within the network. Unlike centralized systems, blockchain networks establish direct connections between nodes, functioning similarly to peer-to-peer (P2P) networks [5]. In this network, all interactions are recorded as transactions, which are subsequently grouped into blocks. These blocks are then shared with every user in the network, enhancing security by requiring any tampering to be replicated across all copies of the ledger, making unauthorized changes nearly impossible [10]. Once added, the immutability of the blockchain ensures that recorded transactions cannot be altered. The security and privacy of these transactions are further strengthened by encryption techniques like SHA-256 and elliptic curve cryptography (ECC). The transparency of blockchain transactions also promotes trust and reliability [11].

Blockchain networks offer redundancy and decentralization, with each node maintaining an identical data copy. Ensuring consistency across all nodes is challenging, given the distributed nature of the data. Consensus mechanisms, such as Proof of Work (PoW), Proof of Stake (PoS), hybrid models combining PoW and PoS, Practical Byzantine Fault Tolerance (PBFT), and Proof of Elapsed Time (PoET), play a critical role in achieving agreement on which data blocks to append to the chain [12], [13].

B. Blockchain process

Blockchain networks are generally composed of five distinct layers: the application layer, middle layer, consensus layer, network layer, and data layer. The application layer features user-facing applications and smart contracts, allowing users to perform transactions. These transactions move to the middle layer for processing and are then validated and verified within the consensus layer, where they are organized into a Merkle tree structure to form a new block [14]. After verification, this new block is distributed across the entire network through the network layer. The data layer ensures data redundancy and decentralization by storing the validated data on each node. Consensus algorithms are critical to maintaining the credibility of blockchain networks by determining the validity of transactions, the sequence of block additions, and authorizing block creation [13].

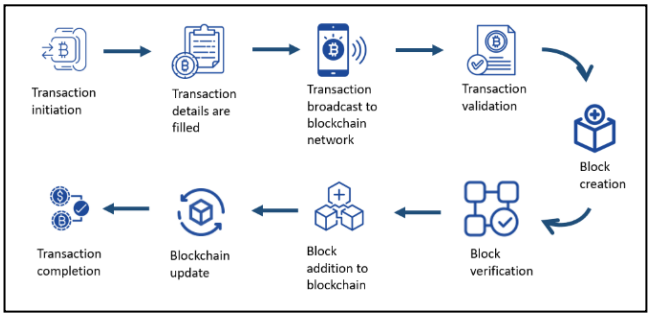

Fig. 1. Blockchain process

The standard framework for transaction processing in a blockchain network starts with transaction initiation, where a user defines transaction details. The network subsequently validates the transaction by confirming the sender's identity and checking fund availability [15]. Once validated, transactions are moved to a transaction pool, where consensus mechanisms, such as mining or validation, are applied to create a new block. Following block creation, nodes verify the block's correctness and compliance with the network's rules. Once confirmed, the blockchain ledger is updated and shared across all nodes in the network. The process concludes with the transaction's completion, where users receive confirmation receipts, miners are rewarded, and recipients gain access to the transferred assets [8], [16].

C. Blockchain in Healthcare

Blockchain technology offers robust solutions to the challenges of data security and privacy in healthcare. By utilizing its decentralized and unchangeable nature, blockchain can significantly enhance the protection of healthcare data like EHRs and Personal Health Information (PHI) [15]. Blockchain works as a decentralized ledger where each participant, or node, in the network keeps an independent copy of all transactions. In healthcare, blockchain provides several benefits. Unlike traditional

ISSN: 2961-5992

centralized systems, any change to a transaction in a blockchain would need to be made across all nodes, making tampering nearly impossible [17]. This feature ensures that once a transaction is recorded, it cannot be altered. It uses strong encryption methods, such as SHA256 and ECC to secure data. The transparency of blockchain allows all recorded transactions to be visible to authorized participants, building trust. Data redundancy is achieved as each node holds a copy of the data, ensuring that data is not lost or tampered. Consensus protocols like PoW and PoS help maintain consistency across all nodes, ensuring agreement on which new data is added to the blockchain. This process ensures the integrity of the blockchain [18].

In healthcare, blockchain enables secure data sharing and interoperability among healthcare providers. It allows patients to control access to their data, addressing privacy concerns. Smart contracts can automate data sharing agreements, ensuring compliance with regulations and improving efficiency [1]. Blockchain's transparency and immutability help maintain accurate medical records, enhancing patient care quality. By integrating blockchain with current healthcare systems, including cloud storage and IoT devices, data security and mobility can be improved. Although challenges like regulatory compliance and scalability remain, blockchain holds the potential to revolutionize healthcare data management by ensuring that data is secure, private, and accessible, ultimately improving patient outcomes and trust in healthcare systems [3], [17].

III. Methodology

A. Research Questions

We conducted this Systemic review by addressing the following research questions (RQs).

***RQ1*:** What are the main technical problems with using blockchain in healthcare, and how can we fix them?

Definition: This question seeks to identify specific technical obstacles such as storage, security, throughput, and scalability, and explore potential solutions to overcome these issues.

RQ2: What are the main non-technical problems, like social acceptance and regulations, when using blockchain in healthcare, and how can we manage them?

Definition: This question focuses on understanding the social, regulatory, and standardization challenges of adopting blockchain technology in healthcare and finding ways to address these concerns.

RQ3: How can combining blockchain with AI and IoT make healthcare better?

Definition: This question explores the potential benefits and improvements in healthcare data management and patient outcomes by integrating blockchain with AI and the IoT.

RQ4: What are the benefits and challenges of using blockchain in Sri Lanka's healthcare, and how can it help improve systems like EHR and telemedicine?

Definition: This question examines the specific applications, advantages, and obstacles of implementing blockchain technology in Sri Lanka's healthcare sector, with a focus on enhancing various healthcare systems.

RQ5: How can blockchain be used in the future to make healthcare better and more secure?

Definition: This question aims to identify future applications of blockchain in healthcare, including the use of smart contracts and the development of patient-centered health record systems, to improve overall healthcare outcomes and data security.

B. Selection of Papers

To explore the applications and issues of BT in healthcare, we conducted a systematic review of 27 [1], [2], [5], [7], [9], [10], [15], [16], [17], [19], [20-35] peer-reviewed papers. These papers were selected based on their relevance, quality, and contributions to the understanding of BT in healthcare. The selection criteria included publications from recognized journals and conferences, focusing on studies that provide empirical data, theoretical insights, and practical implementations of BT in healthcare.

IV. Results and Discussion

A. Applications of Blockchain Technology in Healthcare

Healthcare Record Sharing

Blockchain technology has emerged as a promising solution for enhancing the management and exchange of medical data, including patient monitoring data from IoT devices. Azaria

MedRec [36] is a blockchain-based system designed for managing electronic healthcare data. It aims to address issues such as interoperability and data access response time by creating a private peer-to-peer (P2P) network that tracks and manages network state transitions. However, while MedRec effectively standardizes health data and secures information sharing for research, it does not address real-time data processing needs in dynamic healthcare environments. Comparative approaches, like those using federated learning, allow for decentralized data analysis without sharing raw data, potentially enhancing data privacy and processing efficiency [37].

Blockchain technology can further enhance information sharing by integrating with cloud-based architectures, utilizing smart contracts and immutable bookkeeping for secure data transactions [27]. In contrast, secure multi-party computation (SMPC) enables collaborative data processing without revealing individual data inputs, offering another layer of security for sensitive data while avoiding the high computational costs and slower processing speeds associated with blockchain.

ISSN: 2961-5992

Healthcare Image Sharing

Blockchain facilitates secure sharing of medical images. The Radiological Society of North America (RSNA) has developed the Image Share Network (ISN) [38], [39] to address issues in medical image sharing, using a P2P architecture where each node represents a healthcare entity [25]. Patients have control over their images and can share them securely, using cryptographic keys and consensus algorithms to ensure data integrity and security.

While blockchain solutions provide secure image transfer, traditional systems often suffer from central points of failure and unauthorized access[40]. However, blockchain's high latency and potential scalability issues could limit its effectiveness in high-volume image exchanges. Emerging technologies like federated learning can offer lower latency by processing image data locally while sharing only the necessary model updates.

Healthcare System Log Management

Log management is crucial for maintaining the integrity of healthcare data. Blockchain-based log management systems, like Auditchain [41], utilize Hyperledger Fabric [42] to provide tamper-proof logs with multiple access controls. The immutability of blockchain ensures that logs remain unmodified.

While blockchain ensures tamper-proof logs, traditional approaches may provide more flexibility for modifications when errors occur. Systems like SMPC allow secure multiparty audit logging without storing the actual logs on a single ledger, reducing the risk associated with centralized breaches.

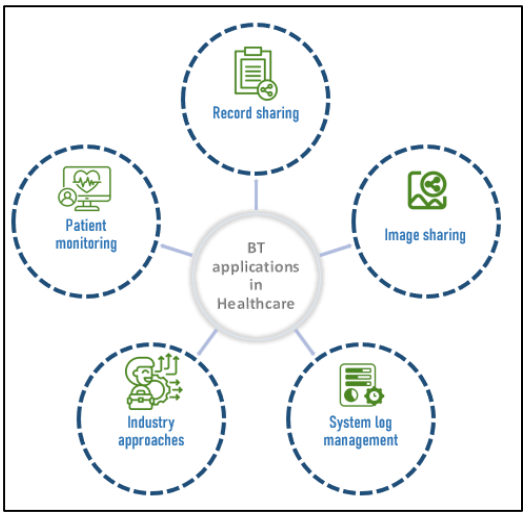

Fig. 2. Application areas of BT in healthcare

Patient Monitoring

Patient monitoring using IoT devices benefits from blockchain's security features, ensuring data confidentiality and regulatory compliance [43], [44]. Wireless body area networks (WBANs) can use blockchain to transmit patient data securely from sensors to central units [45].

Other emerging technologies such as edge computing can be used to process data closer to the source, reducing latency compared to blockchain-based solutions that involve more computational overhead. Moreover, federated learning can provide similar levels of data security without centralizing patient data on a single blockchain.

Industry-Specific Approaches

Various blockchain solutions have been developed to manage electronic health data, such as Medicalchain [46] and Medchain [47]. These platforms leverage Hyperledger Fabric for data management and secure data exchange but still face challenges related to scalability and interoperability.

Blockchain's advantages are apparent in scenarios requiring secure, immutable records and decentralized data management. However, its limitations become clear when compared to technologies like SMPC, which offer enhanced privacy protections without requiring data to be moved or duplicated.

In summary, blockchain technology offers transformative potential for healthcare information management, from secure data sharing and image exchange to robust log management and patient monitoring. These applications can improve data integrity, enhance security, and streamline processes across the healthcare sector

B. Issues Related to Blockchain Technology in Healthcare

Blockchain technologies face several issues in healthcare, both technical and non-technical, that must be critically evaluated.

Technical Issues

While blockchain employs encryption, maintaining data privacy and confidentiality remains challenging due to the decentralized nature of the network [30]. For instance, once data is recorded on the blockchain, it is immutable, which can lead to issues in correcting errors or removing outdated information, especially in sensitive healthcare contexts.

Federated learning, in contrast, allows models to learn from decentralized data without storing the data in a central location, which could potentially provide higher privacy standards and adaptability to changing data.

Scalability and Storage

Blockchain's design for storing low-capacity transaction data may struggle with the vast amounts of data generated by healthcare applications [21]. Storing large datasets, such as medical images, increases complexity and performance issues over time.

Sharding and Layer-2 solutions may offer relief to blockchain's scalability problems; however, alternative technologies like cloud-based architectures combined with SMPC or edge computing can provide more scalable and efficient data handling.

ISSN: 2961-5992

Security and Throughput

Despite its decentralized nature, blockchain requires robust access control mechanisms to prevent unauthorized data access, which can be challenging during emergencies [17].

Technologies such as SMPC can maintain security standards without relying on a single point of failure, which can be a vulnerability in some blockchain implementations.

Interoperability Challenges

Blockchain platforms lack standardization, which can impede the seamless exchange of healthcare data across various providers [17].

Other platforms like Polkadot [48] or Cosmos [49] offer more robust solutions for interoperability among different networks, providing insights into how healthcare blockchains can evolve to overcome current limitations.

C. Proposed Solutions

To address storage maintenance challenges, hybrid storage solutions can be implemented, combining on-chain and off-chain storage. Sensitive data can be stored on-chain, while larger data files, such as images, can be stored off-chain with encrypted references on the blockchain. For security issues, advanced access control mechanisms and multi-signature or threshold-based systems can ensure that data is only accessible to authorized personnel. Implementing zero-knowledge proofs can further enhance data privacy [50].

Improving throughput can be achieved by adopting newer consensus mechanisms like PoS, Delegated Proof-of-Stake (DPoS) [51], or Byzantine Fault Tolerance (BFT) [52]. Layer-2 scaling solutions [53], such as state channels or sidechains, can also be used as a solution. Scalability issues can be mitigated through techniques like sharding, which partitions the blockchain into smaller, more manageable pieces that process transactions independently [23].

To enhance interoperability, standardized protocols and frameworks like Fast Healthcare Interoperability Resources (HL7 FHIR) [54] should be developed and adopted. Blockchain interoperability platforms such as Polkadot [48] or Cosmos [49] can connect different blockchain networks. Reducing latency can be achieved by implementing layer-2 solutions and off-chain transactions, as well as using edge computing to process data closer to the source.

For non-technical issues, comprehensive training programs for healthcare professionals can facilitate the transition to blockchain technology. Awareness campaigns and pilot projects can demonstrate the benefits of blockchain, building trust and acceptance among stakeholders [21]. Collaborating with regulatory bodies to develop clear guidelines for blockchain use in healthcare ensures legal and regulatory compliance. To reduce implementation costs, organizations can employ open-source blockchain platforms and cloud-based blockchain-as-a-service (BaaS) offerings [55]. Additionally, seeking funding and grants can support blockchain initiatives [22].

V. Overall Discussion

This systematic review highlights the transformative potential of blockchain technology in the healthcare sector, offering secure, transparent, and efficient management of healthcare data. The reviewed studies illustrate that blockchain's decentralized nature, combined with advanced cryptographic techniques, provides a robust framework for addressing key challenges in healthcare information management, such as data privacy, interoperability, and scalability [10], [20], [29], [30], [32].

A. Synthesis of findings

The application of blockchain in healthcare, as evidenced by various implementations like MedRec, Medicalchain, and others, demonstrates significant improvements in data sharing, patient monitoring, and system log management. These systems not only enhance data security and patient control over personal health information but also promote greater transparency and trust within the healthcare ecosystem. Furthermore, blockchain’s integration with IoT devices and cloud-based architectures suggests promising advancements in real-time patient monitoring and medical image sharing, although challenges related to storage, throughput, and regulatory compliance remain [5], [9], [17], [21], [30], [32].

The reviewed studies also emphasize the need for scalable solutions that can handle the increasing volume of healthcare data while maintaining low latency and high transaction throughput. Advanced consensus mechanisms, such as PoS and BFT, along with Layer-2 scaling solutions, are proposed as viable options to overcome these limitations.

B. Potential Impact in Sri Lanka

In the context of Sri Lanka, the adoption of blockchain technology in healthcare could address several pressing issues, such as the lack of interoperability between disparate healthcare systems, data security concerns, and the inefficiencies in patient data management. Given the country's ongoing efforts to digitize healthcare, blockchain could play a pivotal role in creating a more connected and secure healthcare infrastructure.

The integration of blockchain with existing systems in Sri Lanka would require careful consideration of the local healthcare landscape, including the legal and regulatory environment, the technical capabilities of healthcare providers, and the specific needs of patients. By adopting standardized frameworks and fostering collaboration between government agencies, healthcare providers, and technology companies, Sri Lanka could integrate blockchain technology to improve healthcare outcomes, enhance data security, and reduce operational costs.

ISSN: 2961-5992

C. Broader perspective

Globally, blockchain is ready to revolutionize healthcare by enabling more efficient and secure data management practices. However, the technology's success in healthcare will depend on overcoming technical challenges, such as scalability and throughput, and addressing non-technical barriers, including regulatory compliance and user adoption. As blockchain continues to evolve, its application in healthcare is likely to expand, with new use cases emerging in areas such as clinical trials, supply chain management, and patient consent management.

Sri Lanka stands to benefit significantly from these advancements, provided that the necessary infrastructure and regulatory frameworks are put in place. By learning from global best practices and applying blockchain solutions to local needs, Sri Lanka can position itself at the forefront of healthcare innovation.

VI. CONCLUSION

Blockchain technology can revolutionize healthcare by providing secure, transparent, and efficient data management solutions. Its decentralized nature ensures data integrity and reduces unauthorized access, making it ideal for handling sensitive health information. However, challenges like storage maintenance, security, throughput, and scalability need to be addressed.

Technical solutions include hybrid storage models, advanced access control mechanisms, new consensus algorithms, and layer-2 scaling solutions. Non-technical challenges, such as adjustment difficulties, social acceptance, legal compliance, and implementation costs, require comprehensive training, awareness campaigns, regulatory collaboration, and cost-effective strategies.

Future directions include integrating blockchain with AI and IoT, using smart contracts, developing patient-centered health record systems, and managing research data securely. In Sri Lanka, blockchain can enhance healthcare by providing secure EHR systems, tracking pharmaceutical supply chains, securing telemedicine platforms, managing clinical trial data, and verifying medical credentials.

Addressing these challenges and implementing solutions can help the healthcare industry integrate blockchain for better patient outcomes, improved data security, and efficient healthcare management. As the technology matures, blockchain is likely to play an increasingly important role in healthcare.

REFERENCES

[1] L. Soltanisehat, R. Alizadeh, H. Hao, and K.-K. R. Choo, "Technical, Temporal, and Spatial Research Challenges and Opportunities in Blockchain-Based Healthcare: A Systematic Literature Review," *IEEE Trans. Eng. Manag.*, vol. 70, no. 1, pp. 353–368, Jan. 2023, doi: 10.1109/TEM.2020.3013507.

[2] Ehizogie Paul Adeghe, Chioma Anthonia Okolo, and Olumuyiwa Tolulope Ojeyinka, "Evaluating the impact of blockchain technology in healthcare data management: A review of security, privacy, and patient outcomes," *Open Access Res. J. Sci. Technol.*, vol. 10, no. 2, pp. 013–020, Mar. 2024, doi: 10.53022/oarjst.2024.10.2.0044.

[3] M. Hölbl, M. Kompara, A. Kamišalić, and L. Nemec Zlatolas, "A Systematic Review of the Use of Blockchain in Healthcare," *Symmetry (Basel).*, vol. 10, no. 10, p. 470, Oct. 2018, doi: 10.3390/sym10100470.

[4] C. C. Agbo, Q. H. Mahmoud, and J. M. Eklund, "Blockchain Technology in Healthcare: A Systematic Review," *Healthcare*, vol. 7, no. 2, p. 56, Apr. 2019, doi: 10.3390/healthcare7020056.

[5] P. K. Ghosh, A. Chakraborty, M. Hasan, K. Rashid, and A. H. Siddique, "Blockchain Application in Healthcare Systems: A Review," *Systems*, vol. 11, no. 1, p. 38, Jan. 2023, doi: 10.3390/systems11010038.

[6] N. Deepa *et al.*, "A survey on blockchain for big data: Approaches, opportunities, and future directions," *Futur. Gener. Comput. Syst.*, vol. 131, pp. 209–226, Jun. 2022, doi: 10.1016/j.future.2022.01.017.

[7] V. Mandarino, G. Pappalardo, and E. Tramontana, "A Blockchain-Based Electronic Health Record (EHR) System for Edge Computing Enhancing Security and Cost Efficiency," *Computers*, vol. 13, no. 6, p. 132, May 2024, doi: 10.3390/computers13060132.

[8] A. Al Mamun, S. Azam, and C. Gritti, "Blockchain-Based Electronic Health Records Management: A Comprehensive Review and Future Research Direction," *IEEE Access*, vol. 10, pp. 5768–5789, 2022, doi: 10.1109/ACCESS.2022.3141079.

[9] A. Kumar and V. S. Goswami, "Blockchain Technology in Healthcare," 2023, pp. 485–495. doi: 10.1007/978-981-19-9304-6_45.

[10] R. Matthew, R. Daga, and M. Maurya, "Blockchain in Healthcare Systems," in *2023 International Conference on Evolutionary Algorithms and Soft Computing Techniques (EASCT)*, Oct. 2023, pp. 1–5. doi: 10.1109/EASCT59475.2023.10392479.

[11] N. Cooper, "Editorial: Blockchain in Health Care," *Front. Blockchain*, vol. 4, Feb. 2022, doi: 10.3389/fbloc.2021.830459.

[12] H. Saeed *et al.*, "Blockchain technology in healthcare: A systematic review," *PLoS One*, vol. 17, no. 4, p. e0266462, Apr. 2022, doi: 10.1371/journal.pone.0266462.

[13] G. Huang and A. Al Foysal, "Blockchain in Healthcare," *Technol. Invest.*, vol. 12, no. 03, pp. 168–181, 2021, doi: 10.4236/ti.2021.123010.

[14] S. Zhang and J.-H. Lee, "Analysis of the main consensus protocols of blockchain," *ICT Express*, vol. 6, no. 2, pp. 93–97, Jun. 2020, doi: 10.1016/j.icte.2019.08.001.

[15] F. M. Ziade, M. M. Daher, and M. F. Ziade, "Blockchain in Healthcare," 2024, pp. 83–96. doi: 10.4018/979-8-3693-1046-5.ch005.

[16] V. Awasthi and P. Kansra, "Blockchain in the Healthcare Industry," 2023, pp. 81–93. doi: 10.4018/978-1-6684-4483-2.ch006.

[17] Akoh Atadoga, Oluwafunmi Adijat Elufioye, Toritsemogba Tosanbami Omaghomi, Opeoluwa Akomolafe, Ifeoma Pamela Odilibe, and Oluwaseyi Rita Owolabi, "Blockchain in healthcare: A comprehensive review of applications and security concerns," *Int. J. Sci. Res. Arch.*, vol. 11, no. 1, pp. 1605–1613, Feb. 2024, doi: 10.30574/ijsra.2024.11.1.0244.

[18] I. A. Omar, R. Jayaraman, K. Salah, I. Yaqoob, and S. Ellahham, "Applications of Blockchain Technology in Clinical Trials: Review and Open Challenges," *Arab. J. Sci. Eng.*, vol. 46, no. 4, pp. 3001–3015, Apr. 2021, doi: 10.1007/s13369-020-04989-3.

[19] K.-A. Aivaz, I. F. Munteanu, and F. V. Jakubowicz, "Bitcoin in Conventional Markets: A Study on Blockchain-Induced Reliability, Investment Slopes, Financial and Accounting Aspects," *Mathematics*, vol. 11, no. 21, p. 4508, Nov. 2023, doi: 10.3390/math11214508.

[20] Y. Singh, M. A. Jabbar, S. Kumar Shandilya, O. Vovk, and Y. Hnatiuk, "Exploring applications of blockchain in healthcare: road map and future directions," *Front. Public Heal.*, vol. 11, Sep. 2023, doi: 10.3389/fpubh.2023.1229386.

[21] M. S. B. Kasyapa and C. Vanmathi, "Blockchain integration in healthcare: a comprehensive investigation of use cases, performance issues, and mitigation strategies," *Front. Digit. Heal.*, vol. 6, Apr. 2024, doi: 10.3389/fdgth.2024.1359858.

[22] S. Mittal and M. Ghosh, "Applications of Blockchain in Healthcare Domain: A Comprehensive Survey," in *2024 11th International Conference on Computing for Sustainable Global Development (INDIACom)*, Feb. 2024, pp. 1015–1022. doi:

ISSN: 2961-5992

10.23919/INDIACom61295.2024.10498682.
[23] A. Raghav and A. M. Tripathi, "Blockchain in Medical Healthcare: A Review of Issues and Challenges," in *2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT)*, Feb. 2024, pp. 1116–1120. doi: 10.1109/IC2PCT60090.2024.10486686.
[24] R. Singh, A. Gehlot, S. V. Akram, R. Sharma, and P. K. Malik, "Integration of Blockchain and the Internet of Things in Healthcare Sector," 2024, pp. 155–170. doi: 10.1007/978-981-97-0088-2_8.
[25] L. Kandasamy and A. Ajay, "Implementation of Blockchain Technology for Secure Image Sharing Using Double Layer Steganography," 2023, pp. 186–195. doi: 10.1007/978-3-031-24475-9_16.
[26] B. N. Hussein EL Ghor, Mohamed Daher, "A Novel Blockchain-Based Approach for Secure and Efficient Electronic Medical Record Sharing," in *Algorithms in Advanced Artificial Intelligence*, 2024, p. 9.
[27] R. Mahmood and V. George, "Review on Blockchain-Enabled Techniques for Secure Storage and Sharing of Patient Healthcare Records," in *2024 Second International Conference on Emerging Trends in Information Technology and Engineering (ICETITE)*, Feb. 2024, pp. 1–7. doi: 10.1109/ic-ETITE58242.2024.10493543.
[28] D. Sahu, N. Tiwari, and M. Chawla, "Blockchain as a Solution for Electronic Health Record Management : A Comprehensive Review," in *2024 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS)*, Feb. 2024, pp. 1–6. doi: 10.1109/SCEECS61402.2024.10482149.
[29] A. Galaba, M. Palagani, R. Vinukonda, J. S. P. Malampati, S. S. Harsha, and K. V. D. Kiran, "Significance of Blockchain Technology in the Healthcare Sector," in *2023 International Conference on Inventive Computation Technologies (ICICT)*, Apr. 2023, pp. 1159–1165. doi: 10.1109/ICICT57646.2023.10134196.
[30] S. Qose, Z. Rajnai, and B. Fregan, "Blockchain Technology in Healthcare Industry: Benefits and Issues," in *2023 IEEE 17th International Symposium on Applied Computational Intelligence and Informatics (SACI)*, May 2023, pp. 171–176. doi: 10.1109/SACI58269.2023.10158669.
[31] A. Tiwari, A. Sikri, V. Sagar, and R. Jameel, "Decentralized Technology and Blockchain in Healthcare Administration," 2024, pp. 229–237. doi: 10.1007/978-3-031-49593-9_14.
[32] S. Upadhyay, S. Agarwal, A. Chaudhary, P. Singh, and R. Sharma, "Blockchain in Healthcare Systems: A Systematic Review," in *2024 2nd International Conference on Disruptive Technologies (ICDT)*, Mar. 2024, pp. 140–147. doi: 10.1109/ICDT61202.2024.10489533.
[33] F. M. AbdelSalam, "Blockchain Revolutionizing Healthcare Industry: A Systematic Review of Blockchain Technology Benefits and Threats.," *Perspect. Heal. Inf. Manag.*, vol. 20, no. 3, pp. 1–19, 2023, [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10701638/
[34] R. Myrzashova, S. H. Alsamhi, A. V. Shvetsov, A. Hawbani, and X. Wei, "Blockchain Meets Federated Learning in Healthcare: A Systematic Review With Challenges and Opportunities," *IEEE Internet Things J.*, vol. 10, no. 16, pp. 14418–14437, Aug. 2023, doi: 10.1109/JIOT.2023.3263598.
[35] S. Ramzan, A. Aqdus, V. Ravi, D. Koundal, R. Amin, and M. A. Al Ghamdi, "Healthcare Applications Using Blockchain Technology: Motivations and Challenges," *IEEE Trans. Eng. Manag.*, vol. 70, no. 8, pp. 2874–2890, Aug. 2023, doi: 10.1109/TEM.2022.3189734.
[36] A. Azaria, A. Ekblaw, T. Vieira, and A. Lippman, "MedRec: Using Blockchain for Medical Data Access and Permission Management," in *2016 2nd International Conference on Open and Big Data (OBD)*, Aug. 2016, pp. 25–30. doi: 10.1109/OBD.2016.11.
[37] K. Liu, Z. Yan, X. Liang, R. Kantola, and C. Hu, "A survey on blockchain-enabled federated learning and its prospects with digital twin," *Digit. Commun. Networks*, vol. 10, no. 2, pp. 248–264, Apr. 2024, doi: 10.1016/j.dcan.2022.08.001.
[38] "RSNA," 1915. https://www.rsna.org/ (accessed Jun. 20, 2024).
[39] "RSNA," 2016. https://www.rsna.org/practice-tools/data-tools-and-standards/image-share-validation-program (accessed Jun. 21, 2024).
[40] R. K. Berwer, S. Indora, and D. K. Atal, "Blockchain-Based Medical Image Processing Mechanism," in *2022 IEEE 4th International Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA)*, Oct. 2022, pp. 38–43. doi: 10.1109/ICCCMLA56841.2022.9989112.
[41] G. R. Vishnia and G. W. Peters, "AuditChain: A Trading Audit Platform Over Blockchain," *Front. Blockchain*, vol. 3, Feb. 2020, doi: 10.3389/fbloc.2020.00009.
[42] "Hyperledger foundation," 2015. https://www.hyperledger.org/projects/fabric
[43] H. Li, L. Yu, and W. He, "The Impact of GDPR on Global Technology Development," *J. Glob. Inf. Technol. Manag.*, vol. 22, no. 1, pp. 1–6, Jan. 2019, doi: 10.1080/1097198X.2019.1569186.
[44] D. Vanderpool, "HIPAA COMPLIANCE: A Common Sense Approach.," *Innov. Clin. Neurosci.*, vol. 16, no. 1–2, pp. 38–41, Jan. 2019, [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/31037229
[45] S. Z. Hussain and M. Kumar, "Secured Key Agreement Schemes in Wireless Body Area Network — A Review," *Indian J. Sci. Technol.*, vol. 14, no. 24, pp. 2005–2033, Jun. 2021, doi: 10.17485/IJST/v14i24.1708.
[46] M. T. Albeyatti, Dr Abdullah, "Medicalchain," 2016. https://medicalchain.com/en/
[47] B. Shen, J. Guo, and Y. Yang, "MedChain: Efficient Healthcare Data Sharing via Blockchain," *Appl. Sci.*, vol. 9, no. 6, p. 1207, Mar. 2019, doi: 10.3390/app9061207.
[48] "Polkadot," 2020. https://polkadot.network/ (accessed Jun. 18, 2024).
[49] "Cosmos," 2019. https://cosmos.network/ (accessed Jun. 15, 2024).
[50] R. Abbasi, M. Waqas, N. Khan, U. Saeed, and R. Ali, "A Systematic Review on the Role of Blockchain Technology in Healthcare: Challenges and Solutions," *Int. J. Artif. Intell. Math. Sci.*, vol. 2, no. 2, pp. 11–20, May 2024, doi: 10.58921/ijaims.v2i2.74.
[51] "Medium," *U2U Network*, 2023. https://medium.com/unicorn-ultra/what-is-delegated-proof-of-stake-dpos-your-comprehensive-guide-to-dpos-07fd5185b108 (accessed Jun. 12, 2024).
[52] A. Ghosh, I. Sarkar, M. Dey, and A. Ghosh, "Artificial intelligence and blockchain: Implementation perspectives for healthcare beyond 5G," in *Blockchain Applications for Healthcare Informatics*, Elsevier, 2022, pp. 93–116. doi: 10.1016/B978-0-323-90615-9.00003-7.
[53] A. Gangwal, H. R. Gangavalli, and A. Thirupathi, "A survey of Layer-two blockchain protocols," *J. Netw. Comput. Appl.*, vol. 209, p. 103539, Jan. 2023, doi: 10.1016/j.jnca.2022.103539.
[54] "HL7FHIR," 2023. https://www.hl7.org/fhir/overview.html (accessed Jun. 15, 2024).
[55] J. Song, P. Zhang, M. Alkubati, Y. Bao, and G. Yu, "Research advances on blockchain-as-a-service: architectures, applications and challenges," *Digit. Commun. Networks*, vol. 8, no. 4, pp. 466–475, Aug. 2022, doi: 10.1016/j.dcan.2021.02.001.