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Implementing Blockchain for Health Sectors in Low- and Middle-Income Countries: Use Cases, Approaches and Challenges

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Background and Purpose: Despite its complexity and resource constraints, the healthcare sector in low- and middle-income countries (LMICs) faces a crucial challenge of ensuring data integrity, interoperability, and transparency. Blockchain technology emerges as a potential solution, offering secure and immutable platform for managing health information. This study investigates the use cases, approaches, and challenges of implementing blockchain in LMIC healthcare, focusing on health services and sector-wide management.
Methods: The study employed a systematic review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure transparency and reproducibility in the review process. Results show that while a number of African countries have embarked on the implementation of blockchain-based applications, most projects remain as proposals or experiments.
Results: The study found 26 (82%) projects had some form of implementation. Of these, 11 (42%) were simulations, 2 (8%) evolved into working prototypes, and only 3 (12%) achieved full-fledged deployments. The most implemented use case was Electronic Health Record systems (EHR), which constituted about 23% of all implementations, followed by Remote Patient Monitoring (15%).
Conclusion: The main challenge in the deployment of blockchain technology in the health sector in LMICs is the limited transition of simulations and prototypes into fully developed solutions. This issue is largely attributed to low levels of readiness, both technical and administrative, which hinder the successful implementation and integration of blockchain systems. Addressing these readiness gaps is crucial to overcoming barriers and unlocking the full potential of blockchain technology to improve healthcare outcomes in these settings.

Keywords: Blockchain, Health Sector, Technology Adoption, Low- and Middle-Income Countries

1 Introduction

The healthcare sector is inherently complex and heavily influenced by political dynamics (Aanestad & Jensen, 2011; Gedikci et al., 2023; Sheikh et al., 2015; Scott & Mars, 2015). It encompasses a multitude of interdependent institutions, each operating with distinct management structures (Braa et al., 2007; Kimaro & Titlestad, 2008). Effective health service provision necessitates seamless alignment and communication across these diverse institutions. To provide a complete and uninterrupted healthcare experience for a patient, it is necessary to coordinate between different departments involved in the process. For instance, the inpatient or outpatient department responsible for prescribing medications and interpreting test results, the laboratory that conducts tests and examinations, and the pharmacy that manages medical equipment and medications all need to work together seamlessly (Reichertz, 2006; Sittig et al., 2018). Data serves as the crucial link connecting these segments, encompassing patient information from outpatient departments, test results from laboratories, and details of medications dispensed by the pharmacy. Recognising the imperative for consistent data across different healthcare sections and ensuring its integrity, several scholars advocate for the integration of blockchain technologies (Haleem et al., 2021; Tandon et al., 2020; Elangovan et al., 2022; Agbo et al., 2019; Kuo et al., 2017) to streamline data management processes in the healthcare sector.

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The healthcare landscape in low- and middle-income countries (LMICs) is characterised by a myriad of challenges that hinder the delivery of effective and equitable care. Resource scarcity further compounds the problem, limiting access to essential medical supplies, diagnostic tools, and qualified healthcare professionals (World Health Organization, 2017; Frenk et al., 2014; Anyangwe & Mtonga, 2007). Inadequate data management systems contribute to the fragmentation of health information, making it difficult to establish comprehensive and interoperable health records (Mkayula et al., 2022). Blockchain technology emerges as a potential remedy to these challenges by providing a decentralised and secure platform for health data management (Mettler, 2016; Agbo et al., 2019; Kuo et al., 2017). In LMICs, the implementation of blockchain can streamline health data infrastructure, including secure storage of data, secure transactions and traceability in logistics and supply chain (P. Zhang et al., 2018).

The potential for using blockchain in the health sector has gained considerable attention (Mettler, 2016; Haleem et al., 2021). The immutable and decentralised nature of blockchain offers promising solutions to challenges such as interoperability, data security, and transparency in healthcare systems. For instance, blockchain can facilitate secure and interoperable health data exchange among diverse stakeholders, including healthcare providers, insurers, and patients (Mettler, 2016). Moreover, its ability to provide a tamper-proof and auditable record of transactions enhances data integrity, a critical aspect of healthcare data management (Iansiti & Lakhani, 2017). In LMICs, where traditional healthcare infrastructure may be limited, blockchain can enable efficient management of health records, streamline supply chain logistics for medical resources, and reduce fraud through transparent and traceable transactions (P. Zhang et al., 2018). The implementation of blockchain in healthcare, however, comes with its set of challenges, including technological barriers, regulatory uncertainties, and the need for skilled workforce training (Agbo et al., 2019). Addressing these challenges is crucial for realising the full potential of blockchain technology in improving healthcare outcomes and services in resource-constrained settings.

While the potential of blockchain in LMIC healthcare contexts is undeniable, its successful implementation is accompanied by distinct challenges. Inadequate infrastructure, especially limited internet access in rural areas, poses significant connectivity hurdles, hindering the seamless deployment of blockchain applications (Mars, 2013; World Bank Group, 2016; Scott & Mars, 2015). The challenges are further compounded by the need to navigate intricate regulatory frameworks governing health data and technology in LMICs, adding a layer of complexity to implementation efforts (Agbo et al., 2019; Kuo et al., 2017; Vazirani et al., 2020). Fostering interoperability between diverse blockchain platforms is crucial for ensuring the seamless exchange of health data across systems, necessitating careful consideration of standardisation efforts (Zhang et al., 2018; Jain et al., 2024) . Moreover, building trust and achieving user adoption among healthcare professionals and patients demand extensive stakeholder engagement and capacity-building initiatives to address concerns related to data privacy, security, and the overall reliability of blockchain systems (Mettler, 2016; Esmaeilzadeh & Mirzaei, 2019; Hasselgren et al., 2019). Following these many huddles, this study gives an account of the extent of the adoption of blockchain in LMICs as well as the types of blockchains involved. The study contributes to the existing body of knowledge by reviewing the use of blockchain technologies in managing the healthcare sector, with a focus on health services management and sector-wide management.

In specific terms, this study aimed to comprehensively examine the use cases, adoption approaches, and associated challenges of implementing blockchain technologies in the health sector, with a specific focus on LMICs. While existing reviews, such as those conducted by Hasselgren et al. (2019), Saeed et al. (2022), and Adere (2022), have provided valuable insights into the utilisation of blockchain technology in healthcare, they predominantly offer generic perspectives and do not adequately scrutinise the unique situations and challenges faced by healthcare systems in LMICs. Hasselgren et al. (2019) delved into the overall landscape of blockchain in healthcare, Saeed et al. (2022) explored its applications and benefits, and Adere (2022) conducted a systematic review of blockchain and IoT technology in healthcare. However, the specific challenges and approaches in adopting blockchain technology in LMICs have yet to be extensively addressed in these reviews, warranting a dedicated investigation to bridge this gap in the literature. This study aimed to address this void.

Research Question(s).

i. How is blockchain technology applied in healthcare within low- and middle-income countries?
ii. What implementation approaches are utilised for blockchain in healthcare in low- and middle-income countries?
iii. What challenges arise in implementing blockchain for healthcare in low- and middle-income countries?
iv. What are the recommended strategies for successful blockchain implementation in healthcare in low- and middle-income countries?

2 Methodology

This study used a systematic literature review to investigate the implementation of blockchain technology in the health sectors in LMICs. The systematic review used follows the guidelines outlined by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure transparency and reproducibility in the review process (Moher et al., 2009). Four reputable literature databases were chosen to gather relevant papers related to blockchain technology in healthcare. These were (1) PubMed: A well-known database for biomedical literature, (2) IEEE Xplore (IEEEX): A comprehensive resource for engineering and technology research, (3) ACM Digital Library: A prominent source of computer science publications, and (4) ScienceDirect: A leading database covering various academic disciplines. The search strategy involved using a combination of relevant keywords and Boolean operators to retrieve relevant papers. The search phrase used was: ("blockchain" OR "block chain" OR "block-chain") AND ("health" OR "healthcare" OR "medicine" OR "medical").

2.1 Inclusion Criteria

To ensure the relevance and quality of the papers, strict inclusion and exclusion criteria were applied during the screening process. The inclusion criteria were as follows:

i. Papers published between the years 2015 - 2022.
ii. Papers related to the application of blockchain technology in the healthcare sector.
iii. Full-text papers available in English.
iv. Studies conducted in LMIC setting

2.2 The exclusion criteria were as follows:

i. Papers not directly related to blockchain technology in healthcare.
ii. Papers not available in full text or not written in English.
iii. Reviews and editorials, only original articles and empirical research were considered.
iv. Articles that discuss the blockchain technology itself rather than its implementation

2.3 Screening Process

The screening process involved two stages: title/abstract screening and full-text screening. Initially, duplicate papers were removed from the search results. Subsequently, two independent reviewers conducted title and abstract screening based on the inclusion and exclusion criteria. Papers that met the criteria were then subjected to full-text screening. During the full-text screening phase, the same two reviewers independently assessed the content of each paper to determine its suitability for inclusion in the review. Any discrepancies were resolved through discussion and consensus.

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2.4 Data Extraction and Analysis

A standardised data extraction form was used to extract relevant information from the included papers. The data extraction process included information on study details (e.g., authors, publication year, country of origin), methodology, blockchain implementation type, healthcare use cases, and main findings. The extracted data from the included papers were synthesised and analysed to identify common themes, trends, and insights related to the application of blockchain technology in the healthcare sector. Seven (7) categories were selected to systematically analyse and evaluate the adoption of blockchain technologies in the health sectors of low- and middle-income countries (LMICs). The categories and corresponding reason for selection are briefly described below:

Solutions Implementation for identifying whether existing blockchain-based solutions are still theoretical or there are practical implementation, providing insight into the maturity of the technology in LMIC contexts.

Level of Implementation for assessing whether the implementation is at experiments pilot, or full rollout. This category highlights the extent of deployment within LMIC healthcare systems, shedding light on the challenges faced at different levels.

Implementation Details Provided for examining the depth of information shared about implementation, such as technical specifications, challenges faced, and strategies used.

Use Cases Implemented e.g., electronic health records, supply chain, or patient identity verification to highlight areas where blockchain technology is most impactful in LMICs.

Blockchain Technology Used for identifying the type of blockchain commonly used e.g., Ethereum or Hyperledger which influence factors such as scalability, security, and cost-efficiency which are critical in resource-constrained environments.

Integration with Other Technologies like IoT, AI, or cloud computing to assess how these synergies enhance functionality, solve complex healthcare challenges, and optimize resource use in LMICs.

Country of Origin of Papers provides insights into geographic trends, potential biases, and the need for more localized studies across different LMICs.

2.5 Limitations

This review acknowledges certain limitations, including the potential omission of relevant papers due to database constraints. Additionally, the scope of the analysis may have been restricted by the availability of full-text articles and the focus on studies published in English.

3 Results

The systematic review process scrutinised a total of 5,485 research papers extracted from selected databases PubMed (487 papers), IEEEX (371 initial papers), ACM Digital (267 papers), and Science Direct (4,360 papers) during the search phase. Following a screening process, a refined set of 31 papers emerged for in-depth examination, categorised across the selected databases as follows: PubMed (4 papers), IEEEX (14 papers), ACM Digital (10 papers), and Science Direct (3 papers). These selected papers were further reviewed, with data systematically collected and organised into 7 categories selected to systematically analyse and evaluate the adoption of blockchain technologies in the health sectors of low- and middle-income countries (LMICs). A summary of the analysis for each retrieved article is included in the appendix.

Table 7: Systematic Review Results

S/N	Category	Implementation	Number of papers
1	Solution Implementation	Yes	19
		No	6

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2	Level of implementation	Algorithm	2
		Simulation	1
		Lab experiments	11
		Working prototype	2
		Full implementation	3
3	Implementations details provided	Clear	7
		Not clear	12
4	Use cases implemented	Electronic Health Records	13
		Remote Patient Monitoring	4
		Payments	1
		Birth/Death Registration	2
		Healthcare Management System	2
		Supply Chain Management	3
5	Blockchain technology used	Ethereum	4
		Hyperledger	8
		Bitcoin	1
		Others	2
		Unspecified	3
6	Integration with other technologies	Artificial Intelligence	1
		IoT	3
		Cloud computing	2
		Machine Learning	1
		Big Data	1
7	Country of Origin of papers	South Africa	4
		Tunisia, Morocco	3
		Kenya	2
		Nigeria, Ghana, Guinea, Algeria, Namibia, Cameroon, Egypt	1

The analysis revealed that 19 out of 25 projects (76%) had implemented some form of solution. While 6 projects remained in conceptual stages (24%), the majority progressed beyond theoretical foundations, demonstrating a growing commitment to practical applications as summarised in Figure 1.

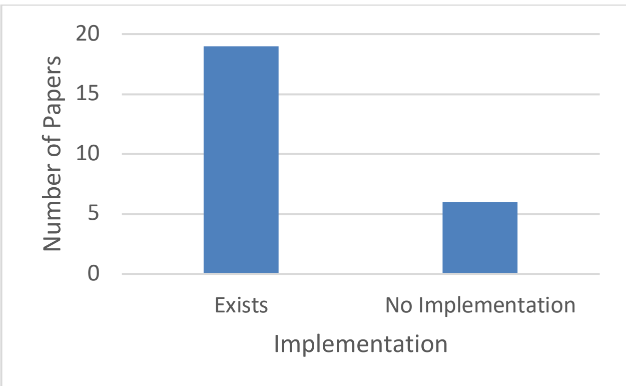

Figure 1. Implementation Exists or Not

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The level of implementation also varied, with 14 projects residing in algorithm, simulation or lab experiments (74%), two (2) evolving into working prototypes (11%), and only 3 achieving full-fledged deployments (15%). The analysis highlights significant progress in the implementation of blockchain solutions in LMIC healthcare systems, with more than three quarters of the reviewed projects moving beyond the conceptual stage as summarised in Figure 2.

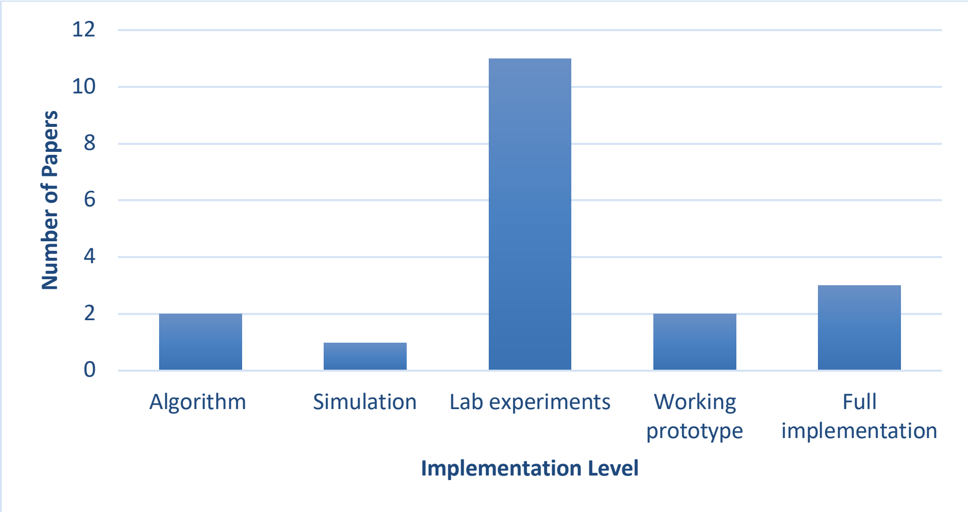

Figure 2. Implementation Level for Reviewed Articles

Examining the specific use cases targeted by the implemented projects, Electronic Health Records systems (EHRs) emerged as the primary focus, with 13 projects aiming to address secure patient data storage, data privacy and data exchange challenges (52%). Remote patient monitoring (4 projects, 16%) and supply chain management for drugs and vaccines (3 projects, 12%) were also key areas, underscoring the potential of blockchain to contribute to telehealth and supply chain assurance in resource-constrained settings. Other projects explored diverse applications including payments, birth/death registration, and healthcare system management (all representing 20% of projects), demonstrating the wide range of issues that can be potentially addressed by the blockchain technology as shown in Figure3.

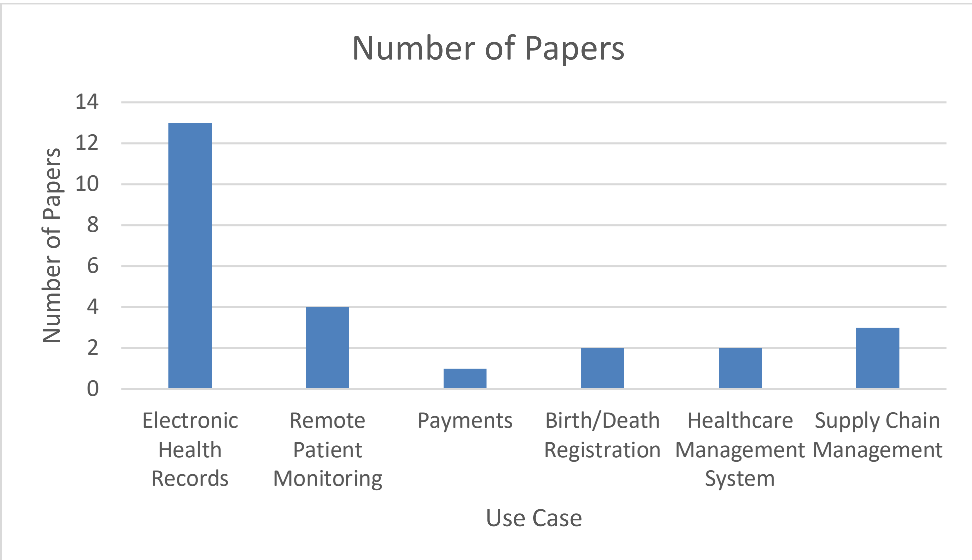

Figure 3. Implemented Use Cases

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From a technological perspective, established platforms dominated the implemented projects, with Ethereum (4 projects, 21%) and Hyperledger (8 projects, 42%) being the most preferred choices as shown in Figure 4. This suggests a focus on stability and reliability for real-world applications. However, the presence of projects utilising Bitcoin and other technologies (3 projects, 16%) indicates ongoing exploration and innovation in the LMIC context. Additionally, 3 projects successfully integrated blockchain with IoT sensors, showcasing the potential for real-time data collection and remote patient care. Cloud technology was integrated in 2 projects, further addressing challenges with data storage and accessibility. These integrations highlight the collaborative power of emerging technologies to drive impactful healthcare solutions.

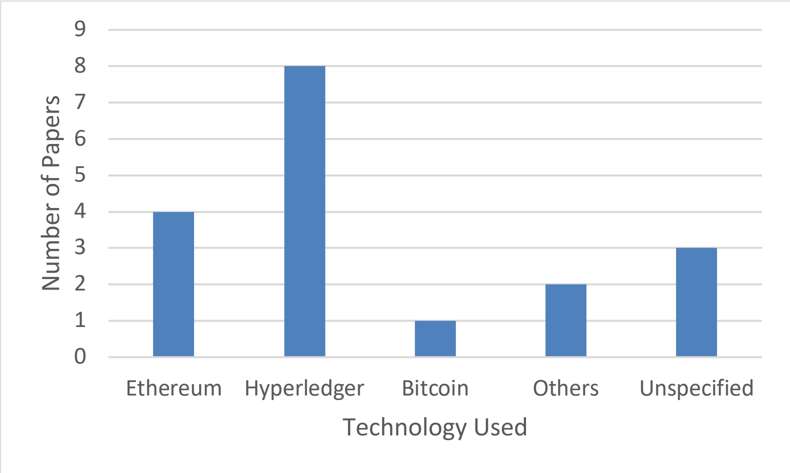

Figure 4. Blockchain Technology Used

4 Discussion

The results of the research demonstrate a growing interest and active exploration of blockchain technology in the health sector across Africa. A considerable number of projects have progressed beyond theoretical concepts, with 15 successful implementations reported. These implementations primarily consist of simulations and lab experiments, indicating a cautious approach to real-world adoption. The diversity of countries contributing to this research highlights the regional interest and collaborative efforts in harnessing blockchain technology for healthcare applications. Each country's unique socio-economic and healthcare challenges influenced the choice of use cases and technologies adopted. Below, the answers to research questions are provided.

Research Question 1: How is blockchain technology applied in healthcare within low- and middle-income countries?
Answer: The results from the analysis reveal that blockchain technology in healthcare within low- and middle-income countries (LMICs) is primarily applied in the implementation of Electronic Health Record (EHR) systems that aim to address data security and interoperability challenges. Beyond EHR, the technology finds more applications in remote patient monitoring and patient data privacy systems. The emergent of Electronic Health Records (EHRs) as the dominant use case reflects the urgent need for secure patient data storage, enhanced privacy, and streamlined data exchange in contexts where fragmented and insecure data management often undermines healthcare delivery. Additionally, the implementations of blockchain in supply chain management for drugs and vaccines highlights the need to enhance supply chain integrity, a vital consideration in resource-constrained environments. Other projects addressing payments, birth/death registration, and healthcare system management demonstrate blockchain's adaptability to diverse healthcare challenges.

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Research Question 2: What implementation approaches are utilised for blockchain in healthcare in low- and middle-income countries?
Answer: The implementation approaches for blockchain in healthcare in LMICs show a rather exploratory approach with 74% of projects residing in simulated or lab environments, indicating that most projects are still in the exploration stage. Additionally, 11% of projects have evolved into working prototypes, while only 15% have achieved full-fledged deployments. This suggests a progression from theoretical exploration to practical applications, emphasising the need for targeted support to bridge the gap between theory and real-world implementation. The results highlight a growing recognition of blockchain's potential and a commitment to translating theoretical concepts into practical applications. However, the varying levels of implementation underscore the challenges in achieving full-scale deployment. The majority of projects remain confined to controlled environments such as simulations or lab experiments, reflecting the technical and logistical complexities of real-world implementation. This calls for more robust strategies to address barriers such as infrastructure, regulatory hurdles, and stakeholder readiness.

Research Question 3: What challenges arise in implementing blockchain for healthcare in low- and middle-income countries?
Answer: The main challenge in the implementations of healthcare-based solutions in LMICs is the majority (74%) of implemented projects remain limited to controlled environments such as algorithms, simulations, or lab experiments. This suggests that while there is a strong commitment to exploring blockchain's potential, significant barriers prevent many initiatives from transitioning to practical, real-world applications. Key factors limiting successful deployment of blockchain based healthcare applications includes; inadequate infrastructure in LMICs such as limited internet connectivity and power reliability, which are essential for blockchain systems to operate effectively. Regulatory frameworks which in most countries either do not recognise or ban the use of crypto technologies. Overcoming these regulatory frameworks and addressing stakeholder concerns around data privacy, security, and interoperability is still a significant challenge. Another significant challenge is the lack of technical and administrative readiness. Many organizations lack the specialized expertise needed to design, develop, and maintain blockchain-based solutions, primarily due to the technology's inherent complexity.

Research Question 4: What are the recommended strategies for successful blockchain implementation in healthcare in low- and middle-income countries?
Answer: Recommended strategies for successful blockchain implementation in LMIC healthcare include addressing the challenges identified. One area that can be immediately addressed is building capacity for technology implementers to equip them with the necessary skills to develop blockchain solutions. Capacity building should also be extended to the administrative layer and decision-makers to create awareness of the benefits of using blockchain technology in the health sector. Additionally, strategies should be developed to enhance resource availability and navigate regulatory frameworks to ensure the smooth adoption of blockchain technology in LMIC healthcare. Lastly, as seen from the analysis, emphasis should be put on deploying blockchain with collaborative emerging technologies, such as IoT sensors and cloud integration, to drive successful healthcare solutions in these resource-constrained settings.

5 Conclusion

This study provides a review and analysis of the implementation of blockchain technology in the health sectors for low- and middle-income countries (LMICs), highlighting its potential to address critical challenges while also uncovering key barriers to widespread adoption. The findings reveal promising advancements, with most projects progressing beyond conceptual stages, demonstrating the growing commitment to practical applications. However, the predominance of projects still in controlled environments, such as simulations or lab experiments, indicates that significant challenges remain in achieving full-scale deployment. Blockchain technology shows promise in areas such as electronic health records, remote patient monitoring, and supply chain management, offering innovative solutions to enhance data security, privacy, and operational efficiency. Additionally, its potential extends to diverse use cases, including payments, healthcare system management, and vital statistics registration, showing its capability

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in addressing a wide range of issues in LMIC healthcare systems. Despite these opportunities, the study highlights substantial obstacles, including inadequate infrastructure, limited technical expertise, and complex regulatory frameworks. Addressing these challenges will require a concerted effort involving capacity building, collaborative policymaking, and the development of context-specific solutions tailored to LMIC environments. This research contributes to the existing body of knowledge by providing insights into the current state of blockchain implementation in LMICs and highlighting the necessity of addressing the gap between theoretical potential and practical application. Future research should extend its focus beyond the healthcare sector, examine regulatory frameworks relevant to blockchain technology, and investigate strategies for integrating blockchain with other emerging technologies.

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APPENDIX

Summary of Analysis for the Retrieved Articles

S/N	Article Title	Implementation Level	Use Case	Blockchain Technology Used
1	Implementation of Blockchain Enabled Healthcare System Using Hyperledger Fabric (Jain & Jat, 2022)	Lab experiment	Health care management system	Hyperledger
2	Patient-Centric Mobile App Solution (Khurram & Sardar, 2020)	Full application	Remote patient monitoring, electronic health records	Not specified
3	Secure Mobile Agents for Patient Status Telemonitoring Using Blockchain (Alruqi et al., 2021)	No implementation (Design proposed)	Remote patient monitoring	Not applicable
4	A Blockchain-Based Framework for Drug Traceability: ChainDrugTrac (Kambilo et al., 2022)	Lab experiment	Supply chain management	Ethereum
5	Improving Vaccine Safety Using Blockchain (Cui et al., 2021)	Lab experiment	Supply chain management	Fisco Bcos
6	Temporal Analysis of Cooperative Behaviour in a Blockchain for Humanitarian Aid during the COVID-19 Pandemic (Ba et al., 2022)	Full application	Payments	xDai
7	Enabling Privacy-Preserving Sharing of Genomic Data for GWASs in Decentralized Networks (Y. Zhang et al., 2019)	Algorithm developed	Electronic health records	Not applicable
8	A Permissioned Blockchain Approach to Electronic Health Record Audit Logs (Adlam & Haskins, 2020)	Lab experiment	Electronic health records	Hyperledger
9	A Framework for the Adoption of Blockchain Technology in Healthcare Information Management Systems: A Case Study of Nigeria (Azogu et al., 2019)	No implementation (Framework proposed)	Electronic health records	Not applicable
10	How Blockchain Helps to Combat Trust Crisis in COVID-19 Pandemic? (Abid et al., 2020)	Working prototype	Electronic health records	Ethereum
11	A Novel Decentralized Blockchain Architecture for the Preservation of Privacy and Data Security against Cyberattacks in Healthcare (Kumar et al., 2022)	Simulation	Electronic health records	Bitcoin
12	Blockchain-Secured Recommender System for Special Need Patients Using Deep Learning (Mantey et al., 2021)	Algorithm developed	Electronic health records	Not applicable
13	Addressing Care Continuity and Quality Challenges in the Management of Hypertension: Case Study of the Private Health Care Sector in Kenya (Walcott-Bryant et al., 2021)	No implementation (Framework proposed)	Healthcare management	Not applicable
14	A Novel Block Chain Method for Urban Digitization Governance in Birth	Full application	Birth/death registration	Ethereum

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	Registration Field: A Case Study (Shi et al., 2022)			
15	Potential Adoption of Blockchain Technology to Enhance Transparency and Accountability in the Public Healthcare System in South Africa (Ndayizigamiye & Dube, 2019)	No implementation	Health care management, supply chain management, electronic health records	Not applicable
16	Design of a Credible Blockchain-Based E-Health Records (CB-EHRS) Platform (Xu et al., 2019)	Lab experiment	Electronic health records	Hyperledger
17	Enabling Care Continuity using a Digital Health Wallet (Osebe et al., 2019)	Lab experiment	Electronic health records	Hyperledger
18	CP-BDHCA: Blockchain-Based Confidentiality-Privacy Preserving Big Data Scheme for Healthcare Clouds and Applications (Ghayvat et al., 2022)	Lab experiment	Electronic health records	Not specified
19	Secure and Privacy-aware Blockchain-based Remote Patient Monitoring System for Internet of Healthcare Things (Zaabar et al., 2021)	Lab experiment	Remote patient monitoring	Hyperledger
20	DSMAC: Privacy-Aware Decentralized Self-Management of Data Access Control Based on Blockchain for Health Data (Saidi et al., 2022)	Lab experiment	Electronic health records	Hyperledger
21	DASS-CARE 2.0: Blockchain-Based Healthcare Framework for Collaborative Diagnosis in CIoMT Ecosystem (Ayache et al., 2022)	No implementation (Framework proposed)	Healthcare management system	Not applicable
22	A Blockchain-based secure PHR data storage and sharing framework (Ghani et al., 2020)	Lab experiment	Electronic health records	Ethereum
23	Blockchain application to improve Vendor management replenishment in Humanitarian supply chain (Lahjouji et al., 2021)	No implementation (Framework proposed)	Supply chain management	Not applicable
24	A Novel Patient-Centric Architectural Framework for Blockchain-Enabled Healthcare Applications (Singh et al., 2021)	Working prototype	Supply chain management	Hyperledger
25	An IoT and Blockchain-Based Multi-Sensory In-Home Quality of Life Framework for Cancer Patients (Rahman et al., 2019)	Lab experiment	Remote patient monitoring, electronic health records	Hyperledger

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