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# Blockchain Technology in Healthcare: A PRISMA-Guided Systematic Review of Implementation Barriers, Trust, Literacy and Institutional Readiness

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**Abstract.** Blockchain technology is transforming the healthcare sector by addressing challenges such as data security and interoperability. This systematic literature review, conducted using the PRISMA 2020 methodology, synthesises findings from 25 peer-reviewed studies to examine the applications, challenges, and future directions of blockchain in healthcare. Results reveal that most studies are theoretical or review-based, followed by case studies, with a small proportion of experimental research. This distribution highlights the early stage of blockchain research in healthcare and emphasises the need for empirical and experimental investigations. By synthesising findings, this study provides an overview of the current state of art regarding blockchain in healthcare.

**Key words:** blockchain in healthcare, data security and interoperability, blockchain adoption, challenges, PRISMA.

## 1. Blockchain in Healthcare Sector

The healthcare sector is undergoing a profound digital transformation, driven by the pressing need for efficient data management, patient-centred care, and secure, interoperable systems. Among the emerging technologies, blockchain has gained prominence as a transformative enabler, offering decentralisation, immutability, and enhanced security (Zhuang *et al.*, 2020; Hylock and Zeng, 2019). By addressing persistent challenges such as data fragmentation, fraud, and inefficiency – particularly in the management, sharing, and protection of sensitive medical information – blockchain holds the potential to revolutionise healthcare operations (Gaynor *et al.*, 2022; Tripathi *et al.*, 2020). These features position the technology as a key solution for mitigating the fragmentation of healthcare systems

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and strengthening trust in data sharing and management processes (Bak *et al.*, 2023; Çolak and Kağnicioğlu, 2022).

Despite its transformative potential, implementation of blockchain in healthcare remains limited due to challenges such as scalability, high implementation costs and regulatory ambiguity (Joshi and Sharma, 2023; Abbas *et al.*, 2022). Integration with existing infrastructures, including electronic health records (EHRs) and the Internet of Medical Things (IoMT), introduces significant technical and operational complexities (Bak *et al.*, 2023; Sakka *et al.*, 2024). Furthermore, the lack of a harmonised regulatory framework and the high computational demands of blockchain systems exacerbate these challenges (Nalin *et al.*, 2019; Bautista *et al.*, 2022).

This review synthesises findings from a comprehensive analysis of studies to explore the diverse applications, challenges and future directions of blockchain in healthcare. Key areas of focus include electronic health records (EHRs), where blockchain ensures patient control and data integrity (Zhuang *et al.*, 2020; Hylock and Zeng, 2019); supply chain management, where it improves traceability and transparency in medical logistics (Abbas *et al.*, 2022; Rovere *et al.*, 2024); privacy frameworks that protect patient identities and enhance regulatory compliance (Sakka *et al.*, 2024; Sangal *et al.*, 2024); organizational and Human capabilities (Bautista *et al.*, 2022; Sangal *et al.*, 2024; Agrawal and Patil, 2024; Akhtar *et al.*, 2022); and population health initiatives, where blockchain facilitates real-time disease surveillance and data aggregation (Gaynor *et al.*, 2022; Sousa, 2023).

By synthesising these findings, this review aims to provide actionable insights for healthcare practitioners, technology developers and policymakers, and to contribute to the ongoing discourse on blockchain implementation in healthcare. The study identifies key opportunities, such as increased interoperability and patient empowerment (Zhuang *et al.*, 2020; Hylock and Zeng, 2019), as well as critical barriers, including organisational resistance and cost constraints (Joshi and Sharma, 2023; Pesqueira *et al.*, 2023).

The paper is structured as follows: Section 2 outlines the methodology, including the PRISMA2020-based approach to article selection and analysis. Section 3 presents the findings; summarising key themes and trends identified in the literature. Finally, Section 4 concludes with recommendations for future research and strategic action to advance the implementation of blockchain in healthcare.

## 2. Methodology

This systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a structured, transparent, and replicable research process (Page *et al.*, 2021). The methodology followed four distinct stages – identification, screening, eligibility, and inclusion – providing a comprehensive framework to explore the applications, challenges, and benefits of blockchain technology in healthcare.

### 2.1. *Data Sources and Search Strategy*

A comprehensive search was conducted across three major academic databases – Scopus, Web of Science, and PubMed – selected for their extensive coverage of multidisciplinary and technical literature relevant to blockchain and healthcare. This approach adhered to the PRISMA 2020 guidelines to ensure transparency and replicability (Page *et al.*, 2021).

The search strategy combined Boolean operators (AND, OR) with a predefined set of keywords to capture studies on blockchain applications in healthcare. Representative search strings included:

- Core keywords: "*blockchain AND healthcare*", "*blockchain AND trust OR literacy*", "*data management AND blockchain AND health*"
- Specific contexts: "*blockchain adoption AND barriers AND healthcare*", "*privacy frameworks AND blockchain*", "*healthcare supply chain AND blockchain*"

Truncation and wildcard characters (e.g. *blockchain** or *healthcare**) were employed to capture singular, plural, and morphological variations of keywords – an established best practice in systematic searches.

The search was limited to peer-reviewed articles published between 1 January 2014 and 31 October 2024 to capture a decade of literature that is aligned with the evolution of blockchain in healthcare. The final database search was conducted on 6 November 2024.

All retrieved articles were exported to Systematic Literature Review software to streamline the organisational process, remove duplicates, and prepare them for the subsequent screening stages.

### 2.2. *Study Selection and Eligibility Criteria*

The selection of studies was conducted using a structured, two-stage approach. First, the studies were screened at the title and abstract level, and then full-text screening was performed, guided by predefined inclusion and exclusion criteria. These criteria were designed to ensure that only studies offering substantive and conceptually relevant contributions to blockchain applications in healthcare were included.

Articles were excluded if they failed to meet the central research objectives, applying three exclusion categories:

1. Studies not related to the implementation of blockchain in healthcare contexts.
2. Articles not addressing blockchain or distributed ledger technologies (DLT) in data management, a core focus of this review.
3. Studies omitting discussion of barriers and challenges to blockchain implementation in healthcare, which are critical to understanding implementation dynamics.

The reasons for exclusion at the eligibility stage are mapped explicitly to these criteria in Fig. 1.

### 2.3. *Thematic Synthesis*

The synthesis was organised thematically to capture the scope of blockchain implementation in healthcare. The findings were categorised under four key application areas: electronic health records (EHRs), supply-chain management, public health surveillance and privacy/identity management. These were then analysed alongside cross-cutting challenges, such as regulatory and legal uncertainties, technical and infrastructural barriers, ethical concerns and organisational and human factors (e.g. trust and digital literacy). This thematic organisation provides a comprehensive overview of the impact of blockchain on the digital transformation of healthcare systems.

## 3. Results

This systematic literature review identified and synthesised the findings of peer-reviewed studies in order to explore the applications, challenges and benefits of blockchain technology in healthcare. The findings were organised according to the following key themes derived from the research questions: Applications, challenges and future directions.

### 3.1. *Summary of Findings*

The review synthesised evidence demonstrating the potential of blockchain technology to address key challenges in healthcare, including those relating to data security, privacy and efficiency. However, significant barriers remain, particularly with regard to scalability, regulatory compliance and organisational implementation. The findings provide stakeholders with actionable insights to help them harness the benefits of blockchain technology while addressing its limitations.

For a full overview of the selection of studies and their thematic distribution, see the PRISMA flowchart and the structured findings in Fig. 1.

Figure 1 presents the PRISMA 2020 flow diagram illustrating the process of identification, screening, and inclusion of studies in this systematic review. A total of 61 records were initially identified through the data extracted from the databases. After automatic removal of four duplicate records, 57 unique records were retained for screening.

During the screening phase, the titles and abstracts were examined to assess their relevance to the research focus: blockchain implementation in the healthcare sector. Studies that did not address healthcare contexts were clearly outside the scope of the review and were therefore excluded. Following this process, 45 studies were selected for full-text retrieval.

During the full-text retrieval, eight studies could not be retrieved due to access limitations. The remaining 41 full-text studies were assessed on detail for methodological quality and relevance. Of these, a total of 16 were excluded based on the three exclusion criteria. Consequently, 25 studies met all inclusion criteria and were incorporated into the final synthesis. These studies formed the basis for the qualitative and descriptive analysis presented in the subsequent sections.

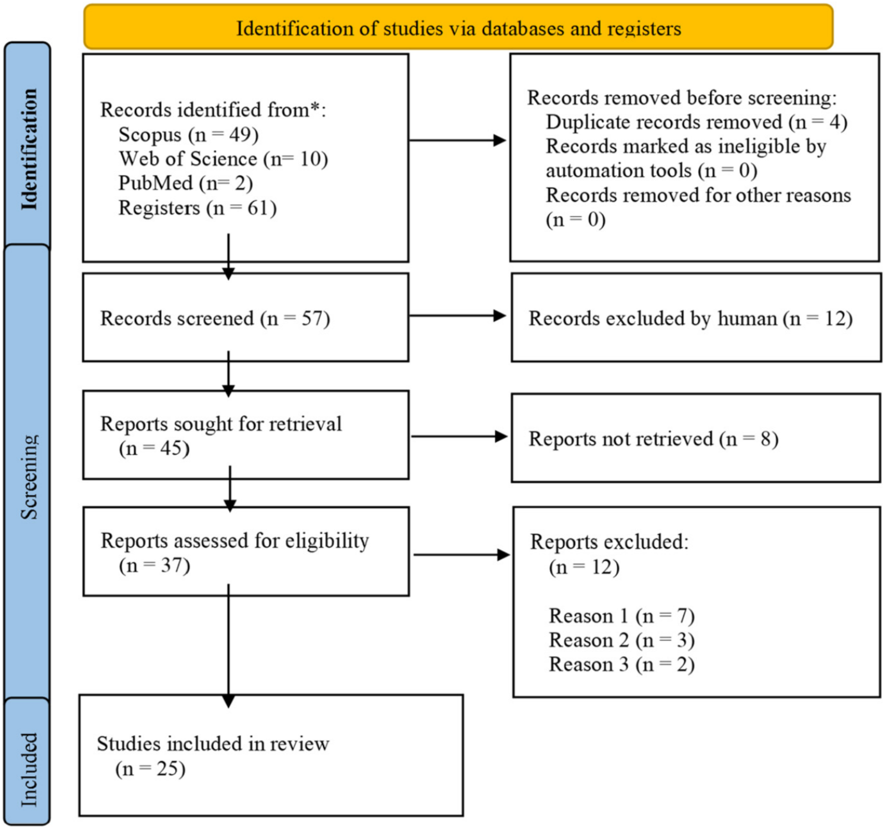


Fig. 1. PRISMA 2020 flowchart.

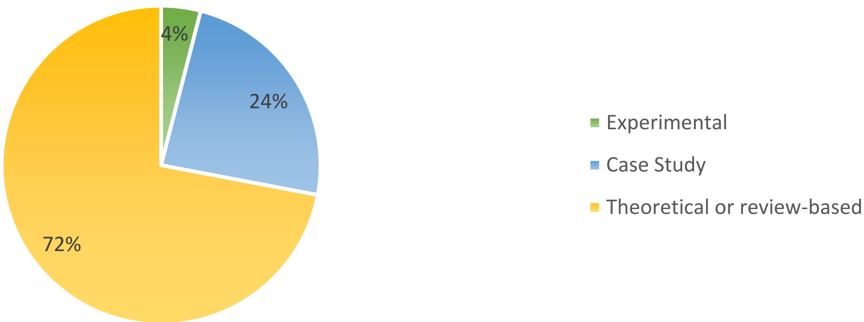


Fig. 2. Study type distribution.

## 3.2. *Statistical Distribution of Study Types*

As can be seen in Fig. 2, mapping revealed that out of 25 studies, 18 (72%) are theoretical or review-based. This data show that it is clear that blockchain research in healthcare is

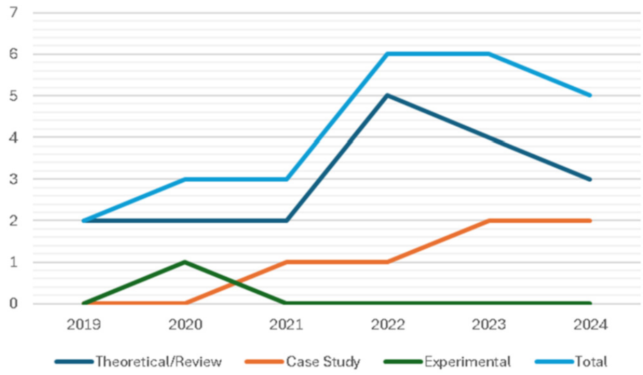


Fig. 3. Distribution of studies by year and type.

still in its exploratory phase. Researchers are primarily focused on synthesising existing knowledge, conceptualising frameworks, and identifying the challenges and opportunities associated with implementing blockchain technology. This phase is crucial for establishing a foundation for further empirical investigation and for guiding the development of practical applications.

The presence of six case studies (24% of the total of 25) suggests an interest in applying theoretical knowledge to practical situations. These studies usually focus on applications of blockchain technology in healthcare, offering valuable insights into its practical advantages, limitations, and challenges. The increased use of case studies reflects the field's gradual shift towards empirical validation.

The limited number of experimental studies (one study, accounting for 4% of the total of 25) suggests that the practical prototyping and testing of blockchain solutions in healthcare is an under-explored area. Such studies are essential for demonstrating the feasibility, scalability and effectiveness of blockchain applications in a dynamic healthcare environment. The lack of such studies indicates a gap that must be addressed if the field is to mature further.

Figure 3 shows the temporal evolution of blockchain research in healthcare across the period represented in the dataset (January 2014 to 31 October 2024). No studies meeting the inclusion criteria were identified between 2014 and 2018. Of the articles analysed in full, those published between 2019 and 2024 revealed a predominance of theoretical and review-based studies in the early years, reflecting a focus on conceptual frameworks and technological potential. From the year 2020 onwards, the number of case studies increases, indicating a gradual shift toward applied and context-specific research. However, experimental studies remain scarce. This suggests that practical validation and studies on the large-scale implementation of Blockchain solutions in healthcare are still in the early stages.

This distribution reflects the gradual maturation of blockchain research in the healthcare domain. The predominance of theoretical and review-based studies highlights the field's strong conceptual foundations; further progress depends on expanding empirical and experimental investigations that can validate the real-world feasibility and effectiveness of blockchain applications. Although the recent increase in case studies is a promising step towards applied research, the scarcity of experimental work underscores the need for deeper technical testing and implementation-oriented studies to consolidate the technology's practical relevance.

## 3.3. *Applications for Blockchain in Healthcare*

### Electronic Health Records (EHRs)

Integrating blockchain technology into electronic health records (EHRs) provides a decentralised, secure solution for managing sensitive patient information. This effectively addresses long-standing issues such as data fragmentation, limited interoperability and access control. Zhuang *et al.* (2020) proposed a layered blockchain architecture to enhance the scalability and efficiency of health information exchanges (HIEs) enabling secure and streamlined data sharing between healthcare providers. Similarly, Hylock and Zeng (2019) introduced the Health Chain framework, which gives patients ownership of, and control over, their medical records, all the while maintaining interoperability across health systems. This patient-centric approach promotes data portability and greater autonomy over personal health information.

Bautista *et al.* (2022) furthered this discussion by examining the ethical, social and regulatory complexities involved in deploying blockchain-based EHR systems. Their findings emphasise the importance of addressing privacy concerns, navigating complex legal frameworks, and fostering stakeholder trust to ensure the successful implementation and implementation of these systems.

These perspectives are complemented by studies identifying benefits associated with blockchain-enabled EHRs, including enhanced data security, real-time monitoring, and improved interoperability. These studies include those by Harris (2021). Agrawal and Patil (2024), Agha (2023), Cernian *et al.* (2020), and Bharimalla *et al.* (2021). However, they also highlight persistent challenges, most notably the technical complexity of integration, high implementation costs and ongoing concerns about data privacy and regulatory compliance.

Table 1 summarises the core thematic domains and associated challenges identified in the literature on blockchain applications in EHR systems.

In the domain of data security and integrity, studies such as those by Agha (2023), Bharimalla *et al.* (2021) and Hylock and Zeng (2019) emphasise the role of blockchain in creating tamper-proof medical records. By enabling immutability and decentralised storage, blockchain technology mitigates the risks of unauthorised access and ensures the trustworthiness of clinical data.

The interoperability challenge is also addressed. Zhuang *et al.* (2020), Cernian *et al.* (2020) and Hylock and Zeng (2019) propose architectures that facilitate the seamless exchange of data across different health information systems, thereby contributing to more coordinated and efficient care delivery.

Regarding patient autonomy, blockchain technology is recognised for its capacity to empower individuals by granting them direct control over access permissions and data

Table 1
Blockchain technology in Electronic Health Records (EHRs).

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Data Security and Integrity | Ensuring tamper-proof medical records | Blockchain enhances data immutability and protection against unauthorized access or manipulation of patient records. | Agha (2023), Bharimalla *et al.* (2021), Hylock and Zeng (2019) |
| Interoperability | Fragmentation across health IT systems | Blockchain facilitates standardization and integration of data across multiple providers and platforms, improving continuity of care. | Zhuang *et al.* (2020), (Hylock and Zeng, 2019), Hylock and Zeng (2019) |
| Patient Autonomy | Limited control over personal health data | Blockchain enables patient-centric models where individuals manage consent and access to their own EHRs. | Harris (2021), Hylock and Zeng (2019), Agrawal and Patil (2024) |
| Implementation Complexity | Technical and operational barriers | High costs, integration complexity, and system migration challenges hinder widespread deployment of blockchain-based EHRs. | Bharimalla *et al.* (2021), Bautista *et al.* (2022), Agrawal and Patil (2024) |
| Regulatory and Ethical | Privacy and compliance issues | Navigating data protection regulations (e.g., GDPR, HIPAA) and ensuring ethical data usage remain key concerns in blockchain implementation. | Bautista *et al.* (2022), Harris (2021) |

sharing. Harris (2021), Hylock and Zeng (2019) and Agrawal and Patil (2024) present models that operationalise patient consent through smart contracts and self-managed identities.

Despite these advantages, several studies have identified implementation complexity as a critical barrier. Significant hurdles include high initial investment costs, integration with legacy systems, and the need for specialised technical expertise, as noted by Bharimalla *et al.* (2021), Bautista *et al.* (2022) and Agrawal and Patil (2024).

Furthermore, the regulatory and ethical dimensions highlight concerns about compliance with privacy laws such as the GDPR and HIPAA. As discussed by Bautista *et al.* (2022) and Harris (2021), it is difficult to balance innovation in blockchain-based systems with ensuring data protection.

Overall, these findings illustrate that, although blockchain technology shows great potential for improving the security, efficiency and patient-centredness of EHR systems, its widespread implementation hinges on overcoming technical and institutional obstacles.

### Supply Chain Management in Healthcare

Blockchain technology has the potential to significantly improve transparency, efficiency and security in healthcare supply chains. It addresses long-standing challenges such as counterfeit products, fragmented systems and a lack of trust among stakeholders in the supply chain. Bak *et al.* (2023) demonstrated in their study of the Indian hospital system how blockchain's decentralised, tamper-proof ledger can offer end-to-end traceability of medical supplies. They found that immutable record keeping improves accountability, facilitates regulatory compliance and fosters trust among suppliers, manufacturers and healthcare providers.

Table 2
Blockchain technology in supply chain management within healthcare.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Traceability and Security | Counterfeit medical products | Blockchain enables product verification and end-to-end traceability, reducing counterfeit risks. | Bak *et al.* (2023), Rovere *et al.* (2024) |
| Transparency | Opaque procurement processes | Immutable ledgers promote transparent transactions and accountability among supply chain actors. | Bak *et al.* (2023), Çolak and Kağnicioğlu (2022) |
| Operational Efficiency | Fragmented and inefficient workflows | Blockchain streamlines data flows, reduces manual reconciliation, and supports real-time tracking. | Bak *et al.* (2023) |
| Implementation Readiness | Organizational and technological barriers | Lack of readiness, high costs, and resistance to change hinder blockchain integration. | Çolak and Kağnicioğlu (2022), Bak *et al.* (2023) |

In the context of orthopaedic practice specifically, Rovere *et al.* (2024) showed that blockchain can preserve the integrity and traceability of surgical records and connected medical devices. Leveraging blockchain for provenance tracking enables healthcare institutions to mitigate the risk of counterfeit implants and ensure the reliability of surgical interventions, thereby improving patient safety and clinical outcomes.

Complementing these perspectives, Çolak and Kağnicioğlu (2022) developed a conceptual model for evaluating blockchain implementation in supply chains, including in the healthcare sector. Their study emphasised critical determinants such as organisational readiness, technological infrastructure, and perceived cost-benefit trade-offs. While blockchain implementation poses challenges, particularly regarding implementation costs and stakeholder resistance, it also offers tangible benefits in terms of enhanced visibility, trust, and cost-efficiency.

Table 2 summarises the key challenges and opportunities related to blockchain implementation in healthcare supply chain management, as identified in the reviewed studies.

These findings highlight the transformative potential of blockchain technology to optimise healthcare supply chains by increasing product visibility, ensuring data integrity and strengthening stakeholder trust. However, realising these benefits requires strategic investment in organisational readiness, stakeholder engagement and the development of interoperable blockchain infrastructures. Further research is needed to explore cross-sectoral models, particularly in public healthcare contexts, to address persistent barriers to implementation and foster sustainable innovation.

## Privacy and Identity Management

Ensuring patient privacy and secure identity management is a fundamental aspect of blockchain's application in healthcare. With increasing concerns about data breaches and regulatory compliance, blockchain offers innovative solutions to enhance data privacy and control. Sakka *et al.* (2024) propose a privacy management framework that integrates blockchain with federated learning, ensuring alignment with GDPR regulations. Their approach leverages advanced privacy-enhancing technologies, such as homomorphic en-

Table 3
Blockchain privacy and identity management in healthcare.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Data privacy and compliance | Ensuring patient data confidentiality | Blockchain must implement robust encryption and privacy-preserving mechanisms to comply with regulations like GDPR and avoid data breaches. | Sakka *et al.* (2024), Harris (2021) |
| Consent management | Lack of patient autonomy over data use | Traditional systems offer limited patient control. Blockchain enables self-sovereign consent and transparent access tracking. | Anderson *et al.* (2023), Agrawal and Patil (2024) |
| Decentralised identity | Centralised identity systems are vulnerable | Centralised models increase exposure to breaches. Blockchain supports decentralised identity models with enhanced resilience and transparency. | Sangal *et al.* (2024), Anderson *et al.* (2023) |
| Technical implementation | Integration of privacy-enhancing tech | Use of advanced technologies like homomorphic encryption, federated learning, and multiparty computation is required but complex to implement. | Sakka *et al.* (2024); Agrawal and Patil (2024) |

cryption and secure multiparty computation, to provide patients with granular control over their data while maintaining robust security measures.

Similarly, Sangal *et al.* (2024) examined the integration of blockchain into omnichannel healthcare systems in emerging economies. Their study demonstrated blockchain's ability to rapidly build trust among users by ensuring transparency and security of data transactions, which is critical to increasing user implementation. By decentralising identity management, blockchain enables secure, patient-centric models that empower individuals to control how and when their health data is shared, reducing reliance on centralised systems that are vulnerable to breaches.

The review identified three key studies addressing privacy and identity management in healthcare through blockchain innovation (see Table 3). Anderson *et al.* (2023) proposed a blockchain-based solution for consent self-management in health information exchange, highlighting increased patient autonomy and trust in decentralised systems. Harris (2021) developed a prototype using blockchain to manage COVID-19 patient health records, highlighting the technology's potential to improve transparency and data security in sensitive healthcare contexts. Agrawal and Patil (2024) used a fit-viability approach to evaluate the application of blockchain for medical record security, demonstrating its effectiveness in enhancing privacy while addressing functional and technical barriers. Collectively, these studies highlight the transformative role of blockchain in ensuring secure, efficient and patient-centric healthcare information management.

Table 3 summarises the key challenges and innovations relating to privacy and identity management in blockchain-based healthcare systems. As health data becomes more digital and interconnected, ensuring secure, transparent and patient-controlled access is becoming a critical concern. The table categorises these issues into four thematic domains: data privacy and compliance; consent management; decentralised identity; and technical implementation.

Within the data privacy and compliance domain, studies have emphasised the importance of aligning blockchain solutions with regulatory standards such as the General Data Protection Regulation (GDPR). Sakka *et al.* (2024), for example, proposed a privacy management framework integrating federated learning and privacy-enhancing technologies such as homomorphic encryption and secure multiparty computation to meet these requirements while preserving data utility. Similarly, Harris (2021) emphasised the importance of blockchain technology for securely managing sensitive health data during the pandemic.

In the field of consent management, blockchain technology introduces novel mechanisms for patient empowerment. Anderson *et al.* (2023) demonstrated that decentralised consent self-management frameworks can increase transparency and user trust. These models enable patients to control how and when their data is shared, thereby reducing their reliance on centralised intermediaries. Agrawal and Patil (2024) also evaluated the effectiveness of blockchain in improving consent processes using a fit-viability approach that considers technical and organisational feasibility.

The decentralised identity domain addresses vulnerabilities in traditional identity systems. By leveraging blockchain technology, healthcare institutions can implement decentralised identity models that enhance resilience and mitigate the risk of data breaches. Sangal *et al.* (2024) emphasised that such systems enhance user confidence by offering granular control over identity attributes, thereby fostering greater engagement and trust in digital health platforms.

Finally, the technical implementation of privacy-preserving mechanisms presents both opportunities and challenges. While solutions such as secure computation and federated learning enhance privacy, their deployment remains technically complex. Integrating these technologies into existing infrastructures requires robust cryptographic design and significant institutional capacity, as noted by Sakka *et al.* (2024) and Agrawal and Patil (2024).

Together, these findings illustrate that blockchain can serve as a foundational layer for secure, patient-centric healthcare data ecosystems. However, successful implementation depends on technological sophistication, regulatory alignment and user-centric design.

These advances underscore the transformative potential of blockchain in privacy and identity management. By providing secure and compliant solutions that align with evolving regulatory landscapes, blockchain can significantly improve trust and efficiency in healthcare data ecosystems, especially in regions with emerging technology infrastructures.

### Population Health and Public Health Surveillance

The decentralised, immutable nature of blockchain technology has proven valuable in addressing challenges in population health and public health surveillance. By enabling real-time data monitoring and ensuring secure and transparent data sharing, blockchain provides a robust framework for tracking disease outbreaks and improving public health responses. Gaynor *et al.* (2022) highlight the potential of blockchain to enhance population health surveillance systems, particularly using smart contracts. These contracts streamline the management of health data and improve transparency in its use, ensuring accountability among stakeholders involved in public health initiatives.

Table 4
Blockchain applications in population health and public health surveillance.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Surveillance infrastructure | Fragmented data collection and sharing | Blockchain enables decentralized, real-time data exchange between institutions, improving outbreak response. | Gaynor *et al.* (2022) |
| Data integrity and accountability | Lack of trust in health data handling | Immutable records and transparent smart contracts foster accountability in public health initiatives. | Gaynor *et al.* (2022), Sousa (2023) |
| Governance and decision-making | Inefficiencies in public sector health systems | Blockchain can streamline bureaucratic processes, enhancing responsiveness and data-informed decisions. | Sousa (2023) |

Sousa (2023) extended this perspective by examining the broader role of blockchain in transforming public sector operations. The study proposed a comprehensive framework for assessing blockchain's impact on organisational efficiency and decision-making processes. By leveraging blockchain, public health systems can improve data integrity and enable more reliable, data-driven policy interventions.

Table 4 summarises the key challenges and opportunities associated with using blockchain technology for population and public health surveillance. The reviewed studies demonstrate how the decentralised, tamper-proof architecture of blockchain technology can strengthen health systems by improving the reliability, traceability and governance of health data.

Together, these studies highlight blockchain's ability to improve public health infrastructure by fostering trust, efficiency and accountability. As global health challenges become increasingly complex, blockchain offers innovative tools to strengthen surveillance systems and enhance the effectiveness of health interventions. These findings emphasise the transformative potential of blockchain technology to enhance public health infrastructure by improving surveillance, data security and inter-agency coordination. However, they also suggest that realising this potential requires overcoming technical, regulatory and institutional barriers.

### 3.4. *Challenges in Blockchain Implementation*

While blockchain technology holds great promise for transforming healthcare, its implementation is hindered by a range of technical, organisational and regulatory barriers. Joshi and Sharma (2023) highlight key challenges in developing countries, including inadequate technological infrastructure, resistance to change among healthcare providers, and the high costs associated with implementing blockchain solutions. These limitations often exacerbate existing inequalities, particularly in resource-constrained settings.

In more developed contexts, regulatory fragmentation remains a significant barrier, as noted by Nalin *et al.* (2019). Their study highlights the complexity of cross-border health data exchange within the European Union, where different data protection laws and a lack of harmonised standards hinder the seamless implementation of blockchain solutions. These regulatory inconsistencies create uncertainty, further discouraging investment in blockchain-based healthcare initiatives.

Table 5
Challenges in blockchain implementation in the healthcare sector.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Regulatory and legal | Lack of regulatory clarity | Ambiguities regarding data ownership, liability, and cross-border compliance hinder implementation. | Joshi and Sharma (2023), Nalin *et al.* (2019), Bautista *et al.* (2022) |
| | Smart contract enforceability | Uncertainties about the legal status and enforceability of smart contracts in healthcare settings. | Joshi and Sharma (2023), Akhtar *et al.* (2022) |
| Technical and infrastructure | Interoperability with legacy systems | Difficulty integrating blockchain with existing EHR and hospital information systems. | Cernian *et al.* (2020), Zhuang *et al.* (2020) |
| | Scalability and performance limitations | Current blockchain architectures face constraints in transaction speed and data storage. | Aich *et al.* (2021), Hylock and Zeng (2019) |
| | Data privacy and confidentiality | Risks of re-identification and technical challenges in implementing privacy-preserving mechanisms. | Bharimalla *et al.* (2021), Sakka *et al.* (2024) |
| Organizational | Misalignment between IT and executive leadership | Strategic disconnects can lead to underfunded or fragmented blockchain initiatives. | Pesqueira *et al.* (2023), Agrawal and Patil (2024) |
| | Low blockchain literacy among healthcare staff | Lack of understanding impedes stakeholder engagement and informed decision-making. | Akhtar *et al.* (2022), Bautista *et al.* (2022) |
| | Resistance to change | Institutional inertia and skepticism about new technologies delay implementation. | Sangal *et al.* (2024), Sousa (2023) |
| Economic and resource-based | High implementation and maintenance costs | Initial investment, infrastructure, and talent acquisition represent significant financial barriers. | Bak *et al.* (2023), Harris (2021) |
| | Lack of funding or incentives | Absence of economic incentives for early adopters within public health systems. | Gaynor *et al.* (2022), Anderson *et al.* (2023) |
| Ethical and social | Trust and data governance concerns | Concerns over data misuse and transparency in patient data control undermine trust. | Bautista *et al.* (2022), Agha (2023) |
| | Digital divide and exclusion | Blockchain solutions may marginalize populations with low digital access or health literacy. | Abbas *et al.* (2022), Akhtar *et al.* (2022) |

Table 5 provides a structured overview of the key challenges related to the implementation of blockchain technology in healthcare settings. These challenges are categorised into five domains: regulatory and legal; technical and infrastructure; organisational; economic and resource-based; and ethical and social.

Scalability remains a persistent technical challenge, as outlined by Abbas *et al.* (2022). High computational demands, long transaction processing times, and energy inefficiencies limit the applicability of blockchain in large-scale healthcare systems. These issues are particularly problematic in real-time applications, such as emergency data sharing and disease surveillance.

At the organisational level, Pesqueira *et al.* (2023) highlighted the role of individual dynamic capabilities in overcoming resistance to change and fostering blockchain innovation in hospital settings. The study highlighted the need for training and capacity building programmes to equip healthcare professionals with the necessary skills to effectively use blockchain technologies.

The most frequently cited barriers within the regulatory and legal domain include a lack of regulatory clarity regarding data ownership, liability and compliance in cross-border contexts, and the legal enforceability of smart contracts. Such uncertainties create hesitancy among institutional leaders and policymakers to endorse or invest in blockchain-based solutions (Joshi and Sharma, 2023; Bautista *et al.*, 2022).

The technical and infrastructure domain encompasses persistent interoperability issues with legacy electronic health record (EHR) systems, limitations in terms of processing speed and storage capacity, and unresolved data privacy challenges. Despite the potential for enhanced data security, concerns about patient re-identification and the complexity of implementing privacy-preserving mechanisms remain significant (Hylock and Zeng, 2019; Cernian *et al.*, 2020).

From an organisational perspective, implementation efforts are often hindered by a lack of alignment between executive leadership and IT departments, compounded by low blockchain literacy among healthcare professionals and institutional resistance to innovation. These factors hinder strategic coordination and limit the capacity of healthcare institutions to integrate blockchain into their digital transformation agendas (Akhtar *et al.*, 2022; Pesqueira *et al.*, 2023).

In the economic and resource-based domain, the substantial initial costs of implementation and maintenance present a significant barrier, particularly in environments with limited resources. A lack of funding incentives or reimbursement schemes also discourages early implementation, particularly within public health systems where budgets are already under pressure (Gaynor *et al.*, 2022; Bak *et al.*, 2023).

Finally, the ethical and social domain is raising growing concerns about data governance, patient trust and digital exclusion. Although blockchain technology has the potential to enhance data control and transparency, the risks of misuse and the potential marginalisation of populations with low digital literacy remain unresolved issues that must be addressed to ensure equitable implementation (Abbas *et al.*, 2022; Bautista *et al.*, 2022). Furthermore, the ethical and social dimensions of blockchain implementation cannot be overlooked. Abbas *et al.* (2022) identified the digital divide, trust deficits, and data privacy concerns as significant barriers. Addressing these challenges requires transparent communication with stakeholders, robust governance mechanisms, and the development of trust-building strategies to facilitate implementation.

Taken together, these findings show that the path to widespread implementation of blockchain in healthcare is fraught with challenges that will require the coordinated efforts of policymakers, technologists, and healthcare providers to overcome. Overcoming these barriers will be essential to realising blockchain's transformative potential in creating more efficient, secure, and patient-centred healthcare systems.

### 3.5. *Literacy and Blockchain Implementation*

The implementation of blockchain technology in healthcare is largely shaped by the level of literacy of key stakeholders, including healthcare practitioners, administrators and IT specialists. Joshi and Sharma (2023) highlighted that limited knowledge and awareness of blockchain concepts create significant barriers to implementation, leading to scepticism and resistance among healthcare professionals. Similarly, Bautista *et al.* (2022) highlighted that inadequate education about blockchain exacerbates ethical and social challenges, contributing to a lack of trust and misalignment with organisational goals. These findings highlight the importance of increasing blockchain literacy to reduce resistance to change and promote alignment with institutional objectives.

Joshi and Sharma (2023) identified literacy gaps as a critical factor affecting blockchain implementation in developing countries. Their study found that insufficient knowledge of the technology's potential applications and benefits led to scepticism and reluctance among healthcare professionals to integrate blockchain into existing systems. This lack of understanding extended to technical staff, further complicating the implementation process and reducing the effectiveness of pilot projects.

Bautista *et al.* (2022) highlighted the ethical and social implications of literacy in the implementation of blockchain. Their findings showed that inadequate training and education create inequalities between stakeholders, leading to unequal access to the technology and its associated benefits. This 'digital divide' is particularly pronounced in resource-constrained settings, where access to educational resources is limited.

Similarly, Pesqueira *et al.* (2023) highlighted the importance of individual dynamic capabilities in fostering blockchain innovation within hospitals. The study highlighted that training programmes aimed at increasing blockchain literacy among healthcare professionals could significantly reduce resistance to change and improve implementation rates. By equipping stakeholders with a deeper understanding of blockchain's functionalities and benefits, organisations can foster a culture of innovation and trust.

Furthermore, Sousa (2023) suggested that literacy programmes tailored to different stakeholder groups could help bridge the gap between technical experts and non-technical healthcare workers. By aligning blockchain education with specific roles and responsibilities, healthcare organisations can improve collaboration and streamline the technology implementation process.

Table 6 summarises the key challenges related to literacy and its impact on the implementation of blockchain technology in healthcare systems. Organised across three thematic domains – knowledge and awareness, training and education, and institutional capacity – the table illustrates how low literacy levels act as a fundamental barrier to integrating blockchain into clinical and administrative environments.

Within the knowledge and awareness domain, studies have consistently demonstrated that a limited grasp of blockchain concepts among healthcare professionals fosters scepticism and opposition to innovation. Joshi and Sharma (2023) identified widespread misconceptions and a general lack of familiarity with blockchain's practical applications as major impediments to successful implementation, particularly in developing countries.

Table 6
Literacy and blockchain implementation in healthcare.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Knowledge and awareness | Low blockchain literacy among stakeholders | Limited knowledge and understanding of blockchain among healthcare professionals hinder implementation. | Joshi and Sharma (2023), Bautista *et al.* (2022) |
| | Misconceptions and scepticism | Lack of familiarity with blockchain leads to mistrust and resistance to pilot projects and innovations. | Joshi and Sharma (2023), Akhtar *et al.* (2022) |
| Training and education | Inadequate training programmes | Absence of structured education and upskilling efforts limits readiness and user confidence. | Bautista *et al.* (2022), Sousa (2023) |
| | Lack of role-specific educational strategies | Generic approaches to training fail to meet the specific needs of clinicians, administrators, and IT staff. | Sousa (2023), Pesqueira *et al.* (2023) |
| Institutional capacity | Barriers to capability development | Organisations lack internal programmes and incentives to promote blockchain literacy and innovation. | Pesqueira *et al.* (2023), Sousa (2023) |
| | Inequitable access to digital education | Literacy disparities reinforce the digital divide, especially in resource-constrained settings. | Bautista *et al.* (2022), Abbas *et al.* (2022) |

Similarly, Bautista *et al.* (2022) emphasised the ethical and organisational risks posed by knowledge gaps, noting that insufficient awareness undermines trust and stakeholder engagement.

The training and education sector highlights the lack of structured learning opportunities that are tailored to the specific needs of the various stakeholders in healthcare. While technical experts require advanced knowledge of blockchain architectures and protocols, clinicians and administrators benefit more from applied, context-specific literacy. Sousa (2023) emphasised the importance of role-specific educational strategies, suggesting that generic training programmes fail to address the nuanced requirements of different professional groups. Pesqueira *et al.* (2023) echo this view, advocating for the development of individual dynamic capabilities through focused training initiatives.

Finally, the institutional capacity domain explores how organisational readiness to support blockchain literacy varies widely, particularly in settings with limited resources. The absence of internal capability-building frameworks and limited access to digital education exacerbates existing inequalities, thereby reinforcing the so-called ‘digital divide’. These structural deficiencies hinder implementation and perpetuate disparities in access to technological benefits across the healthcare workforce (Abbas *et al.*, 2022; Bautista *et al.*, 2022).

Overall, the table highlights that improving blockchain literacy is a multidimensional imperative involving cultural, educational and institutional transformation, not merely a technical challenge. Tailored initiatives in these areas are crucial for reducing resistance, fostering trust, and realising the full potential of blockchain technology in healthcare.

In essence, improving literacy around blockchain technology is essential for its successful implementation in healthcare. Addressing this gap requires targeted training programmes, accessible educational resources, and ongoing engagement with stakeholders. Such initiatives can empower healthcare professionals, mitigate resistance to change, and harness blockchain's potential to enhance healthcare systems.

### 3.6. *Trust in the implementation of blockchain technology in healthcare*

The review identified several studies highlighting the role of trust in the implementation of blockchain technology in the healthcare sector. Bazel *et al.* (2023) conducted a systematic review that highlighted privacy, regulatory clarity and trust as critical factors influencing the implementation of blockchain in healthcare. Akhtar *et al.* (2022) identified trust-related challenges, such as integration issues and user scepticism, as significant barriers, while recognising the potential of blockchain to improve security and efficiency in healthcare operations. Similarly, Aich *et al.* (2021) proposed a model to address regulatory uncertainties and build trust as a fundamental dimension for successful blockchain implementation.

Zahid *et al.* (2022) explored design frameworks for precision healthcare ecosystems, identifying trust as a central element for user acceptance and system effectiveness. Finally, Pesqueira *et al.* (2023) highlighted the importance of dynamic individual capabilities (IDCs) in driving blockchain implementation, with trust being a critical factor for effective implementation in hospitals.

Table 7 summarises key studies examining the central role of trust in the implementation of blockchain technologies within the healthcare sector. Trust emerges as a cross-

Table 7
Trust in the implementation of blockchain technology in healthcare.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Trust and implementation | Lack of stakeholder trust | Trust issues related to data privacy, governance, and the immutability of blockchain deter healthcare implementation. | Bazel *et al.* (2023) |
| | Integration with existing systems | Technical and cultural barriers to integrating blockchain with legacy healthcare systems hinder trust in new technologies. | Akhtar *et al.* (2022) |
| | Unclear regulatory environment | Regulatory ambiguities around blockchain implementation affect institutional trust and hinder long-term implementation plans. | Aich *et al.* (2021) |
| | Low user acceptance in precision healthcare | Patient and practitioner trust is essential for implementing blockchain in precision healthcare environments. | Zahid *et al.* (2022) |
| | Organizational readiness and leadership gaps | Trust is linked to dynamic capabilities of individuals and leadership commitment in hospitals. | Pesqueira *et al.* (2023) |
| | Interoperability and patient trust in data usage | Omnichannel healthcare systems face challenges in ensuring consistent trust across platforms using blockchain. | Sangal *et al.* (2024) |

cutting enabler, underpinning stakeholder engagement, regulatory compliance and the legitimacy of blockchain-based interventions.

Bazel *et al.* (2023) conducted a thorough systematic review and identified trust, alongside privacy and regulatory clarity, as a fundamental prerequisite for implementation. They emphasise that without sufficient institutional and user trust, even technically robust systems may fail to scale. Similarly, Akhtar *et al.* (2022) highlight that scepticism arising from integration issues and limited digital literacy undermines blockchain implementation, particularly in under-resourced environments.

Aich *et al.* (2021) adopt a systems management perspective on trust, proposing models that incorporate governance and regulatory transparency to mitigate uncertainty and resistance. Zahid *et al.* (2022) further contribute to this discussion by conceptualising trust as a design artefact within precision healthcare. They assert that, to be trustworthy, blockchain applications must be designed with ecosystem-wide trustworthiness in mind.

Pesqueira *et al.* (2023) highlight trust as a dynamic capability developed through leadership alignment and stakeholder learning processes in hospital settings. Their study suggests that trust is not only a precondition for implementation, but also an evolving asset requiring continuous reinforcement. Finally, Sangal *et al.* (2024) examine blockchain in omnichannel healthcare systems, emphasising the importance of trust in ensuring user commitment and cooperation in sharing data across platforms.

Altogether, these complementary studies present trust as a vital result and enabler of blockchain-based change in healthcare. Overcoming institutional inertia and fostering sustainable innovation will require enhancing trust through transparency, literacy, regulation, and co-designed systems.

### 3.7. *Organizational and Human Capabilities for Blockchain Implementation*

While much of the scholarly discussion on blockchain implementation in healthcare has focused on technological and regulatory dimensions, the success of such implementations also critically depends on organisational and human capabilities. Integrating disruptive technologies such as blockchain requires more than just technical infrastructure; it also demands a dynamic interplay of leadership engagement, managerial agility and institutional capacity for managing organisational change (Bautista *et al.*, 2022; Akhtar *et al.*, 2022). In this context, the internal dynamics of healthcare institutions – including their decision-making structures, professional cultures and resource allocation mechanisms – play a decisive role in determining whether blockchain initiatives are embraced, resisted or abandoned.

Table 8 outlines the key organisational and human factors influencing the implementation of blockchain technology in healthcare institutions. The reviewed literature highlights that successful implementation requires more than just technical readiness; it also involves leadership engagement, managerial agility and institutional learning processes.

Recent research emphasises the role of individual dynamic capabilities (IDC) in facilitating the implementation of blockchain technologies within hospital settings. According to Pesqueira *et al.* (2023), individuals' capacity to sense opportunities, seize resources

Table 8
Organizational and human capabilities for blockchain implementation.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Organizational and human capabilities | Lack of individual dynamic capabilities (IDCs) | Without the ability to sense, seize, and transform, healthcare leaders may struggle to identify blockchain's value or adapt operational workflows. | Pesqueira *et al.* (2023) |
| | Strategic misalignment between IT and executive leadership | Divergent priorities between IT professionals and executives can create institutional tension, hindering unified blockchain strategies. | Pesqueira *et al.* (2023) |
| | Low blockchain literacy among non-technical staff | Limited understanding of blockchain among clinicians and administrators restricts engagement and informed decision-making. | Agrawal and Patil (2024), Akhtar *et al.* (2022) |
| | Resistance to institutional change | Cultural inertia and professional silos often slow the uptake of disruptive innovations like blockchain in hospitals. | Bautista *et al.* (2022) |
| | Fragmented governance and decision-making structures | Uncoordinated structures and lack of shared governance impede cross-departmental collaboration and strategic integration. | Bautista *et al.* (2022) |
| | Lack of capability-based assessment frameworks | Healthcare organizations lack frameworks to assess readiness in terms of leadership, digital competence, and cross-functional collaboration. | Sangal *et al.* (2024) |

and transform existing routines is central to technological innovation. These microfoundations enable healthcare managers and leaders to anticipate changes in the external environment, identify the strategic value of blockchain applications and adapt operational practices to align with evolving institutional priorities. Without such capabilities, however, blockchain implementation risks becoming isolated and disconnected from broader digital transformation strategies, ultimately becoming unsustainable in the long term.

In hospital environments, the role of information technology (IT) departments in aligning technological innovation with strategic and clinical goals is pivotal. However, the successful implementation of blockchain technology depends not only on technical readiness, but also on the development of individual dynamic capabilities (IDC), which enable professionals to identify, exploit and transform opportunities within healthcare organisations (Pesqueira *et al.*, 2023). The authors emphasise that a lack of alignment between executive and IT management teams can constrain dynamic capability cycles in hospitals, resulting in fragmented decision-making regarding blockchain initiatives. Meanwhile, IT specialists tend to emphasise the technological advantages of decentralisation and interoperability, whereas managerial decisions are often dominated by regulatory, financial and workforce concerns, as observed in empirical blockchain implementation studies (Agrawal and Patil, 2024). Furthermore, Akhtar *et al.* (2022) highlight that low trust and limited digital literacy among healthcare stakeholders continue to undermine the perceived reliability and practical integration of digital technologies, such as blockchain, thereby reinforcing cross-functional gaps and impeding organisational learning.

Addressing these challenges requires more than technical solutions: it involves developing shared governance models, interdisciplinary leadership structures and organisational learning processes that foster communication and trust across departments. As Bautista *et al.* (2022) note, blockchain implementation is as much an organisational transformation as a technological upgrade, and success depends on institutional actors coordinating their efforts around shared goals and values. In this regard, capability-based assessments rooted in IDC theory offer a useful framework for evaluating the readiness of healthcare institutions to engage in blockchain innovation. These assessments enable organisations to reflect on leadership commitment, staff digital competence, openness to redesigning workflows, and the quality of collaboration across hierarchical and functional boundaries.

Such an approach aligns with the recent work of Sangal *et al.* (2024), who argue that the integration of blockchain technology into the healthcare sector should be considered from two theoretical perspectives: technological fit and strategic viability. This perspective highlights the importance of balancing technical innovation with human and organisational realities to ensure that blockchain applications are feasible, contextually relevant, and institutionally sustainable.

### 3.8. *Benefits and Future Directions*

Blockchain technology is increasingly recognised for its transformative role in healthcare. It offers innovative solutions to long-standing challenges and paves the way for systems that are more secure, efficient and patient-centric. Abbas *et al.* (2022) and Hylock and Zeng (2019) emphasise blockchain's ability to promote interoperability and transparency, thereby strengthening trust and collaboration among stakeholders. At the same time, its decentralised architecture enhances data integrity and gives patients greater control over their health records. The work of Tripathi *et al.* (2020) further exemplifies this, as they propose a smart healthcare system supported by blockchain that enables privacy-preserving, real-time data exchange – critical for timely clinical interventions and personalised care.

Looking to the future, the integration of blockchain with emerging technologies shows great potential. Sakka *et al.* (2024) demonstrate how combining blockchain with federated learning can address privacy concerns and ensure compliance with regulatory frameworks such as the GDPR, while maintaining the analytical capabilities of AI systems. Meanwhile, Bak *et al.* (2023) propose a model integrating blockchain with the Internet of Medical Things (IoMT). This offers substantial improvements in traceability and efficiency across healthcare supply chains, particularly in mitigating counterfeit risks and ensuring product authenticity.

At the institutional and policy levels, strategic frameworks have been developed to support the structured implementation of blockchain technology. Sousa (2023) outlines a model for assessing the impact of blockchain on public sector governance and decision-making, and Gaynor *et al.* (2022) highlight its application in population health surveillance and smart contract management. These frameworks are instrumental in aligning blockchain initiatives with broader policy objectives and operational realities.

Table 9
Benefits and future directions of blockchain in healthcare.

| Thematic domain | Challenge | Description | Supporting sources |
|---|---|---|---|
| Data security and empowerment | Patient control over data and improved record integrity | Blockchain empowers patients by enabling secure access, data ownership, and tamper-proof records. | Hylock and Zeng (2019), Abbas *et al.* (2022) |
| Interoperability and transparency | Enhanced collaboration across providers through transparent data sharing | Transparent and interoperable systems promote trust among stakeholders and efficient information exchange. | Hylock and Zeng (2019), Abbas *et al.* (2022) |
| Smart healthcare integration | Real-time data management and personalized healthcare services | Blockchain enables secure communication between IoMT devices and real-time monitoring for critical care. | Tripathi *et al.* (2020) |
| Privacy-preserving AI integration | Federated learning for global privacy compliance | Combining blockchain with federated learning ensures data privacy while enabling AI-driven insights. | Sakka *et al.* (2024) |
| Supply chain optimization | Improved traceability and reduced inefficiencies in logistics | Blockchain-IoMT integration improves the authenticity and tracking of medical products in the supply chain. | Bak *et al.* (2023) |
| Strategic policy and public health planning | Frameworks for efficient implementation and decision-making in healthcare policy | Frameworks help align blockchain use with policy goals, enhancing decision-making and implementation strategies. | Sousa (2023), Gaynor *et al.* (2022) |

Table 9 summarises the key benefits and emerging future directions of implementing blockchain technology in the healthcare sector, as reported in the reviewed literature.

Together, these studies suggest that blockchain's value in healthcare goes beyond technical innovation. When integrated with complementary technologies and guided by strategic policy frameworks, blockchain has the potential to transform healthcare delivery. This would enable the development of systems that are technologically advanced, ethically sound, inclusive and responsive to evolving health needs.

## 4. Conclusions

This systematic literature review explored the transformative potential of blockchain technology in healthcare, synthesising findings from peer-reviewed studies to highlight its applications, challenges and future directions. The findings show that blockchain addresses critical issues such as data security, interoperability, and patient empowerment, providing decentralised and immutable solutions that increase trust and transparency across the healthcare ecosystem (Zhuang *et al.*, 2020; Hylock and Zeng, 2019).

Blockchain applications span key domains, including electronic health records (EHRs), supply chain management, privacy frameworks, and public health surveillance. For example, blockchain-enabled EHRs can increase patient control over personal data and improve interoperability (Hylock and Zeng, 2019; Bautista *et al.*, 2022). Blockchain also ensures traceability and transparency in healthcare supply chains, reducing counterfeit medicines and improving operational efficiency (Bak *et al.*, 2023; Rovere *et al.*, 2024). In addition, it supports real-time disease monitoring and secure data aggregation for public health surveillance (Gaynor *et al.*, 2022; Sousa, 2023). These advances address the sector's need for secure, patient-centric and interoperable systems.

However, the review also highlights persistent barriers to blockchain implementation. Scalability issues, high implementation costs, and regulatory fragmentation remain significant obstacles, particularly in resource-limited settings and cross-border healthcare systems (Abbas *et al.*, 2022; Nalin *et al.*, 2019). Organisational resistance and lack of technical literacy among stakeholders further hinder the integration of blockchain into existing infrastructures (Joshi and Sharma, 2023; Pesqueira *et al.*, 2023). Ethical concerns, such as digital divides and trust deficits, also need to be addressed to ensure equitable implementation (Joshi and Sharma, 2023).

Our findings reveal that the majority of studies are theoretical or review-based (72% of the total), followed by case studies (24%) and experimental research (4%). This distribution reflects the early stage of blockchain research in healthcare, highlighting the urgent need for further empirical and experimental studies to test its practical applications. The lack of experimental research indicates limited practical implementation, emphasising the necessity of pilot projects and real-world testing to validate blockchain solutions in healthcare. Such studies are essential for demonstrating the feasibility, scalability and effectiveness of blockchain applications in a dynamic healthcare environment. The absence of such studies indicates a gap that must be addressed if the field is to mature further.

The analysis highlights that successfully implementing blockchain technology in healthcare requires not only technical and regulatory readiness, but also organisational and human capabilities. The importance of individual dynamic capabilities (IDCs) and strategic alignment between IT and executive leadership for institutional integration is clear. Similarly, trust remains a fundamental factor in influencing stakeholder acceptance and the long-term sustainability of blockchain systems. Advances in privacy and identity management, particularly through patient-controlled data and federated learning, highlight blockchain's potential to meet stringent data protection requirements while empowering users. Finally, the discussion on future directions emphasises the transformative potential of integrating blockchain with emerging technologies and supporting it with strategic policy frameworks, signalling its growing importance in creating secure, transparent and patient-centred healthcare ecosystems.

Future directions point to the integration of blockchain with emerging technologies, such as artificial intelligence (AI) and the Internet of Medical Things (IoMT). These synergies offer promising opportunities to enhance predictive analytics, data sharing and personalised medicine (Bak *et al.*, 2023; Sakka *et al.*, 2024). The frameworks proposed in the reviewed studies emphasise the need for harmonised regulations, stakeholder engagement, and strategies to improve technical scalability (Gaynor *et al.*, 2022; Tripathi *et al.*, 2020).

In conclusion, while the studies demonstrate the transformative potential of blockchain technology for healthcare, they also highlight that widespread implementation will require the resolution of technical, organisational, and regulatory barriers, as well as the enhancement of organisational and human capabilities. The current preponderance of theoretical and review-based studies highlights the importance of advancing empirical and experimental research to effectively test and implement blockchain solutions. The findings synthesised here provide a foundation for future research and practical strategies to advance the implementation of blockchain in healthcare and promote secure, efficient, and patient-centred systems. These findings serve as a roadmap for researchers, policymakers, and healthcare practitioners seeking to harness blockchain's capabilities to drive innovation and improve healthcare delivery.

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