



## A Comprehensive Review on Blockchain Technology in Healthcare System.

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### Abstract.

Blockchain technology is a transformative force with far-reaching implications in various professional sectors, including healthcare. This technology is characterized by its continuous evolution, fostering trust and information security across geographical distances through a linked series of data blocks. In recent years, the surge in blockchain adoption has spurred extensive research and innovation, particularly in healthcare applications. This survey offers a comprehensive examination of emerging blockchain-based healthcare technologies and their associated applications. It delves into key research areas within this rapidly growing field, providing detailed insights. Moreover, it underscores the potential of blockchain technology to revolutionize the healthcare industry by enhancing data security, fostering transparency, and enabling innovative solutions.

**Keywords:** blockchain technology; healthcare; data management; supply chain management; internet of medical things.

## **Introduction**

The rapid acceleration of digitization within the healthcare sector has resulted in the accumulation of vast electronic patient records. This exponential growth has placed unprecedented demands on ensuring the protection of healthcare data, particularly during its utilization and sharing. Blockchain technology has emerged as a viable and transparent means of storing and disseminating data, offering innovative solutions to the pressing issues of data privacy, security, and integrity in healthcare. Blockchain has garnered significant attention from both industry stakeholders and academia in recent years, resulting in a continuous influx of novel applications and research endeavors.<sup>1-4</sup>

Blockchain, recognized as a distributed ledger technology facilitating peer-to-peer (P2P) digital data transactions, can be deployed for both public and private data distribution. Its core function revolves around the dependable and verifiable storage of diverse data types. Central to blockchain is the concept of smart contracts—legally binding agreements governed by customizable rules that enable decentralized automation in interactions among various parties. The healthcare domain, among others, has witnessed a proliferation of smart contract applications stemming from blockchain technology<sup>5-7</sup>

Blockchain's inherent features, such as transparency and the elimination of reliance on third-party intermediaries or administrators, set it apart. It operates by leveraging consensus mechanisms and cryptographic protocols to validate transaction legitimacy within an environment characterized by distrust and uncertainty. In a blockchain network, transactions within the distributed P2P network undergo rigorous scrutiny by receiving nodes. If a transaction proves accurate, it is duly recorded within a block, contributing to the creation of an immutable ledger<sup>8</sup>.

Blockchain technology involves the creation of a chain composed of blocks, each containing data. To confirm the data in each block before its addition to the chain, a consensus algorithm, known as Proof-of-Work (PoW), is employed. In the realm of healthcare, blockchain's potential becomes evident as it tackles issues concerning data security privacy, sharing, and storage<sup>9</sup>.

Within the healthcare industry, achieving interoperability is crucial. Interoperability refers to the capacity of two parties, whether human or machine, to efficiently, precisely, and consistently exchange data or information. The primary objective of interoperability in healthcare is to facilitate the seamless exchange of health-related information, particularly electronic health records (EHRs), among healthcare providers and patients. This data sharing should occur across diverse healthcare environments and multiple hospital systems. Moreover, interoperability empowers providers to securely share patients' medical records, provided they have the necessary permissions, regardless of their location or trust relationships<sup>10-11</sup>.

Blockchain technology resolves the issue of interoperability in healthcare by offering a secure means to store, manage, and share EHRs within healthcare communities. Furthermore, the rising costs of healthcare infrastructure and software have placed significant strain on global economies. In the healthcare sector, blockchain technology is making a positive impact by

optimizing business processes, enhancing patient outcomes, managing patient data, ensuring compliance, reducing costs, and facilitating more effective utilization of healthcare-related data<sup>13-15</sup>.

Equally noteworthy is blockchain's capacity to influence the flow of drugs and medical equipment within the complex healthcare supply chain. Employing blockchain in the healthcare supply chain holds the promise of eliminating the risk associated with counterfeit drugs, thereby safeguarding patients worldwide. Presently, blockchain technology is under exploration for various healthcare applications, encompassing data management, storage, connectivity of devices, and security in the Internet of Medical Things (IoMT)<sup>16</sup>.

Most notably, the advantages offered by blockchain technology in the aforementioned application areas have a positive impact on the quality of experience (QoE) for a broad spectrum of stakeholders and end users. These stakeholders include patients, care providers, researchers, pharmaceutical companies, and insurance firms. The capability to share healthcare data securely, without jeopardizing user privacy and data security, represents a pivotal step towards a smarter healthcare system. It promises an enhancement in the quality of healthcare services and the overall user experience<sup>17</sup>.

The primary objective of this paper is to deliver a timely review of blockchain technology's applications in healthcare and the resulting implications for healthcare economies, QoE, and emerging business opportunities. Although several review papers exist in open literature, covering blockchain applications in domains such as finance, IoT, the energy sector, government, privacy, and security, there is a conspicuous gap in the comprehensive review of recent research concerning blockchain-based healthcare applications. Prior reviews have typically concentrated on specific aspects or limited use cases within the healthcare sector<sup>18-19</sup>.

### **Understanding Blockchain Technology**

At its core, blockchain is a digital ledger that records transactions and information in a highly secure and transparent manner. Think of it as a chain of interconnected blocks, where each block contains data and is linked to the previous one, forming an unchangeable and chronological record.

### **Defining Blockchain Technology**

Imagine a digital diary shared among numerous participants in a network. Unlike a traditional diary, where one person holds the sole pen, blockchain operates on a decentralized principle. Multiple users possess copies of the same diary, and any addition or modification is collectively validated before becoming a permanent entry<sup>20-21</sup>.

### **Key Features Enhancing Transparency and Traceability**

- **Decentralization:** In traditional systems, data is typically stored on central servers susceptible to breaches. Blockchain, however, distributes data across its network

of participants, making it incredibly difficult for any single entity to manipulate information.

- **Immutability:** Once data is recorded on a blockchain, it becomes virtually impossible to alter or delete. Each block contains a reference to the previous one, and altering any block would require changing subsequent blocks across the network – a nearly impossible feat.
- **Transparency:** Every participant in a blockchain network has access to the same information. Transactions are visible to all, fostering a high level of transparency and reducing the likelihood of fraudulent activities.
- **Smart Contracts:** These are self-executing contracts with predefined rules. When certain conditions are met, the contract automatically executes the specified actions. In pharmaceuticals, this can ensure adherence to quality standards and contractual agreements throughout the supply chain.
- **Data Security:** Blockchain uses cryptographic techniques to secure data, enhancing protection against unauthorized access. This is particularly crucial in the pharmaceutical industry to safeguard sensitive patient information and intellectual property.
- **Traceability:** Due to the chronological and unalterable nature of blockchain records, it's possible to trace the entire journey of a product or information. In pharma, this means tracking the origin of raw materials, manufacturing processes, distribution, and even patient usage.

As we move forward in this blog, we will uncover how these distinctive features of blockchain intertwine with quality management practices to bring about a new era of accountability and trust in the pharmaceutical landscape.

### **Need of blockchain in healthcare**

As far as healthcare is concerned, the urgency of development increases to more incredible speeds. Today the need is for quality health facilities supported by advanced and newer technologies. Here, Blockchain would play a critical role in transforming the healthcare sector. In addition, the landscape of the health system is moving towards a patient-centred approach focusing on two main aspects: accessible services and appropriate healthcare resources at all times. The Blockchain enhances healthcare organisations to provide adequate patient care and high-quality health facilities. Health Information Exchange is another time-consuming and repetitive process that leads to high health industry costs, quickly sorted out using this technology. Using Blockchain technology, citizens may take part in health study programs. In addition, better research and shared data on public wellbeing will enhance treatment for different communities. A centralised database is used to manage the entire healthcare system and organisations<sup>22-25</sup>

Until now, the most significant problems faced are data protection, sharing, and interoperability in population health management. This particular problem is reliable by using Blockchain. This technology enhances security, data exchange, interoperability, integrity, and real-time updating

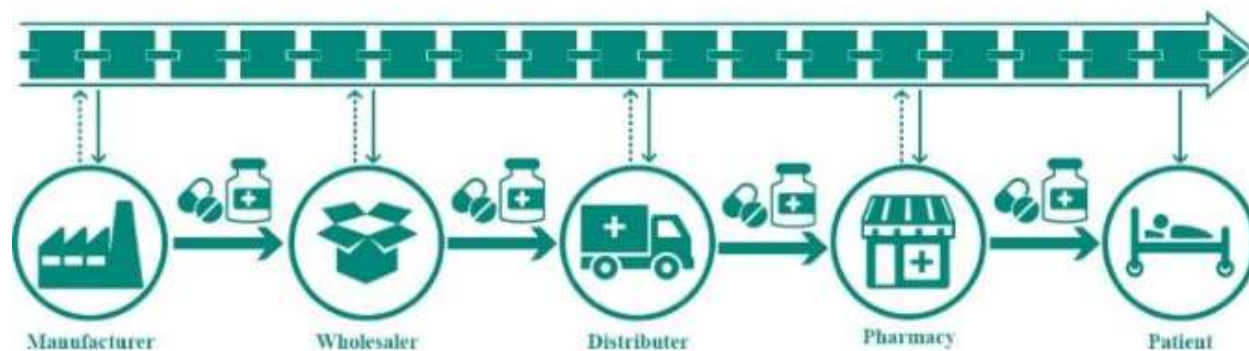
and access when correctly implemented. There are also significant concerns about data protection, especially in the fields of personalised medicine and wearables. Patients and medical personnel require safe and straightforward means of recording, sending, and consulting data over networks without safety concerns; thus, Blockchain technology is implemented to resolve these issues<sup>26-27</sup>

### **Various Capabilities of Blockchain Technology to support the healthcare culture globally**

In healthcare, Blockchain has a wide range of applications and functions. The ledger technology helps healthcare researchers uncover genetic code by facilitating the secure transfer of patient medical records, managing the drug supply chain, and facilitating the safe transfer of patient medical records. Fig.1 reflects the variety of features and critical enablers of Blockchain philosophy in umpteen healthcare spheres and its allied domains. Protection of healthcare data, various genomics management, electronic data management, medical records, interoperability, digitalised tracking and issues outbreak, etc., are some of the technically derived and impressive features employed to develop and practice Blockchain technology. The complete digitalised aspects of Blockchain technology and its use in healthcare-related applications are the significant reasons for its adoption<sup>28-29</sup>

### **Why Transparency and Traceability Matter in Pharma**

In the pharmaceutical industry, transparency and traceability are not mere buzzwords; they form the backbone of safety, quality, and ethical practices. Let's delve into the crucial reasons why these concepts hold unparalleled significance in the pharmaceutical landscape.



*Figure 1: Blockchain Based Pharmaceutical Supply Chain Management System*

### **The Importance of Transparency and Traceability**

- **Patient Safety:** At the heart of every pharmaceutical endeavor lies the well-being of patients. Transparent supply chains and traceable processes ensure that medications are manufactured, stored, and distributed under stringent quality standards, minimizing the risk of compromised products reaching patients.



- **Regulatory Compliance:** The pharmaceutical sector is subject to a labyrinth of regulations and standards. Transparency and traceability assist companies in demonstrating compliance with these requirements, avoiding legal complications and reputational damage.
- **Counterfeit Drugs Mitigation:** Counterfeit drugs pose a significant threat to patient health and the industry's credibility. Transparent supply chains make it far more challenging for counterfeiters to infiltrate the system, as the journey of each product can be reliably verified.
- **Quality Assurance:** Pharmaceuticals undergo a complex journey from raw materials to final products. Transparent processes and traceable data points enable real-time monitoring, facilitating early detection of quality deviations and ensuring timely interventions.
- **Data Integrity:** In an era dominated by digitalization, maintaining the integrity of data is paramount. Transparent and tamper-proof blockchain records minimize the risk of data manipulation, fostering trust in clinical trials, research, and regulatory submissions.



### **Challenges in Achieving Transparency and Traceability**

- **Complex Supply Chains:** Pharma supply chains span the globe, involving multiple intermediaries, making tracking and verifying each step a formidable challenge.
- **Counterfeit Drugs:** Counterfeiters capitalize on information gaps and lack of transparency. As a result, patients might unknowingly consume substandard or even dangerous products.

- **Data Fragmentation:** With diverse stakeholders involved, data often resides in silos, impeding seamless information sharing and traceability.
- **Regulatory Variability:** Differing regulations across regions can create inconsistencies in tracking and reporting practices.
- **Data Privacy:** While transparency is key, protecting sensitive patient data is equally important. Striking the right balance between transparency and privacy is a delicate task.

In the next section, we'll explore how the marriage of blockchain technology and quality management practices offers a compelling solution to overcome these challenges and elevate the pharmaceutical industry to new heights of transparency and traceability<sup>30-32</sup>.

### **Blockchain: A Solution to Pharma's Transparency and Traceability Challenges**

As we navigate the intricate landscape of pharmaceutical transparency and traceability, blockchain emerges as a beacon of hope, offering innovative solutions to the industry's persistent challenges. Here, we'll explore how blockchain technology can effectively tackle these challenges and reshape the future of pharmaceutical operations<sup>33-34</sup>.

### **Addressing Challenges with Blockchain**

- **Supply Chain Transparency:** Blockchain's decentralized nature ensures that every participant has real-time access to an immutable record of each transaction. In pharma, this means tracking the entire journey of a drug, from its inception as raw materials to its delivery to patients. For instance, if a batch of medications needs to be recalled due to quality concerns, blockchain enables precise identification of affected products, minimizing the impact on patients.
- **Counterfeit Drug Prevention:** Blockchain's tamper-proof records and transparent nature make it exceptionally difficult for counterfeiters to infiltrate the supply chain. Consumers can verify the authenticity of their medications by tracing their origins on the blockchain. This empowers patients to make informed decisions about the products they consume.
- **Data Integrity:** In clinical trials and research, maintaining data integrity is paramount. Blockchain's immutability ensures that research findings, patient data, and clinical trial results are recorded accurately and cannot be altered retrospectively. This builds trust among researchers, regulators, and the public.
- **Streamlined Regulatory Compliance:** Blockchain automates data collection and verification, making compliance with complex regulatory standards more efficient. With all necessary documentation stored securely on the blockchain, audits become quicker and more accurate.
- **Interoperability and Data Sharing:** Blockchain can facilitate secure data sharing across stakeholders while maintaining control over sensitive information. Researchers, clinicians, manufacturers, and regulators can access the information they need without compromising data privacy<sup>35</sup>.

### **Real-World Examples of how blockchain has helped healthcare companies' tackle internal challenges**

- **MedRec:** In the realm of electronic health records, MedRec employs blockchain to create an auditable trail of patient interactions with healthcare providers. This enhances data accuracy, privacy, and accessibility, promoting informed medical decisions.
- **VeChain:** VeChain, a blockchain-based supply chain solution, partnered with a major pharmaceutical company to enhance traceability in its supply chain. The partnership aims to prevent counterfeit drugs from entering the market by allowing consumers to verify a product's authenticity.

In the subsequent section, we'll uncover how the fusion of quality management principles with blockchain's capabilities results in a robust framework that propels the pharmaceutical industry into a new era of transparency, traceability, and excellence<sup>36-37</sup>

### **Real-World Examples of Blockchain in Pharma**

Examining concrete instances where blockchain has catalyzed transformative change in the pharmaceutical sector underscores its efficacy in ensuring transparency and traceability. Let's explore a selection of successful case studies that exemplify blockchain's impact on the industry.

#### **Real-World Examples**

- **Chronicled's Serialization Solutions:** Chronicled, a blockchain-based serialization platform, collaborates with pharmaceutical companies to combat the menace of counterfeit drugs. By assigning unique digital identities to individual products and recording their journey on the blockchain, the platform empowers consumers and supply chain stakeholders to verify the authenticity of medications. This technology-driven trust ensures patients receive genuine and safe products.
- **IBM's Drug Supply Chain Application:** In partnership with global pharmaceutical companies, IBM's blockchain platform facilitates end-to-end visibility and transparency across the drug supply chain. This real-time tracking ensures adherence to quality standards, mitigates risks associated with substandard products, and expedites recalls when necessary. This initiative significantly bolsters patient safety and regulatory compliance.
- **Modum's Temperature Monitoring:** Modum employs blockchain and IoT technology to address a critical challenge in pharmaceutical logistics—ensuring the integrity of temperature-sensitive medications during transit. By tracking temperature data at each stage of transportation and storing it on the blockchain, Modum safeguards the efficacy of drugs and guarantees they remain within specified storage conditions.

#### **Impact and Results**

- Chronicled's solution has led to a substantial reduction in counterfeit drugs entering the market, bolstering patient safety and pharmaceutical brand reputation.



- IBM's blockchain initiative has streamlined supply chain operations, reducing the time and effort required for regulatory compliance checks and ensuring that patients receive authentic and unadulterated medications.
- Modum's temperature monitoring not only prevents compromised drugs from reaching patients but also minimizes financial losses resulting from spoilage due to improper storage conditions.

Having witnessed the tangible benefits of blockchain technology in enhancing transparency and traceability, the following section of this blog delves into the potential evolution of blockchain's role within the pharmaceutical ecosystem. We'll explore emerging trends, challenges, and the untapped possibilities that await as blockchain continues to redefine the future of pharmaceutical operations.

### **The Future of Blockchain in Pharma**

As blockchain's prowess in revolutionizing transparency and traceability becomes increasingly evident, its role in the pharmaceutical industry is poised to expand even further. Let's journey into the exciting realm of future possibilities where blockchain's impact is set to reshape the landscape of pharmaceutical operations<sup>38-39</sup>.



### **Emerging Applications of Blockchain in Pharma**

- **Clinical Trials:** Blockchain can bring unprecedented transparency to clinical trial data, ensuring the authenticity and accuracy of results. Immutable records can verify patient consent, data integrity, and adherence to protocols, thereby fostering trust between stakeholders.
- **Regulatory Compliance:** Blockchain's automated verification mechanisms can streamline the complex process of regulatory compliance. By creating a secure and tamper-proof

repository of regulatory documents, companies can expedite audits and ensure adherence to global standards.

- **Personalized Medicine:** Blockchain's capability to securely store and share patient data could facilitate the development of personalized treatment plans. Patients can control access to their medical history, empowering them to contribute to research while safeguarding their privacy.
- **Supply Chain Innovation:** Blockchain's potential in supply chain optimization goes beyond transparency. It can enable predictive analytics, facilitating demand forecasting, inventory management, and minimizing supply chain disruptions.

### **Challenges and Barriers to Adoption**

- **Technological Complexity:** Integrating blockchain into existing systems requires technical expertise and resource allocation. Overcoming this hurdle demands collaboration between tech specialists and pharmaceutical professionals.
- **Regulatory Landscape:** Regulatory frameworks are still evolving in response to blockchain technology. Striking a balance between innovation and compliance is essential to ensure blockchain solutions meet legal requirements.
- **Data Privacy:** While blockchain enhances transparency, privacy concerns persist. Striking the right balance between transparent data sharing and patient privacy is an ongoing challenge.
- **Resistance to Change:** The pharmaceutical industry is traditionally cautious about adopting new technologies due to potential disruptions. Addressing concerns and demonstrating the value of blockchain is crucial for widespread adoption.
- **Interoperability:** Achieving seamless data exchange between different blockchain networks and legacy systems remains a technical challenge that must be overcome.

As we venture into this blockchain-powered future, the pharmaceutical industry is at the cusp of transformation. By acknowledging and addressing these challenges, stakeholders can collectively steer the industry toward a future where transparency, traceability, and patient-centricity reign supreme.

The provided text summarizes the outcomes of a comprehensive analysis aimed at comprehending the development of blockchain technology applications in the healthcare sector. In this endeavor, specific research objectives were set, encompassing the identification of blockchain's roles in healthcare, examination of instances of its practical implementation, exploration of the difficulties and constraints faced by blockchain-based healthcare solutions, scrutiny of current strategies in application development, and the delineation of potential directions for further research<sup>40</sup>.

The research procedure adhered to a systematic mapping study framework, leading to the selection and analysis of 65 pertinent academic papers to address these research inquiries. The results spotlighted several domains where blockchain technology holds promise within healthcare, including the management of electronic medical records, optimization of drug and

pharmaceutical supply chains, advancements in biomedical research and education, enhancements in remote patient monitoring, and the refinement of health data analytics.

Additionally, the analysis revealed that the development of prototype healthcare applications has incorporated emerging blockchain paradigms, with examples such as the integration of smart contracts, utilization of permissioned blockchains, and incorporation of off-chain data storage methods. Concurrently, the study acknowledged the existence of substantial impediments and constraints in this domain, such as issues related to scalability, latency, interoperability, and paramount concerns about security and privacy.

Looking forward, it is evident that additional research endeavors are necessary on multiple fronts. This includes the pursuit of a more profound understanding and characterization of blockchain technology's efficacy in the healthcare sector, comprehensive resolutions to the previously mentioned challenges, and innovative approaches aimed at bolstering blockchain's applicability and efficiency in enhancing healthcare systems and services

### **Conclusion**

In this exploration of blockchain's transformative potential in the pharmaceutical industry, we've journeyed through the intersection of quality management practices and cutting-edge technology. The fundamental importance of transparency and traceability has been illuminated, shedding light on their profound impacts on patient safety, regulatory compliance, and overall operational excellence.

We've examined how blockchain's unique features—decentralization, immutability, transparency, smart contracts—address challenges that have long plagued the pharmaceutical landscape. Real-world examples have demonstrated the tangible impact of blockchain, from combating counterfeit drugs to ensuring data integrity and optimizing supply chains.

Looking ahead, the future of blockchain in pharma holds promises of enhanced clinical trials, personalized medicine, and streamlined regulatory processes. However, challenges such as technological complexity, regulatory adaptation, and privacy concerns must be navigated to fully unlock blockchain's potential.

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