The Role of Blockchain in Ensuring Drug Traceability and Reducing Counterfeit Medicines"- A Systematic Review

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EXECUTIVE SUMMARY

Introduction:

Pharmaceutical supply chain is a very important aspect of pharmaceutical handling industry, which plays the role of facilitating availability of safe, effective and quality medicines to patients, at the right time. Over the past few years, it has been noted that the rising level of substandard and counterfeit drugs has become a major global health concern. Counterfeit drugs are unsafe to human health and result in treatment failures, morbidity and mortality as well as undermine the healthcare system. Conventional pharmaceutical supply chains have a very high degree of centralized databases that are characterized by fragmented information systems that cannot provide proper level of transparency and traceability thus making the supply chain susceptible to infiltration of counterfeit drugs. Blockchain technology has emerged in this respect as one of the possible solutions to improve drug traceability and expand security in the supply chains.

Aim and Objectives:

The main objective of this research is to discuss the importance of the use of blockchain technology to achieve drug traceability and limit the spread of Counterfeit medications among the pharmaceutical distribution channels.

Research Methodology:

The research design comprises descriptive and exploratory; the study is going to be conducted entirely on secondary data. The data were collected using peer-reviewed research articles available in the Google Scholar index, international journals, regulatory reports, and publications related to blockchain and pharmaceutical supply chains in the pharmaceutical industry. A purposive sampling technique was used to select the relevant literature and the data was analyzed by content analysis and thematic analysis. Such a method revealed the opportunity to conduct a systematic evaluation of the use of blockchains in preventing counterfeits and tracking drugs.

Results and Discussion:

The research conclusions show that the blockchain technology is a massive positive influence on the traceability of the drugs because the technology enables monitoring the goods in real-time, leaving a trail that would not be altered throughout the process of pharmaceutical supply chain. The blockchain-based systems contribute to enhancing the transparency rate, reduce data manipulation, and allow the parties to determine the authenticity of medicines in every level. It is also found out that blockchain plays a critical role in preventing the counterfeit medicines by preventing the illegal infiltration of counterfeit drugs into the lawful supply chains
stakeholder confidence, and improves efficiency of recalling drug systems. However, such problems exist as the cost of implementation, scaling, systems integration and privacy of the data that still remain a significant impediment to the mass adoption.

Conclusion:

The research paper concludes that the blockchain stands high chances of transforming pharmaceutical supply chain management by using drug traceability and eradication of counterfeit drugs. It is also decentralized and cannot be changed and this enhances transparency, accountability and trust among the stakeholders of the supply chains. Although there are difficulties in the implementation of blockchain, they also contain advantages connected with better patient safety and regulation compliance and supply chain efficiency that overpower the limitations. Planned, stakeholder collaboration, and regulation are the ways in which blockchain can serve as a valuable instrument in the development of supply chains in the healthcare industry.

Keywords:

- Blockchain Technology
- Drug Traceability
- Counterfeit Medicines
- Pharmaceutical Supply Chain
- Supply Chain Transparency
- Patient Safety

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INTRODUCTION

The pharmaceutical sector has been significant in global healthcare in that safe, effective, and quality medicines are available to patients. The threat of the integrity of the pharmaceutical supply chain has however been growing with the prevalence of counterfeit and substandard drugs. Counterfeit medicines This term refers to drugs that have been unscrupulously and intentionally mislabeled in regards to identity, composition or origin. Such medicines can have wrong ingredients, wrong doses, or be dangerous, a fact that can be very dangerous to the health and safety of the patients. The distribution of fake drugs contributes to treatment failure, rise in morbidity and mortality, emergence of drug resistance and mistrust in the health care systems.

Generation of counterfeit drugs has become a major health problem in the world. World Health Organization (WHO) claims that nearly every ten percent of the drugs circulating in low and middle income countries are substandard or falsified. The traditional systems of supplying pharmaceuticals are marked by the fragmentation, the absence of transparency, and the ineffective system of data-sharing and, consequently, the dissemination of counterfeiting drugs.

According to Shetty et al. (2022) systematic review of the use of blockchain technology in pharmaceutical supply chains, the traceability systems formed with blockchain systems play a significant role in transparency, accountability, and data integrity. They argued that blockchain will offer a secure mechanism of monitoring the flow of the drugs between the drug manufacturers and the patients, and this will lower the possibilities of counterfeiting. The study indicates that blockchain improves the compliance and governance of the supply chain.

Zakari et al. (2022) performed a broad systematic literature search on the application of blockchain in pharmaceutical industry. By doing this, the authors found that blockchain can improve the supply chain stakeholders by increasing trust, traceability, transparency, and real-time monitoring. By reviewing 38 articles, they discovered that blockchain is a powerful system to follow the history of drugs, logistics and authentication, hence it can become a powerful tool in combating counterfeit drugs.

One of the pharmaceutical supply chain frameworks that Haqu and Muselemu (2018) proposed is grounded on blockchain and ensures end-to-end visibility and traceability. As their study demonstrated, the only way to use permissioned blockchain-based solutions is to allow authorized parties to update records and exclude the risk of manipulating the records and leading to tampering and data manipulations. They came to the conclusion that a significant improvement in the efficiency of recalls and patient safety will be possible with the help of drug tracking through blockchain.

Rai et al. (2022) recommend a system known as the Blockchain-Based Traceability of Counterfeited Drugs (BBTCD) that is founded on smart contracts and runs on Ethereum and tracks the movement of pharmaceutical products. Their

experimental results have demonstrated that they have enhanced traceability, real-time drug authentication and enhanced counterfeit infiltration. The study demonstrates that blockchain can be helpful in improving pharmaceutical logistics security.

Gomasta et al. (2023) proposed one of Hyperledger fabrics PharmaChain framework, which is built on the creation of confidentiality, accountability, and interoperability in drug supply chains. The authors have observed that blockchain enables provenance of data securely and centralized elimination of vulnerabilities, which improves traceability and regulatory measures.

The production and distribution of medicine framework developed by Islam et al. (2024) with the application of block chain addresses the aspect of medicine counterfeiting. Their findings show that blockchain works better in enhancing real-time monitoring, product verification and supply chain resilience. The article brings out the implementation of blockchain and the emerging digital technologies in the direction of the simplified pharmaceutical operations.

A systemic review of the adoption of blockchain in healthcare supply chains by Fiore et al. (2023) found out that blockchain is applicable in improving the transparency of the supply channel, its efficacy, and patient safety. In their analysis, they note that blockchain-based drug traceability systems reduce the risk of counterfeits and also improve regulatory compliance systems.

Kumar et al. (2024) investigated the scheme of counterfeit drugs detection with the help of blockchain and came to the conclusion that the immutable registry offered by blockchain and the decentralized nature of the verification process is a significant contributor to the accuracy of authentication. Their study justifies the use of blockchain in protecting the supply chains of pharmaceuticals against counterfeit drugs.A new drug traceability model under inception by Perumalsamy et al. (2025) is based on the concept of a Blockchain Non-Fungible Token model of the pharmacological supply chain management. They found that there is better authenticity of products, traceability, and accuracy of inventory and prove that blockchain can transform the drug logistics management.

Araujo et al. (2022) conducted a review of blockchain in the healthcare supply chain and found that blockchain enhances visibility, trust, and coordination of stakeholders in the supply chain. Nevertheless, other obstacles highlighted in the study include technological complexity, regulatory uncertainty and integration difficulties.

Counterfeit drugs are of particular concern in the developing and low- and middle-income nations, where the regulatory enforcement mechanisms and the system of monitoring supply chains are low in strength. The world health statistics indicate that fake drugs represent a large proportion of the pharmaceutical market particularly in areas where the distribution channels are not sufficiently connected. The advanced nations are not spared because High-tech globalized supply chains expose the countries to weaknesses that can be used by counterfeiters. Financial effects of counterfeit drugs are also enormous in the sense that it keeps the pharmaceutical companies in the industry out of business and the health care system incurring high costs as a result of ineffective therapy and extended disease duration.

Despite potentially causing some beneficial outcomes, the application of blockchain in pharmaceutical supply chains does not happen without challenges. Primary barriers to adoption are the upfront costs, the technical expertise, scaling challenge, data confidentiality as well as unpredictability of regulation. Additionally, the adoption of blockchain supposes the collaboration of multiple stakeholders that can be a difficult undertaking due to the difference in technological maturity and business priorities. These issues should be realized in order to understand the viability and sustainability of blockchain traceability systems.

As the issue of fake and counterfeited medicines is becoming increasingly severe and the existing supply chain management tools are unable to deliver the needed characteristics, it is vital to take into account the innovative approaches to enhance the efficiency of the drug trace system and patient safety. The current paper is directed at the discussion of the opportunities to implement drug traceability and reduce the amount of counterfeit drugs in the pharmaceutical supply chain with the help of blockchain technology. The proposed study will review the literature, frameworks, and use of blockchain technology in an attempt to delineate its efficiency, benefits and disadvantages in addressing one of the most critical problems of the healthcare system in the entire world.

AIM AND OBJECTIVES

Aim:

To study the application of blockchain technology to ensure drug traceability and reduce the distribution of counterfeit drugs in the pharmaceutical distribution system.

Objectives:

1. To understand the application of block chain in drugs traceability and transparency of the supply chain provided by blockchain.
2. To establish the extent to which the blockchain is effective in preventing counterfeit drugs.
3. To identify challenges and hindrances to the implementation of blockchain in the pharmaceutical system.

RESEARCH METHODOLOGY

This study employed a Systematic Literature Review (SLR) approach to synthesize existing evidence on the application of blockchain technology in pharmaceutical supply chain management, with particular emphasis on drug traceability and counterfeit drug mitigation. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure a transparent, rigorous, and reproducible review process.

Research Question

- The review was guided by the following research questions:

- How is blockchain technology being implemented in pharmaceutical supply chain management?
- What role does blockchain play in improving drug traceability?
- How effective is blockchain in mitigating counterfeit pharmaceuticals?
- What challenges, limitations, and future research opportunities exist in implementing blockchain-enabled pharmaceutical supply chains?

Search Strategy

A comprehensive literature search was conducted across the following electronic databases:
Google Scholar & Pubmed.
Period- 20217-2025

Inclusion criteria

- Published studies factored in Google Scholar & Pubmed.
- The international journals in the area of healthcare management, pharmaceutical sciences, supply chain management and information technology.
- Publications of international health authorities.
- Plans and laws of drug safety and traceability.
- White papers and case studies on the use of blockchain in pharmaceuticals.
- Only those sources, which were directly related to blockchain, drug traceability and prevention of counterfeit medicine, were counted.

Keywords Searched:

- "Blockchain AND drug traceability"
- "Blockchain technology AND pharmaceutical supply chain"
- "Blockchain AND counterfeit medicines"
- "Drug traceability AND counterfeit drugs"
- "Blockchain AND healthcare supply chain transparency"

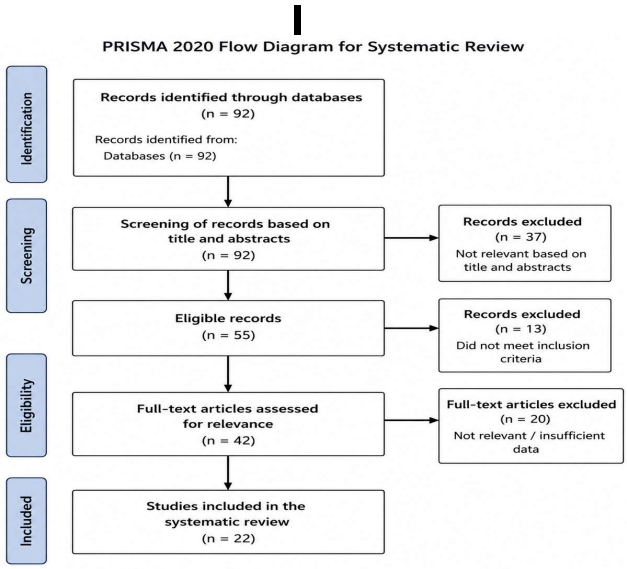

fig 4.1 Prisma Flowchart

Methods of Data Analysis

The data obtained was analyzed using the methods as follows:

- Content Analysis
- Review and interpretation of research findings concerning: was done by content analysis.
- Reasons behind fake medicines.
- Weaknesses of the conventional drug tracing systems.
- Characteristics of blockchain technology that are applicable in traceability.

Thematic Analysis

The major themes in studies were recognized as:

- Data integrity and transparency.
- End-to-end drug traceability
- Elimination of counterfeit drugs.
- Blockchain implementation issues.
- These were the themes discussed and drawn with

conclusions.

Ethical Considerations

As the research relies on secondary data:

- There is proper reference and citation of all sources.
- No confidential or personal information is applied.
- Academic integrity is upheld during the research.

RESULTS AND FINDINGS

S.No	Title of the Study	Author(s)	Source of the Study / Journal	Year of Publication	Key Findings of the Study
1	A study on the public health and socioeconomic impact of substandard and falsified medical products	World Health Organization	WHO Report	2017	Highlights the global burden of counterfeit medicines and their negative impact on public health and healthcare systems.
2	Blockchain's roles in meeting key supply chain management objectives	Kshetri, N.	International Journal of Information Management	2018	Explains how blockchain improves transparency, traceability, and trust in supply chain management systems.
3	A systematic literature review of blockchain-based applications	Casino, F.; Dasaklis, T.K.; Patsakis, C.	Telematics and Informatics	2019	Identifies blockchain applications across industries and emphasizes its potential for secure and transparent systems.
4	A review of existing and emerging digital technologies to combat the global trade in fake medicines	Mackey, T.K.; Nayyar, G.	Expert Opinion on Drug Safety	2017	Discusses digital solutions including blockchain to reduce counterfeit medicines in global supply chains.
5	Blockchain application in food supply information security	Tse, D.; Zhang, B.; Yang, Y.; Cheng, C.; Mu, H.	IEEE International Conference	2017	Demonstrates blockchain's role in enhancing traceability and information security in supply chains.
6	Blockchain technology: A critical evaluation	Boehm, E.; Peschke, S.	Journal of Healthcare Informatics Research	2018	Critically evaluates blockchain benefits and challenges in healthcare-related systems.

7	Hitching healthcare to the chain	Engelhardt, M.A.	Technology Innovation Management Review	2017	Explores opportunities for blockchain adoption in healthcare data management and security.
8	Drug Supply Chain Security Act (DSCSA) Implementation	U.S. Food and Drug Administration	FDA Report	2020	Outlines regulatory requirements for drug traceability and supply chain security.
9	An agri-food supply chain traceability system	Tian, F.	IEEE Conference on Service Systems	2016	Proposes a blockchain-based traceability framework applicable to pharmaceutical supply chains.
10	Blockchain technology and supply chain sustainability	Saberi, S.; Kouhizadeh, M.; Sarkis, J.; Shen, L.	International Journal of Production Research	2019	Shows how blockchain enhances transparency and sustainability in supply chain operations.
11	Blockchain in pharmaceutical supply chains	Deloitte	Deloitte Industry Report	2019	Explains real-world use cases of blockchain for improving pharmaceutical traceability.
12	Blockchain for healthcare and life sciences	IBM	IBM White Paper	2020	Highlights blockchain-enabled solutions for secure healthcare and pharmaceutical supply chains.
13	The impact of blockchain on supply chain management	Treiblmaier, H.	Supply Chain Management Review	2018	Analyzes blockchain's influence on coordination, transparency, and efficiency in supply chains.
14	Global counterfeit medicines report	PwC	PwC Report	2018	Examines the economic and health impacts of counterfeit medicines worldwide.
15	Blockchain: Blueprint for a new economy	Swan, M.	O'Reilly Media	2015	Provides foundational knowledge on blockchain technology and its applications across industries.
16	Investigation and Assessment of Blockchain Technology Adoption in the Pharmaceutical Supply Chain	S. S. S. R. K. Prasad et al.	Materials Today: Proceedings	2021	The study highlighted blockchain's capability to improve transparency, traceability, and trust across pharmaceutical supply chains. It emphasized that immutable records help detect counterfeit

					medicines and improve inventory visibility while supporting secure cold-chain logistics.
17	Traceability of Counterfeit Drugs in Pharma Supply Chain through Blockchain Technology: A Systematic Review of the Evidence	Adithya D. Shetty, Sandeep S. Shenoy, D. Sreedhar, Ankitha Shetty, Rohini Rao & Komal Jenifer D'Souza	Research Journal of Pharmacy and Technology	2022	Using PRISMA guidelines, the review found that blockchain enables end-to-end drug traceability, minimizes counterfeit medicines through tamper-proof records, enhances transparency among stakeholders, and improves regulatory compliance in pharmaceutical logistics.
18	Blockchain Technology in the Pharmaceutical Industry: A Systematic Review	Marcelo Henrique de Sousa et al.	PeerJ Computer Science	2022	The systematic review analyzed 38 studies and classified blockchain applications into counterfeit drug prevention, drug distribution, tracking and tracing, and data security. The authors concluded that blockchain significantly improves supply chain transparency and patient safety but
					requires greater interoperability and scalability.
19	Blockchain-Enabled Traceability in Pharmaceutical Supply Chains: A Mapping Review of Evidence for Visibility, Anti-Counterfeiting, and Chain-of-Custody Control	Multiple authors	Journal of Supply Chain Management (MDPI)	2026	Based on 103 publications, the mapping review showed rapid growth in blockchain research after 2019. The study identified blockchain, smart contracts, and digital identity as key technologies improving medicine traceability, preventing counterfeit drugs, and strengthening chain-of-custody management.
20	Assessment of Blockchain Technology in the Improvement of Supply Chain Management in the Pharmaceutical Industry	Dinesh Kumar, Rajni Tanwar, Debarshi Kar Mahapatra, Nisham Lohan, Geetanjali Dahiya & Divya Jain	Current Pharmaceutical Biotechnology (Bentham Science)	2026	The review concluded that blockchain supports compliance with pharmaceutical serialization regulations such as the Drug Supply Chain Security Act (DSCSA), enabling secure drug authentication, real-time product tracking, improved data integrity, and reduced circulation of counterfeit

					medicines.
21	Development of a Blockchain-Based System for Drug Counterfeiting and Traceability in the Pharmaceutical Supply Chain	Asfia Aziz & Sunil Suman	Research & Reviews: A Journal of Pharmaceutical Science	2024	The authors developed a blockchain-based framework integrated with IPFS and Artificial Intelligence to enhance drug traceability and counterfeit detection. The proposed system demonstrated improved transaction efficiency and achieved **96.52% accuracy** in counterfeit drug detection, indicating its potential for secure pharmaceutical supply chain management.
22	Leveraging Blockchain Technology to Establish a Transparent and Counterfeit-Resistant Pharmaceutical Supply Chain	Shruthi Kumarswamy & Poornima Athikatte Sampigerayappa	Journal of Electrical Systems and Automation (IIETA)	2024	The study proposed a blockchain-enabled pharmaceutical supply chain architecture to ensure end-to-end drug traceability and authenticity. Smart contracts and immutable ledgers improved transparency, reduced counterfeit risks, and enhanced trust among manufacturers, distributors, pharmacies, and regulators.

Table 1 – Summary of the studies Included

The findings are discussed against the objectives of the research and concentrate on assessing the potential the blockchain technology plays in guaranteeing drug traceability and lessening the counterfeit drugs in the pharmaceutical supply chain. The discussion harmonizes the results of various studies to bring to the fore the major results, advantages, and drawbacks of blockchain adoption.

Results

Associated with Drug Traceability.

According to the review of the literature, it is possible to conclude that the blockchain technology makes the drug traceability in the pharmaceutical supply chain much more effective. According to most researches, blockchain provides end-to-end visibility where each transaction of a drug, such as its manufacturing and packaging, are registered to an immutable and secure ledger.
According to the results of research, the system of traceability based on blockchain allows tracking pharmaceutical products in real-time. A different digital identity may be attached to each batch or unit of medicine and this is updated continuously as the product passes through the supply chain. This leaves a clear audit trail to be accessed by the relevant stakeholders such as manufacturers, distributors, pharmacists and regulating bodies. Consequently, the source, flow, and location of medicines can be traced at any given moment.
Blockchain has a higher level of data integrity compared to the traditional tracking systems. The risk of tampering data is very low because blockchain records can not be modified or erased without the consensus of the networks. This aspect provides the reliability of supply chain documentation and enhances their reliability among the stakeholders. The findings have shown that blockchain enhances the accuracy and reliability of traceability, which is essential in the

establishment of drug quality and safety.

Findings with regards to minimizing the number of counterfeit medicines.

The articles examined show that blockchain is effective in addressing counterfeit drugs. The poor traceability, absence of transparency and coordination of stakeholders in the supply chain mean that counterfeit drugs find their way into the supply chain. The blockchain is a s to these challenges because it develops a system that is immutable and transparent and thus it is hard to penetrate the legitimate distribution channels by counterfeit products.

The evidence shows that blockchain makes it possible to provide authenticity of drugs at every supply chain stage. Before dispensing medicines to patients, pharmacists and other medical professionals can verify the authenticity of medicines by looking at blockchain written records. This minimizes the chances of fake medicines getting to the final consumers. Other studies also indicate that blockchain-based mechanisms allow patients to check the validity of drugs by reading QR codes or other digital platforms so that it makes them more patient-aware and safe.

Also, blockchain enhances drug recalls efficiency. When it is identified that counterfeit or substandard medicines have been shipped, blockchain enables the fastest identification of the impacted batches and the point of distribution. This will minimize the time taken to respond and the amount of harm that may be inflicted on the patients. All in all, these outcomes provide evidence that blockchain is a key component of enhancing counterfeit prevention mechanisms.

Supply Chain, Transparency and trust results.

The other valuable outcome that comes out in the literature is enhancement of transparency of the supply chain and trust between the stakeholders. Various actors are involved in pharmaceutical supply chains, and information silo and inefficiencies are common when there is absence of trust among the actors. The blockchain makes available a common and synchronized registry hence all the authorized parties have access to the same validated information.

Research also shows that there is enhanced coordination and accountability among the players of the supply chain due to higher transparency. Manufacturers are able to track distribution activities, regulators are able to confirm compliance and healthcare providers use authentic medicines as they can be assured that they have. The decentralization aspect of blockchain eradicates the use of a single controlling body hence a high chance of manipulation of data and failure of the system.

The findings prove that the blockchain leads to a trust-based ecosystem, which is the key to the successful pharmaceutical supply chain management and control of counterfeit.

The discussion of Regulatory Compliance and Monitoring.

Another outcome that is reflected in the findings is the role of blockchain in enhancing regulatory compliance and monitoring. The regulatory bodies need precise and real-time information to implement the drug safety laws and traceability requirements. Blockchain helps with regulatory needs by maintaining a transparent and verifiable record that may be audited in real time.

According to the literature, blockchain would ease the process of meeting drug traceability laws by automating the data recording and verification process. Regulatory requirements like serialization and reporting can be enforced using smart contracts which minimizes manual intervention and errors. This improves the efficiency of the regulation and makes the pharmaceutical industry stronger in the governance.

Nevertheless, there are reports that regulatory policies regarding the use of blockchain are under development and they can influence the large-scale adoption.

Issues Found in the Implementation of Blockchain.

Alongside the positive outcome, the literature also revealed that there are a number of challenges related to the use of blockchain in pharmaceutical supply chains. High initial implementation cost is one of the most commonly reported challenges that envisage the development of infrastructure, the integration of the system, and training requirements.

Scalability is another significant challenge. Since pharmaceutical supply chains produce substantial amounts of data, it can be challenging to keep the performance and speed on blockchain networks. Another issue that is mentioned is the integration with the current legacy systems since many organizations operate on the basis of the traditional databases that might not be compatible with blockchain platforms.

The problem of data privacy and confidentiality is also addressed, as well as in the context of sensitive commercial and patient information. Although blockchain is a promising protocol that guarantees transparency, data privacy in a decentralized system is a relevant problem. These issues imply that blockchain is practical, but it needs a well-thought out strategy and favorable policies to achieve successful application.

General Discussion with respect to the Objective of the Study

The findings of the research are well-cased with the research objectives. The results prove that blockchain technology can be used to increase the level of drug traceability, improve transparency, and reduce the chances of counterfeit medication significantly. Another aspect revealed in the analysis is that blockchain enhances trust among supply chain stakeholders and helps to comply with the regulations.

Simultaneously, the discussion does not ignore the fact that the use of blockchain is not unlimited. There are technical, financial, and regulatory issues that one has to tackle to achieve sustainable implementation. All in all, the findings allow concluding that blockchain can be used as a potent instrument to enhance the security of the pharmaceutical supply chain, assuming that the challenges r elated to the implementation will be addressed successfully.

CONCLUSION

The increased use of counterfeit medications is a critical risk to the health of the population, patient safety as well as the quality of healthcare systems in general. Because of its multi-stakeholder and complicated nature, the pharmaceutical supply chain is very exposed to the penetration of counterfeit and poor-quality drugs. Conventional drug traceability processes that mostly rely on central databases and disjointed record-keeping procedures have not been very useful in ensuring that this challenge is overcome. In this respect, the current research presented the application of the blockchain technology to guarantee the traceability of drugs and prevent the spread of counterfeit medications in the pharmaceutical chain of supply.

Through the analysis of secondary data based on peer-reviewed academic literature, regulatory reports, and research conducted on the industry, the results are apparent that the blockchain technology can be used as a powerful and secure means to enhance the security of pharmaceutical supply chains. Among the main findings of the research, it can be mentioned that blockchain contributes massively to the end-to-end drug traceability. Blockchain allows real-time tracing and proper monitoring of pharmaceutical products by documenting all transactions associated with the lifecycle of a medicine on a decentralized and immutable ledger. This guarantees that the source, transaction, and whereabouts of medicines can be established at any point of the supply chain.

The paper also concludes that blockchain helps to reduce the spreading of fake medications. The impossibility of introducing counterfeit drugs to legal supply chains without any indication is immensely difficult due to the unalterability and visibility of blockchain data. The authentication processes enabled by blockchain can provide a system that can help the manufacturers, distributors, pharmacists and even the patients to verify the authenticity of the medicines before they are used. This would go a long way in

minimizing the possibility of counterfeit drugs making it to the final consumer and also aid in improving patient safety and treatment outcome.

The other important study lesson is that transparency and trust between the pharmaceutical supply chain stakeholders are increased. The blockchain enables a shared and synchronized structure of reaching verifiable information by all legitimate subjects. This reduces information asymmetry, conflicts and maximizes coordination between the stake holders. The other factor that is enabled by increased transparency is the better decision making and accountability, which are significant components of healthy healthcare management. The findings also point out that the blockchain technology contributes to compliance with regulation and monitoring. Time sensitive access to authentic data which cannot be tempered will also assist the regulatory bodies in improving supervision, audit and implementation of the drug safety laws. Another advantage of the systems facilitated by blockchain is the efficiency of the drug recall processes because it enables identifying and isolating affected batches within a limited period of time, eliminating threats to patients.

However, the study also concludes that despite the great advantages of blockchain usage on pharmaceutical supply chains, there exist certain challenges. The high initial implementation cost, problem of scaling, necessity to connect the adopted new system to the present system, and the data privacy and clarity of regulations are still the major barriers. These problems indicate that blockchain technology has been proven successful, however, the process of its implementation should be planned strategically, be technologically ready, and have a friendly regulatory environment.

On the whole, this research finds that blockchain technology has great opportunities to revolutionize the pharmaceutical supply chain management through drug traceability and elimination of counterfeit drugs. Though it is not a solution in its own right, with proper governance, stakeholder cooperation, and integration of technology, blockchain can make healthcare supply chains much safer, more efficient, and reliable. The present study results can help advance the knowledge about the potential of blockchain in managing healthcare and form the basis of further studies and creation of policies to address the problem of counterfeit medicines.

Recommendations

1. To establish end-to-end monitoring of the medicines in production up to their distribution, pharmaceutical manufacturers need to implement traceability systems using blockchain technology.
2. Regulatory bodies and governments should come up with true principles of regulation of blockchain implementation in pharmaceutical supply chain to make it standardized and compliant.
3. The current drug serialization methods should be complemented by blockchain systems that do not interfere with the existing operations.
4. Pilot projects on the blockchain ought to be extended on national and regional levels to determine scalability, feasibility, and cost-effectiveness before going to scale.
5. Healthcare professionals and supply chain personnel should be introduced to training and capacity-building programs to enhance the level of knowledge and successful application of blockchain technology.
6. The privacy and security provisions in data privacy and security frameworks need to be enhanced to safeguard sensitive commercial and patient-associated data in blockchain systems.
7. Partnerships between the stakeholders in the supply chain (i.e., manufacturers, distributors, pharmacies, and regulators) should be promoted to guarantee the successful uptake of blockchain.
8. Authentication instruments that involve blockchain implementation should be decentralized to the pharmacy level so that the authenticity of drugs can be checked before dispensation to patients.

Conflict of Interest – None

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