A SYSTEMATIC REVIEW OF BLOCKCHAIN TECHNOLOGY USE IN E-SUPPLY CHAIN IN INTERNET OF MEDICAL THINGS (IOMT)

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ABSTRACT

For every sector, managing supply chains is a difficult task, but the healthcare sector faces risks and complication since a disrupted supply chain could have a direct impact on patient security and medical results. In this assignment we will discuss how Blockchain technology is one possible method for enhancing the health E-supply chain's security, integrity, data provenance, and usefulness. The medical supply, medical product and supply, Internet of Medical Things (IOMT), and health care sector are all given such priority, the goal of this research is to provide a description of the advantages and drawbacks of using blockchain technology in the medical distribution and supply network. The unfulfilled potential of blockchain technology to increase the health supply chain requires greater research, analysis, and integration with regulatory frameworks has been discussed.

Keywords: E-Supply Chain, Blockchain, IoMT.

1. INTRODUCTION

Globalization, increasing usage of information systems and related technology, and a sector populated by various businesses in several jurisdictions have all contributed to the development of a complex and self-replicating health supply chain. One of several initiatives to safeguard supply chains in the broader sense of all commodities and items is the US National Strategy for Global Supply Chain Security. "Promote efficient and secure services" and "increase resilience" are two

goals of the White House [1]. Although this government plan for SC security is crucial for all industries, the healthcare sector is particularly in need of it since a compromised supply chain can have several negative effects on resulting health and patient safety. These include chance of failure to store and deliver life-saving supplies, unfavorable outcomes related to supply chain breaches, and a rise in end-user or patient morbidity and death [2].

When creating technology-driven solutions and use cases, one of the verticals that is most heavily considered is the pharmaceutical supply chain [3]. For instance, billions are spent annually on the worldwide market for subpar, counterfeit, and grey market medications. Studies have indicated that many medications, medical equipment, and biologics are counterfeited in low-, middle-, and high-income countries. This shows that this kind of global pharmaceutical criminality affects the entire drug supply chain. Supply chain vulnerabilities as well as new types of technologies have emerged as a result of the introduction of digital health platforms, along with the expansion of the pharmaceutical business internationally and an increase in worldwide medication sales [4]. Up until now, Technology like ownership-transferable radio frequency identification (RFID) chips, smartphone apps to trace pharmaceutical pedigree (for example m-pedigree), and other item authentication systems have received the majority of the attention in efforts to protect and improve supply chain [5].

Enhancing security and reducing risks in the space available of healthcare goods and equipment is a priority issue in relation to pharmaceutical counterfeiting. Given the growth of linked devices and mobile health (mHealth) applications, the medical device business is particularly significant. Examples of difficulties with the expansion of the Internet of Medical Things (IOMT) and how its advancement and acceptance have greatly surpassed security needs include people with implanted cardiac devices being made susceptible owing to massive security gaps [6]. Governmental organizations and authorities are taking action to raise public responsiveness of the hazards to the public and the healthcare network in the IOMT in response to problems like the cybersecurity vulnerability found in pacemakers. Put another way, escalating medical supply prices are prompting healthcare organizations to reevaluate fundamental operational tenets [7]. Even though these procedures would enable systems to make greater use of a health system setting with abundant distribution network information, supply management still wouldn't be entirely facilitated.

1.1 Problem definition

The penetration of the mutual classification of substandard and falsified (SF) medications is a severe and well-known hazard to the pharmaceutical supply chain, which are typically stated as fake items. However, it usually take on an unique authorized meaning. These several forms of tainted and fake pharmaceuticals may show up as a result of drug theft and diversion, poor manufacturing practices or improper storage, importation of subpar medications without local authorization, and entry of subpar or fake items into grey markets [8]. Would blockchain technology be a better supply chain and anti-counterfeiting system than the ones we currently have? These are the key inquiries to ask in order to fully comprehend how blockchain can protect and enhance supply chain activities for the creation, dissemination, and distribution of medical products [9]. Does it have features or processes that aren't present in legacy systems or centralized databases? What kind of interactions might a blockchain have with pre-existing supply chain data like RFID, GS-1, EPCIS, and anti-counterfeiting technology? Can it provide a regulatory and compliance solution that can reduce risk while also boosting compliance and patient safety, hence enhancing both manufacturer and customer benefits?

1.2 Proposed Solution

Crisis and disaster mitigation and management, including shielded goods for medical personnel access to vital drugs, vaccinations, and immunizations during public health emergencies, as well as essential medication, vaccine, and access issues, are all aspects of the public health supply chain that need to be addressed [10]. Blockchain technology use case scenarios in the healthcare supply chain and combating SF medicines of ensuring access to necessary and superior medicines all interact with use case scenarios for sustaining satisfactory stock at point of sales (e.g., qualifying stock outs) [11], speeding up the effective delivery of health services and supplies, and reducing corruption in the health systems' drug procurement processes [12].

One way to address the issues is through the deployment of blockchain technologies for things like product tracing, verification, detection, and notification as well as source data. Following are some of these problems and their solutions: -

- Product identification - The use of block chains is consistent with the requirement for a unique product identity that is validated as a side chain [13].

- Product Tracing -With the help of product tracing, producers, distributors, and dispensers may supply tracing data in a common ledger with automated confirmation of crucial data.
- Product Verification- Product identification and other supplied information are verified using an open system that is created for this purpose [14].
- Detection & Response - Enables both public and private actors to report and discover medications that may be hazardous, illegal, or counterfeit [15].

Public health supply chain difficulties involve tragedy and crisis management and handling, including availability to necessary drugs, vaccinations, and immunizations, as well as protective materials for healthcare personnel during public health emergencies [16]. In order to guarantee access to required and high-quality medications, blockchain technology applications intersect with use cases in the healthcare supply chain and fight SF drugs[17]. These applications include maintaining sufficient quantities at the distribution point (e.g., preventing stock outs) [18], decreasing the corruption associated with health systems in the purchase of pharmaceuticals, and speeding up the effective provision of healthcare and commodities. [19].

In order to establish strong use cases and localize the context of the myriad experiments encountered by supply chains in different countries [20], the answers to these questions should serve as the basis for first evaluation of blockchain design features and feasibility studies [21]. Using the Drug Supply Chain Security Act (DSCSA) as an example, each regulatory element must be compatible with bitcoin technology for anything to be a workable solution. By creating use scenarios, simulation studies, and blockchain solution prototypes, a number of enterprises are dynamically investigating the presentation of blockchain for medicinal supply chain [22]. The thought process behind this research is being led by the Center for Supply Chain Studies, a nonprofit organisation established to investigate the practicality of innovation through a virtual pilot project with participation from many stakeholders from throughout the pharmaceutical supply chain [23]. Furthermore, it is working on reference models for DSCSA and blockchain scalability and compatibility.

In order to investigate technical professional organizations have also planned workshops, webinars, and are currently overseeing a Supply Chain/Clinical Trials Technology Implementation Industry Connections program [24]. These initiatives aim to improve patient safety in both the

pharmaceutical supply and clinical trials sectors. Several businesses are concurrently pursuing these objectives from various angles [25]. For example, they are developing use cases, looking into vendor partnerships [26], and incorporating blockchain technology into pharmaceutical and related healthcare applications, as well as other industries (such food supply chains) [27].

A case study reviewed has been looking at how blockchain technology might increase the security of the pharmaceutical supply chain while at the same time mentioning the combating long-lasting clinical experiment of SF medications [28]. Several players in the blockchain research and startup communities for advances, public health, and healthcare have expressed interest in this case study [29]. Even though a study like MediLedger shows a cooperative approach across multiple groups, the concrete and practical application of blockchain to this issue is still uncertain and requires additional work.

Private blockchains are beginning to emerge in other healthcare specializations that are usually tech-focused and subject to tight regulation, outside of pharmaceutical and the medicinal distribution chain [30]. Clinical trial participants, health information and data processing providers and businesses, and as previously said, the medication supply chain are perhaps the most developed healthcare industries going forward with blockchain implementation [31]. However, there are applications for medical equipment and supply, IOMT, and public health that are aligned with the core concepts of better data management [32] and the reliability of the wellness supply chain, and these are briefly discussed below [33].

Medical equipment and supplies for a security weakness that exposed the device to possible hacker operation, over half a million customers with implanted cardiac pacemakers were recently recognized as requiring a crucial firmware upgrade [34], [35]. This comes after past incidents, such as the SymbiqTM Infusion System recall, when it was found that Hospira's smart pumps could well be retrieved and operated by unauthorized users over a hospital network to adjust patients' doses [36]. The appropriate usage of these technologies along with their risks become increasingly obvious as the use of linked and digitally enabled medical equipment increases [37].

Additionally, due to its efficiency and accountability around trust, blockchain does have potential to save costs, In response to the FDA and EU legislation requiring that medical equipment possess a Unique Device Identifier (UDI) enhance patient safety and prevent medical device fraud [38]. Blockchain technology has the potential to enhance equipment preventative maintenance

through the use of automated smart contracts [39], [40]. The National Health Service (NHS) National Services Scotland, Edinburgh Napier University, and Spiritus Development are working together in a university-industry partnership using blockchain technology to help the medical equipment supply chain and track devices throughout their lives, with assistance from The Data Lab and Scottish Funding Council. The pilot's secondary goal is to observe the opportunities used in patient care to use analytics to increase efficiency and security, such as quicker responses to instrument recalls and field alerts from responsible businesses and authorities [41].

By enhancing logistics operations and connecting clinical communities, blockchain technology also has the potential to lower costs and increase the value of healthcare. In order to do this, Johns Hopkins Medicine (JHM) established a supply chain strategy with an emphasis on managing blood, joints, and the spine [42]. JHM placed this cost effective program with a "things not staff" mentality to focus on lowering supplier expenses rather than employee cutbacks while maintaining a focus on increasing the value of treatment. One of the most well-known outcomes of this JHM program was the Armstrong Institute for Patient Safety and Quality (AIPSQ), and it was noted that the coordination of these interrelated initiatives was a crucial factor in its success [40].

With their healthcare medical societies concentrating on supply management of medical goods, the communities for spine, joint, and blood management collectively contributed to realizing millions in cost reductions. When considering how blockchain technology might secure and optimize SCM for the production, delivery [43]. The first thing that should be considered is whether or not it would be a better alternative to the logistical network, anti-counterfeiting systems, and databanks [44]. The need to recognize whether it have functions or procedures that aren't found in centralized databases or legacy systems? What potential interactions could a blockchain have with prevailing supply chain data like RFID, Global Standards One (GS-), Electronic Product Code Information Services (EPCIS), and anti-counterfeiting technology? Can it provide a regulatory and compliance solution that can reduce risk while also boosting agreement and patient security and safety by enhancing both manufacturer and customer benefits?

2. LITERATURE REVIEW

Recently, over 500,000 patients with implanted cardiac pacemakers were recognized as requiring a critical firmware upgrade owing to a potential weakness that exposed their implant to potential hacking [45]. This follows earlier incidents, such as the removal of the SymbiqTM Infusion System [46] when it was revealed that unauthorized individuals could access and manipulate Hospira's smart pumps over a hospital network to adjust patients' doses [47], [48]. As the usage of linked and digitally enabled medical equipment grows in popularity, so do their appropriate applications and risks [49].

The use of blockchain might help improve preventative maintenance of equipment through the implementation of smart contracts [50]. Recently, over 500,000 patients with implanted cardiac innovators were recognized as requiring a critical firmware upgrade owing to a security weakness that exposed their device to potential hacking [51]. This follows earlier incidents, such as the recall of the SymbiqTM Infusion System when it was revealed that unauthorized individuals could access and manipulate Hospira's smart pumps over a hospital network to adjust patients' doses [52].

As the usage of linked and digitalized medical equipment grows in popularity, so do their appropriate applications and vulnerabilities [53], [54]. The use of blockchain might help improve device preventative maintenance by deploying a medical products supply network to track devices throughout their lives [45]. The pilot will also look for ways to use analytics to improve quality and reliability throughout the patient care route [55]. For example, Farma Trust is creating a blockchain solution for the pharmaceutical supply chain, as well as an Initial Coin Offering (ICO) particularly for the European market [56]. A corporation like Walton is in the early stages of using RFID and IoT; with the purpose of scaling to the business ecosystem, a startup named Chronicled has teamed with The LinkLab for a blockchain-enabled DSCSA compliance platform.

3. RESEARCH METHODOLOGY

This research aims to assess prior work that applies blockchain technology to the healthcare sector. The shortlisted papers were grouped using research questions. In order to conduct systematic review a secondary study that first establishes clear research objectives before gathering, organizing, and extracting all available material to address those concerns. There are several writing guides available for systematic literature reviews. To perform the current research, nevertheless, Barbara Kitchenham's suggestions are followed. Review papers published in journals

with high impact factors adhere to this practice. This method was developed expressly for carrying out systematic literature review for proposed research.

In order to identify the technology's greatest potentials in the healthcare industry, this research concentrated on elaborating on its qualities. To totally reform the system, it is also necessary to explore the uses of blockchain technology in-depth with all the stakeholders in the healthcare industry. Furthermore, this review of the literature follows a specific set of steps to obtain findings that set it apart from earlier non-structured reviews.

4. DATA ANALYSIS

The findings of this study are created in response to the first stage of the systematic literature review to fill in the gaps identified, as indicated below.

Motivating the research question

Q.1 What are the main concerns of the stakeholders in healthcare?

The goal is to draw attention to the significant problems impeding the healthcare sector's performance.

Q.2 What Blockchain functionalities are applied to address the concerns found?

The goal is to investigate cutting-edge technology that advances the relevant concerns and the industry.

Q.3 What are the difficulties and problems in implementing blockchain technology?

The objective is to identify any unresolved implementation concerns using blockchain technology.

In order to find as much material as possible, numerous studies were gathered after rigorous examination of various databases and publications. Throughout this stage, it was discovered that certain papers were fully or partially out of relevance, while others were determined to be precisely connected with the study field (Blockchain and Healthcare). Given their titles and cited keywords were determined to be comparable to popular search, inclusion criteria reduced the studies to a few. Studies from renowned publishers and publications with high impact factors were selected. Prior to categorizing the studies, we first evaluated each study's abstract considering the

publications' research topics, methodologies, and conclusions. The additional searched documents were disregarded since their titles and abstracts lacked the required keywords. Additionally removed were duplicate or pointless research and articles written in languages other than English.

5. DISCUSSIONS

This section of the assignment provides details on the study questions listed in the Methodology and further divided into subsections. The subsections include lists of the aspects of the blockchain that can address the issues the healthcare industry is currently experiencing, a breakdown of the common problems in that sector by the numerous participants, and finally research that highlights the issues and challenges with blockchain implementation that would need to be resolved in the future. The Discussions of the assignment are based on the below questions which are precisely answered.

5.1 Q.1 What are the principal concerns involving Healthcare Stakeholders?

Ans: -A system is made up of a number of components or items that interact to produce a useful result. Providers, patients, payers, supply chain bearers (manufacturers, suppliers, pharmacies), and research organizations are the five key participants that make up the healthcare sector. A significant component and typical third party are the provider (hospital, doctor, specialist, etc.). Some problems that are serious topics of worry are being faced by each player. Under each situation, the following concerns are covered:

- *Providers*

A main participant in the healthcare industry is a provider. For doctors and patients to have excellent results, patient information management is crucial. The management and curation of the patient records, however, presents various difficulties. Additional time and resource costs may result from a lack of interoperability standards for sharing patient records among labs and hospitals. For patients, payers, and pharmacies, providers serve as a reliable third party.

- *Patients*

The most significant component of the health sector is the patient. Although providers collect patient health information, patients do not have the legal authority to grant or deny access to medical information as they see fit.

- *Payers*

Insured claim payments made by payers (insurer or employer) on behalf of patients must also be validated from centric IT systems, which are prone to security flaws and deliberate fraud. Records (bills, prescriptions, etc.) can be fabricated using phony credentials for medical professionals, incorrect invoicing, false tests, etc. To track legitimate insurance claim procedures, accounting and data provenance are essential.

- *Research Organizations*

To keep track of emerging ailments, develop therapies for them, and find new drugs, research centers and pharmaceutical corporations need public health data. The exchange of health care data is a requirement for clinical audit, national data collecting, and research. Without the patients' consent, a physician may disclose patient data with these groups, which is against patient privacy.

- *Pharmaceutical Supply Chain Management*

The sellers, agents, processors, and pharmacies are the main participants in the pharmaceutical supply chain. It is a complicated system with a wide variety of manufacturing, storage, distribution, and raw material acquisition-related operations. Reliability must be ensured by proper administration and oversight. The origins and quality of drug ingredients may come from a variety of uncertified sources.

5.2 Q.2 What aspects of the blockchain are employed to address the problems found?

The main advantage of blockchain technologies is their adaptability to various situations. By applying the blockchain technology's following capabilities and addressing the industry's key problems, the healthcare sector may progress quickly. The capabilities are addressed and discussed as below: -

- *The problem of record management is solved via Distributed Digital Ledger*

Every firm must maintain its records effectively in order to succeed, and this demands a significant investment in both human and technological resources. Blockchain, a decentralized distributed ledger technology, promises to replace the present expensive systems with less expensive, simpler-to-implement solutions that are more productive and efficient.

- *The problem of data interchange is solved by interoperability*

The inconsistent fragmentation of patient health records may be resolved by blockchain distributed ledger technology, enhancing provider communication and quality. Since the data flow will positively affect market competition, it will promote real-time patient communication, the sharing of the most recent health and treatment information, and quicker product creation.

- *The problem of safety and privacy is solved via consensus mechanisms and cryptography*

Immutable blockchain's capacity to capture consumers' attention by demonstrating accuracy and consistency and transparency is its charm. By utilizing the consensus algorithm and strong encryption in blockchain technology, patient-controlled safe access is ensured because only the private key may decode the data.

- *Lack of data provenance is resolved via traceability and time stamping*

Payers can avoid risky financial loss by using time-stamped, validated records for claim qualifying. Clinical study results must be transparent, free of data eavesdropping, with precise endpoint switching, etc.

- *The monetization problem is solved by digital currency*

In a blockchain-based network, miners receive bitcoin as payment for using their processing power to support and maintain the network.

Now that the healthcare sector has embraced blockchain technology, what issues does it now face?

- Scalability: When a blockchain-powered health care incorporates sensor devices for patient care, storage issues and computationally intensive tasks must be overcome.
- Security (risk of attack of 51%): Consensus powers the blockchain. Malicious miners may control the majority, or more than half, of all nodes, or 51%, and prevent other honest miners from accepting their blocks. Their increased computing

power may also let them to steal valuable data or currencies. A bigger network, however, reduces the likelihood of this attack.

- Confidentiality disclosure: Because the blockchain database is open - source platform, it is subject to the restriction that "openness reveals confidentially." Because patient-related records are so delicate, it is particularly important for patient healthcare records and biomedical applications.
- Confidentiality and identity privacy: The ambiguity and fraud hype that surrounds blockchain is another issue. Criminals may use cryptocurrency while benefiting from the blockchain network's anonymity. On the Dark Web, individuals may use bitcoins to purchase illicit substances.
- Unsustainability for the environment: Another problem with existing blockchain implementations is their inefficiency and unreliability for the environment. The wattage required by the "proof-of-work" requirements in current blockchain implementations is equivalent to powering a single Bitcoin transaction.
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6. CONCLUSIONS AND FUTURE RECOMMENDATIONS

The potential benefits of blockchain technology are some possible advantages for enhancing supply chain management: 1) eliminating fraud and mistakes; 2) cutting down on paperwork delays; 3) improving stock control; 4) identifying issues faster; 5) lowering parcel expense; and 6) improving/building customer trust. However, applying these latent assistances to urgent supply chain issues in the healthcare industry is still a promise unfulfilled. In the future, more financing and research will be needed. However, applying these potential benefits to urgent supply chain issues in the healthcare industry is still a promise unfulfilled. In the future, more research and funding may be needed to boost supply chain performance.

As evidenced by the requirement to adhere to legal frameworks like the Health Insurance Portability and Accountability Act (HIPAA) in the United States and the General Data Protection Regulation (GDPR) in the European Union, it is equally challenging to identify confidentiality and privacy concerns specific to the healthcare sector. Although many blockchain-based health supply chain initiatives are still in the Proof of Concept (PoC) or pilot stage, more mature installations are being looked into across other industrial sectors that can be implemented for the healthcare sector

and centralised to policy rewards provided by governments (e.g., compatibility with the DSCSA). The health supply blockchain appears to have endless potential and opportunities.however only time will prove if the highly regulated and complicated healthcare sector can fully exploit everything that blockchain technology has to offer.

The use of blockchain technology in IOMT computation and medical healthcare is also very young. With its characteristics and qualities, this technology offers significant potential to address some of the most pressing problems in the E-supply chain of the healthcare industry. The ecology might undergo a technological revolution. However, a significant amount of research must be done on the pharmaceutical supply chains and health insurance systems. It is essential to manage the health E-supply chain well in order to guarantee the best patient safety and outcomes for overall community health. Paradoxically, this activity depends on cutting-edge innovation but does not properly utilize it. A medical supply chain with flaws, such as the international trade in counterfeit drugs, stock outs and shortages of medications, and security flaws in connected medical equipment, highlight how high stakes this industry is in comparison to others. As a result, solutions must consider and strike a balance between E-supply chain management optimization, supply chain efficiency, and risk mitigation. Enhancing the health supply chain's functionality, resilience, integrity, and data provenance is crucial across all healthcare verticals.

Future study, financing, and design of systems that can be systematically assessed for their real determinant of patient safety and public health outcomes will be necessary. There will probably also be a lot of use scenarios in the healthcare industry. Medication recall management and combating prescription drug addiction are two other examples from the pharmaceutical industry that highlight special advantages that a blockchain-powered procurement may provide (e.g., opioids).

Another key method through which blockchain technology might aid in improving supply chain performance is the ability to use decentralized applications to automate procedures and cut expenses. It is challenging to manage privacy and data protection issues related to the E-supply chain of the healthcare business, as evidenced by the Health Insurance Portability and Accountability Act necessity to comply with legal frameworks.

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