Entomology and Applied Science Letters
Volume 8, Issue 2, Page No: 71-77

Available Online at: www.easletters.com

ISSN No: 2349-2864

Prospects for Using Blockchain Technology in Healthcare: Supply Chain Management

Lidiia Pavlovna Mokrova[1]*, Maria Anatolievna Borodina[2], Vitaly Viktorovich Goncharov[3], Stepan Aleksandrovich Popov[4], Yuri Nikitovich Kepa[4]

[1] Department of Business Administration, Faculty of Higher School of Management, Financial University under the Government of the Russian Federation, Moscow, Russia.
[2] Department of Foreign Languages, Faculty of Philology, Peoples' Friendship University of Russia (RUDN University), Moscow, Russia.
[3] Department of State and International Law, Kuban State Agrarian University named after I. T. Trubilin, Krasnodar, Russia.
[4] Higher School of Design, Russian State University of Tourism and Service, Cherkizovo, Moscow Region, Russia.

ABSTRACT

Blockchain technology radically transforms resource management mechanisms at any level and scope of activity, making them highly productive, perfect, and efficient. The purpose of this paper is to consider the prospects for the application of blockchain technology in healthcare for the supply chain management. The essence of the blockchain as a systematized database stored on more than one server corresponds to the tasks of modern healthcare. An additional advantage is the accumulation of information in information blocks, which allows creating chains of interdependent blocks that are duplicated on all computers in the system. Based on the analysis of scientific literature, the paper explores the concept of blockchain and identifies the benefits of blockchain technology for healthcare. Based on the expert survey, the authors have identified the stages of the supply chain management process using blockchain technology in healthcare and presented the possibilities of blockchain technology in supply chain management in healthcare. The study concludes that blockchain technology will transform the healthcare system, not only bringing transparency into the supply chain management process but also improving the safety of healthcare.

Keywords: Pharmaceutical quality, Clinical trials, Claims, Billing, Transaction.

HOW TO CITE THIS ARTICLE: Mokrova LP, Borodina MA, Goncharov VV, Popov SA, Kepa YN. Prospects for Using Blockchain Technology in Healthcare: Supply Chain Management. Entomol Appl Sci Lett. 2021;8(2):71-7. https://doi.org/10.51847/ZjaH7bYkpB

Corresponding author: Lidiia Pavlovna Mokrova
E-mail ✉ lp.mokrova@mail.ru
Received: 14/03/2021
Accepted: 28/06/2021

INTRODUCTION

In healthcare, blockchain technology (BT) is used in the following areas: storage of data from electronic medical records; medication tracking; control over the distribution of budgetary funds; a collection of data for clinical trials; ensuring the reliability of the results of clinical trials; fundraising (crowdfunding) for innovative developments [1, 2].

In modern electronic systems used in healthcare, the problems of confidence, reliability, and proper preservation of medical data of patients are relevant. To prevent unauthorized access and amendment of patient information, many countries use blockchain systems [3], including for the registration of medical data. This allows the formation of a clinical summary (medical history) of patients including laboratory results, diagnoses, and treatment. Moreover, access to such information

is possible only if a certain list of trusted digital signatures of the doctor and patient is used. In addition to the doctor, representatives of the insurance company can also have access to this information, with the patient's permission, but only if they are provided the appropriate certificate using a smart contract.

In global practice, since 2016, the use of BT in healthcare has gained a powerful development. For example, the goal of the Guardtime program is to protect more than 1 million digital records inpatient medical records [4]. In the UK, the National Health Service (NHS) has developed a blockchain-based medical data registration system called Verifiable Data Audit based on Google services, which regulates the processing of patient information by healthcare institutions [5]. In the Netherlands, the REshape Center corporation in cooperation with SNS Bank NV and the auditing company Deloitte has developed a blockchain system based on the PreScrypt banking application (analog of Internet banking) using the online iDIN service – authenticity checks, which are used by chronically ill patients to purchase the medications that have to be refilled from time to time with digital prescriptions [6].

Also of great importance is the ability of BT to influence the movement of medications and medical equipment in the supply chain. For example, large pharmaceutical conglomerates Pfizer and Genentech, with a total market capitalization of more than USD 300 billion, announced the creation of MediLedger, a blockchain project using the Quorum platform, which is based on Ethereum. The purpose of the blockchain is to exclude counterfeit goods from accessing the supply system [7]. Additionally, with the new Ethereum system, pharmaceutical manufacturers will be able to identify substandard medications before they enter the supply chain [8-10].

Literature review

Understanding the essence of BT is an important stage in the study of the features of its implementation, including the practice of supply chain management (SCM) in healthcare. Thus, S. Underwood [11] identifies the following directions in the interpretation of blockchain: blockchain innovation (the first manifestation of the use of blockchain: bitcoins, as well as smart contracts, etc.), BT, blockchain as a chain of blocks. Let us summarize the views of scientists on the definition of the term "blockchain" in **Table 1**.

Table 1. Approaches to understanding the concept of blockchain in the literature

Source	Understanding of BT
[12]	Decentralized, distributed ledger of transactions in which all participants can register, view, control and approve an identical shared copy in real-time
[13]	A distributed ledger, the data recorded in which is immutable, verified and traced
[4]	A type of distributed electronic database (ledger) that can store any information (for example, records, events, transactions) and set rules for updating this information
[14]	Digital records, combined into blocks, which, based on an algorithm, are linked by a "chain" among themselves in connection with the operations performed
[15]	A distributed database of records or public ledger of all transactions or digital events that have been performed and shared between participants
[16]	Multifunctional and multi-level information technology designed for reliable accounting of various assets; a decentralized transparent ledger with transaction records, a database updated by participants, controlled by everyone and owned by no one
[17]	A new type of database that allows sharing it between many parties and modifying it securely, even if the parties do not trust each other

Summarizing the approaches in the literature, we note that BT is based on the distributed ledger technology (DLT), a type of distributed database technology, where the databases are stored on many computer devices. At the same time, copies are kept by all users, records are also made simultaneously by all users, and each user is the guarantor of the accuracy of the information. The volume of the specified database grows as the participants add new blocks with records of the latest transactions in linear chronological order. Since this base is decentralized, it does not belong to any business entity or participant, is not controlled or regulated by a third party (all functions in the system are distributed between participants), and is characterized by anonymity and the use of an agreed consensus mechanism. Proof of work and/or proof of stake is used to confirm the record, all changes must be approved by the majority of participants, and when entered into the system, the transaction is almost impossible to change or delete.

That is why researchers consider the BT ideal for the healthcare sector, as it tracks operations, reports on all changes in the system, and does not allow deliberate distortion and manipulation of data that remain relevant regardless of the degree of trust in the counterparty.

Based on our review of the literature, we believe that so far no study has conducted a comprehensive study of the use of BT in SCM in healthcare.

Research hypothesis: BT will change the healthcare system, not only bringing transparency into the SCM process but also increasing the safety of healthcare.

Research objectives

- to define the stages of the SCM process using BT in healthcare;
- to consider the possibilities of BT in SCM in healthcare.

The paper consists of an introduction, a review of the literature, research methods, research results, their discussion, and conclusion.

MATERIALS AND METHODS

During the study, we used the following research methods:

- analysis of scientific literature on the problem of the prospects for the use of BT in healthcare management;
- expert survey. Several questions were posed to the experts regarding the various current uses of BT for healthcare SCM; characteristics of the SCM process using BT in healthcare; the potential of BT in healthcare SCM.

The online expert survey was attended by 35 experts (employees of medical institutions, management of pharmaceutical companies, employees of insurance, and IT companies), whose areas of interest include the use of BT in the SCM in the healthcare sector. The experts included people whose professional activities were related to financial security and financial law for more than 10 years.

All participants were warned about the purpose of the survey and the planning of the research organizers to publish the research results in a summary form.

RESULTS AND DISCUSSION

According to the experts, SCM is a promising direction in the healthcare sector, since the risk of disruption to the supply of medical materials, medications and critical resources can directly affect patient safety. In addition to counterfeiting, lack of a product register and packaging errors can disrupt the entire supply chain.

Based on the expert survey, we identified seven stages of the SCM process using BT in healthcare **(Table 2)**.

Table 2. Stages of the SCM process using BT in healthcare

Stage	Characteristics of the stage
I	A block is created when a new medication, medical equipment, or service, including patent protection and the clinical trial process, is invented. This information is entered into the digital ledger in the form of a transaction.
II	Upon completion of clinical trials of a new medication or medical equipment, patent documentation is sent to the product manufacturer for the creation/testing of a prototype and further mass production. Products created at the manufacturing enterprise are subject to separate identification, integrated with another blockchain transaction.
III	The manufactured batch of medical products (medications, medical equipment) is placed in a warehouse before being transported to distributors, where it receives unique production time stamps, product batch numbers, a barcode, and the expiration date. All the listed information is also included in the blockchain.
IV	During subsequent transportation, the blockchain includes information about the progress of the movement of the goods (medications, medical equipment), including the time of movement between the internal warehouses of the manufacturer, the method of transportation, the person responsible for transportation, etc.
V	The distribution of medical products (medications, medical equipment) to medical service providers and pharmacy networks is usually handled by a third party, namely the distributor (distribution network), using its warehouse arranged for the final distributor. This transaction is also included in the blockchain.
VI	N the subsequent implementation of medical services, their suppliers are obliged to provide customers with full information about the batch of the medical products previously integrated into the blockchain to verify the authenticity. This action is also included in the blockchain.
VII	Retailers (pharmacy chains) perform actions similar to stage VI.
VIII	Buyers and consumers of medical products can get information about their authenticity at any stage of the SCM

Note: compiled from the expert survey

According to one of the respondents (expert 4), "blockchain is the most effective monitoring technology that allows you to track the comprehensive movements of medical products of any kind. Since the register contains all the transactions made recorded in each node, the origin of medical products, the distributor, and the final seller can be quickly verified, both by consumers of medical services and by healthcare workers."

"Blockchain technology in the future makes it possible to create an effective network of suppliers because thanks to reliable and timely identification of medical products, pharmacy chains, and medical service providers will be able to guarantee the authenticity of medical products. This will enable health administrators to prevent patients from contacting questionable providers. Besides, with the help of blockchain technology, the forecast of demand for medical goods and services can be improved" (expert 12).

The use of blockchain in SCM in the healthcare sector offers the following opportunities **(Table 3)**.

Table 3. BT possibilities in healthcare SCM

No.	BT possibilities	%*
1	Quality management of pharmaceuticals	80%
2	Clinical trials in healthcare	75%
3	Claims and billing management	65%

Note: compiled based on the expert survey; * is the percentage of expert references

Next, we will discuss the possibilities of BT in the category of SCM in healthcare in more detail.

Medication quality management. A medication is considered to be counterfeit if it contains inappropriate ingredients and the seller intends to conceal or imitate the origin of the medication, its authenticity, and especially its effectiveness during the sale [4]. We should also mention the impact on SCM of counterfeit medications, the effectiveness of which is a competitive factor in pharmaceuticals, undermining the credibility and reducing the profitability of healthcare [14]. Consumers of medical services may not have accurate information about the sources of medical products they purchase and consume on the market. This, according to experts, leads to reputational risks for the original pharmaceutical companies, forcing significant financial costs for counter-measures for manufacturers and distributors of pharmaceutical products.

Study [15] showed that spectroscopy and chromatography methods were very effective in detecting counterfeits, which made it possible to recognize the composition of the ingredients of the tested medication sample. However, these methods have certain limitations associated with increased overhead costs, since they require expensive devices to use them. A way to mitigate these restrictions is to obtain complete information on the blockchain about medication manufacturers, including serial numbers and packaging numbers, so that any interested person can verify the authenticity of information when connected to the blockchain. This ensures inexpensive but reliable medication quality control, registration, traceability, and the possibility of counterfeiting throughout the SCM process.

Medication manufacturers are constantly trying to improve their quality and create new medications, which must, in the process of their creation, be provided with patent protection, safety, efficacy, reliability of clinical trial results, and regulatory approval. Experts specify that, as a rule, the time from first development to commercialization takes more than one year, where most of the time is taken up by clinical trials. Consequently, the length of the process makes it vulnerable, can lead to a recall, or the creation of counterfeit medications due to breaches of security and confidentiality. This problem can also be overcome by using BT throughout the entire pharmaceutical process. Experts note that the use of a distributed blockchain ledger will preserve confidentiality and guarantee security, if every time a new medication is tested, a record is made on the blockchain, thus protecting the test results from hacking.

A private blockchain can be used to enforce medication patent protection through a smart contract that provides transparency, traceability, and integrity. According to the study [16], about 60% of medication manufacturers are either already working with or trying to use BT, which characterizes the potential of BT in pharmaceuticals.

According to experts, counterfeit medications pose significant public health risks. Abbas *et al.* [17] developed a blockchain pharmacovigilance model to improve the ability to trace counterfeit medications in the supply chain.

Clinical trials in healthcare.

Experts believe that many problems arise during the implementation of clinical trials, including insufficient confidentiality of personal data, possible problems with data exchange, and patient registration. With the help of BT, these problems can be solved, since the use of BT provides complete transparency and reproducibility in the implementation of data exchange.

In the study [18], a proposal was made to use smart contracts on the Ethereum platform to solve problems of trust and increase the transparency of clinical trial results. The study concluded that the scientific reliability of clinical trial results could be improved by overcoming problems such as lack of results and selective publication. Study [19] proposed a new data management structure for several research centers using smart contracts to reduce the costs of ensuring the integrity and confidentiality of clinical trial results.

Table 4 provides a comparative analysis of healthcare SCM tools using BT.

Table 4. Comparative analysis of SCM tools in healthcare using BT

BT platform	Data record type	Result
Ethereum	- clinical trials; - transactions	A smart contract that ensures transparency of clinical trial results. Protection from counterfeit products based on radio frequency identification technology
Hyperledger Fabric	- transactions	Improving the ability to trace counterfeit medications
Gcoin	- transactions	Transparent data on the movement of narcotic drugs, a transition from state regulation (audit) to the supervisory network

Note: compiled based on [20-22]

Claims and billing management. The process of calculating the cost of medical services, making requests to insurance companies, and their processing (billing) is an integral part of healthcare since it is impossible to ensure the provision of medical services without it. Billing is carried out starting from the patient's admission to the medical institution until the end of the treatment process and is a rather complex process, since some types of treatment are fully covered by health insurance, and some are paid for by the patient outside of the insurance policy. One of the problems of billing, according to experts, is the inflated cost of medical services due to the lack of necessary transparency between healthcare providers, customers, and insurers. As noted in the study [23-29], there are constant corrupt practices in the implementation of billing in healthcare, but the problem can be solved by creating transparency for all interested parties using the blockchain.

CONCLUSION

Many scholars today consider the introduction of the principles of BT functioning into the practice of SCM in healthcare to be a promising area of its application. The study has shown that the development of BT in healthcare is indeed developing at a rapid pace.

In this paper, we have examined the various possibilities of using BT in SCM in healthcare and identified the main ones:

- the ability of BT to manage the quality of pharmaceuticals when BT eliminates the risk of counterfeit medications that threaten patients around the world;
- the use of BT in clinical trials, when the blockchain system allows interested patients to make their data available to pharmaceutical companies and research institutions. At the same time, research results are automatically recorded in the blockchain, without the possibility of making changes or falsifying research;
- BT claims management and billing possibilities with the claims and bills that can be resolved or mitigated with a transparent system such as blockchain.

Thus, the hypothesis of the study that BT would change the healthcare system, not only bringing transparency into the SCM process but also increasing the safety of healthcare, was confirmed.

However, some issues require further study. Therefore, further research can be devoted to the application of blockchain in the field of the Internet of Medical Things (IoMT).

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship and compliance with policies on research ethics.

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