Review Article

Applying Blockchain in Telemedicine: A Systematic Review

Abstract

Background: Blockchain has many applications in healthcare and can improve mobile health applications, monitoring devices, electronic media record sharing and storage, clinical trial data, and insurance information storage. In this study, the aim was to investigate the application areas of blockchain and its impact in telemedicine. **Methods:** This study considers articles use blockchain for telemedicine. PubMed, Science direct, and Web of Science databases are considered as searchable databases. Information on authors' names, year of publication, country, application, privacy mechanism, blockchain platform, and encryption techniques are used. 249 studies were retrieved after the initial search. Finally, 16 cases had the necessary criteria to enter this study. The JBI checklist was applied to all 16 studies. **Results:** China with 5 studies and Italy with 3 studies are the most important countries about blockchain in telemedicine that electronic health records are more used than others. Blockchain platforms are Ethereum, Internet of thing, cloud-service provider, and GPS. Encryption techniques are Attribute-based encryption: Decentralized identity: Order-preserving encryption- hashcode- Double blockchain. **Conclusions:** Blockchain plays an important role in creating security for telemedicine technology. In the future, the use of technology will have a significant and important leap, which will attract the attention of many researchers.

Keywords: *Blockchain, encryption, role, telemedicine*

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Introduction

Telemedicine is a broad term that describes the use of technology in health services for patients and families.[1,2] Such services include distance education, distance counseling, and telecommunication platforms that increase the effectiveness and accessibility of health care. Teleconsultation and telehealth provide efficient access to health care and coordination of care and better treatment outcomes. Centralized architecture is an obstacle for existing telehealth and telemedicine systems.

Internal and external medical data set face various problems that can lead to the generation of incomplete data. This issue can compromise the reliability and availability of the system.[3,4] Blockchain technology can help solve such important problems. Blockchain technology follows a distributed architecture to manage a shared ledger of health records among different participants. In it, all versions of the ledger are verified and synchronized with every node affiliated with the blockchain.[5,6]

Blockchain technology has different characteristics. The first characteristic is decentralization, which means that patients' information may be stored in different computers in different places. The second feature is that patient information will be anonymous to preserve their privacy. The third feature is public access to profile information of different doctors.[7]

Tracking locations visited by infected patients, protecting remote patient and physician consultation records, tracking drugs and medical test kits throughout the supply chain, authenticating doctors and proving the origin of malfunctioning medical test kits are among the key challenges. which can be paid through blockchain technology.[8]

Ahmed has studied the role of blockchain technology in telemedicine. Blockchain technology can improve telehealth and telemedicine by providing remote healthcare services in a decentralized, tamper-proof, transparent, traceable, reliable, trustworthy, and secure manner.[9] Hamid investigated the combination of blockchain and fifth-generation technology in intelligent telemedicine using the Internet of Things.

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Blockchain is a system block chain for storing and sharing information that is secure due to its transparency. Blockchain has many applications in healthcare and can improve mobile health applications, monitoring devices, electronic media record sharing and storage, clinical trial data, and insurance information storage.[10] Koshechkin *et al*.[11] pointed out the role of blockchain technology in providing various telemedicine services. The 5 important features in this study are medical data access, medical service processing, purchase transactions, and fundraising for the development of telemedicine tools. Due to the importance of remote medicine in the current situation and respect for patients' privacy in addition to the high accessibility of information, blockchain can be very useful in this field. In this study, the aim was to investigate the application areas of blockchain and its impact in telemedicine.

Materials and Methods

This systematic review study considers articles published in English that use blockchain for telemedicine. PubMed, Science direct, and Web of Science databases are considered as searchable databases [Table 1]. Table 1 shows the number of published studies in the mentioned dataset.

Search strategy

A combination of keywords and synonyms is searched based on Boolean logic (OR). Search results are combined and searched using Boolean logic (AND).

(Telehealth OR EHealth OR Telecare)

AND

("Blockchains" OR Blockchain OR Block chain OR Block Chains)

AND

(Security OR Encryption OR Cybersecurity

OR Data Security OR Security, Data OR Data Encryption OR Encryption, Data)

Inclusion criteria

Studies in English using Applying Blockchain in Telemedicine are included.

Exclusion criteria

Studies which are not in English language and not related are not considered.

Table 1: Number of records in each database

Database	The number of records
PubMed	71
Web of Science	54
Science direct	124
Total	249

Selection of studies

Duplicate records are removed, and then, the title and abstract of the remaining studies are considered based on input and output criteria. Unrelated studies were excluded in terms of title and abstract. Then, the full text of the articles was considered; then, among the remaining articles, the articles whose full text was not related were deleted. Finally, the remaining articles were considered.

Data extraction and classification

According to PRISMA, the steps of reviewing the eligibility of relevant studies, as well as data extraction and study summarization, will be carried out by two researchers, once independently and again together, and a third researcher will supervise these steps. In cases where there is a disagreement between the two researchers, the third researcher's opinion will be the criterion after discussion. Two authors will extract the data, disagreements will be resolved by discussion between the two authors, and in case of disagreement, the opinion of a third author in the same group will be sought. Information on authors' names, year of publication, country, application, privacy mechanism, blockchain platform, and encryption techniques are used. 249 studies were retrieved after the initial search. Finally, 16 cases had the necessary criteria to enter this study. Table 1 shows the number of initial studies retrieved from each database. 25 studies that were duplicates were excluded. The remaining studies (224) were reviewed and evaluated based on the title and abstract, and 94 studies were excluded. After studying the full text of the remaining studies (94 cases), 78 studies were excluded, and finally, 16 studies were selected [Figure 1].

Quality assessment

The JBI checklist was applied to all 16 studies; none were excluded based on quality assessment, and all studies were rated as unclear or high risk of bias. Data identification and numerical quantification comprise the first component. Another aspect of quantitative research is a more structured

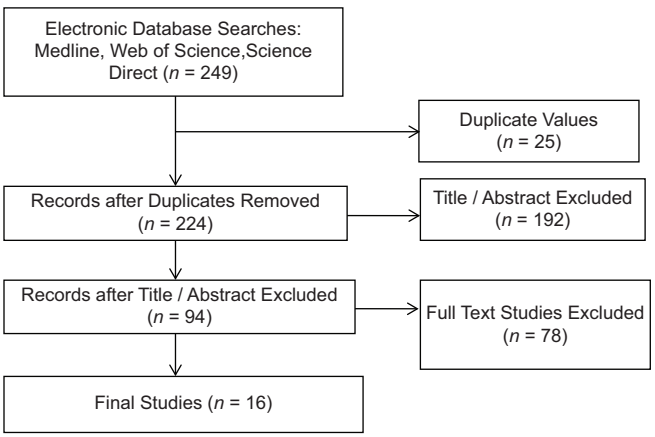

Figure 1: Extraction Strategy of studies

sourcing procedure where the researcher has a clear or unambiguous goal as a starting point for their investigation. The supporting function of qualitative research when used in conjunction with quantitative research is a third aspect of quantitative research.

Findings

After searching and evaluation, the final analysis was performed on 16 articles. Findings were presented in five sections: country, application, privacy mechanism, blockchain platforms, and encryption techniques. The studies year is between 2018 and 2021. This subject shows the importance of the subject. Moreover, one-level privacy mechanism was used in more than ten papers.

Table 2 represents that China with 5 studies and Italy with 3 studies are the most important countries about blockchain in telemedicine.

Figure 2 represents that electronic health records are more used than others. Telecare is the second most important application of blockchain. E-health Services is another usage of blockchain in telemedicine.

Blockchain platforms

Blockchain platforms are: 1. Ethereum, 2. Internet of thing, 3. cloud-service provider, and 4.GPS.

Ethereum

Ethereum is a platform based on blockchain technology and open source that enables the creation of decentralized applications and was created to support smart contracts and secure financial transactions. Ethereum has been widely used and has made many changes after entering the world of digital currencies. In addition, this platform made it possible to develop, expand rapidly, and use various applications to improve many industries. Ether is the name of the cryptocurrency of this network, and Ethereum network transactions and decentralized applications based on this network are paid for by Ether. In fact, Ether is considered as a vehicle for movement on the platform of Ethereum, and many developers who are looking for the development of Ethereum and its programs use this cryptocurrency. The use of ether shows itself more in two ways.

Internet of Things

Internet of Things is a relatively new paradigm that is rapidly growing in modern wireless communication scenarios. The main idea behind this concept is the pervasive presence of all kinds of objects around us—including RFID tags, sensors, actuators, mobile phones, etc.—that through unique addressing schemes are able to coordinate by communicating

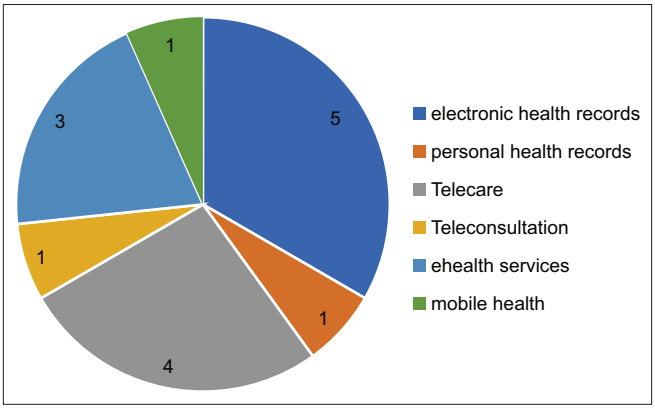

Figure 2: Application of blockchain in telemedicine

Table 2: Article, year, country, and privacy mechanism

Title	Year	Country	Privacy mechanism
Flexible and efficient blockchain-based ABE scheme with multiauthority for medical on demand in telemedicine system	2019	China	Multilevel authority
Blockchain-based eHealth system for auditable EHRs manipulation in cloud environments	2021	China	One level
Decentralized telemedicine framework for a smart healthcare ecosystem	2020	UAE	One level
BMPLS: Blockchain-Based Multilevel Privacy-Preserving Location Sharing Scheme for Telecare Medical Information Systems	2018	China	Multilevel
HapiChain: A blockchain-based framework for patient-centric telemedicine	2020	France	One level
Health-ID: A Blockchain-Based Decentralized Identity Management for Remote Healthcare	2021	Ireland	One level
Is Blockchain Technology Suitable for Managing Personal Health Records? Mixed-Methods Study to Test Feasibility	2019	Korea	One level
Telemedicine System Design using Blockchain in Bangladesh,	2019	Bangladesh	One level
A Patient Agent to Manage Blockchains for Remote Patient Monitoring	2018	Australia	One level
Blockchain-based healthcare workflow for tele-medical laboratory in federated hospital IoT clouds	2020	Italy	One level
A blockchain approach applied to a teledermatology platform in the Sardinian region (Italy)	2018	Italy	Multilevel
Design of secure authentication protocol for cloud-assisted telecare medical information system using blockchain	2020	Korea	One-level
A privacy protection scheme for telemedicine diagnosis based on double blockchain	2021	China	Multilevel
Blockchain-Based Secure IoT Telemedicine System	2021	India	One-level
Enhancing the security of E-Health services in Bangladesh using blockchain technology	2022	Bangladesh	One-level
Using blockchain technology for design of telemedicine system based on mobile terminal	2018	China	One-level

with each other and cooperating to achieve common goals. The term Internet of Things was first introduced in 1999 by the British Kevin Ashton. Ashton proposed this concept in the form of a world where everything and every object has a digital identity and computers control and manage them.

Cloud-service provider

Since cloud computing is increasing, it will limit the activities of large companies such as Amazon Web, Microsoft Azure, and Google Cloud. Of course, this part is similar to operating systems such as mobile phones, which are limited and under the control of a limited number of service providers.

The world's largest cloud computing companies have quickly taken advantage of the ever-increasing need for fast access to information and storage of IT resources and have gained a large share of the market. For example, Amazon has managed to gain more than 32% of the market in 2020, and in this way, it can earn three times more than its competitors.

GPS

Now with blockchain technology, all of these issues can be addressed, creating a fast and reliable global mapping system that is completely private to end users. By leveraging the power of decentralized technology plus other powerful network protocols, a new kind of internet-based map can be created. Having all host data on a single blockchain can potentially dramatically improve the latency of sending and receiving data, as Dapps can combine your device reference information with remote sensing and blockchain data, meaning less data transfer as well as less processing.

Encryption techniques

Encryption techniques are:

Attribute-based encryption (ABE)- decentralized identity- Order-preserving encryption- hashcode- Double blockchain.

Attribute-based encryption

Attribute-based encryption provides the ability to determine if data should be decrypted based on various attributes and policies. The three main types of attribute-based encryption are content-based, role-based, and multiauthority access policies.

Decentralized identity

Decentralized identity: A type of identity management that allows people to control their own digital identity without depending on a specific service provider.

Order-preserving encryption

Order-preserving encryption (OPE) allows encrypting data while still enabling efficient range queries on the encrypted data. Moreover, it does not require any change to the database management system, which makes OPE schemes very suitable for data outsourcing with threats from weak adversaries.[12]

Hashcode

The hashCode() method is used to generate the hash values of objects. Using these hash values, these objects are stored in Java collections such as HashMap, HashSet, and HashTable.

Double blockchain

Double-spending occurs when someone alters a blockchain network and inserts a special one that allows them to reacquire a cryptocurrency. Double-spending can happen, but it is more likely that a cryptocurrency is stolen from a wallet that was not adequately protected and secured.

Discussion

In this research, various aspects of the role of blockchain in telemedicine were discussed, considering that the patient information that is supposed to be sent to the doctor through telemedicine, therefore, it is necessary to maintain the confidentiality of this information. China is one of the pioneers of using blockchain for its telemedicine. According to the analysis of the obtained results, it can be said that developed countries have performed better in this field than other countries. On the other hand, Bangladesh, which is one of the developing countries, has been able to make good use of this technology. In research,[13] it was pointed out that a huge population of people in developing countries can benefit from blockchain technology.

Blockchain is more useful in electronic health records than other fields and has been able to allocate 5 studies. Blockchain could alter the way patient's electronic health records are exchanged and kept by enabling safer mechanisms for health information transmission of medical data in the healthcare business, by safeguarding it across a decentralized peer-to-peer network.[14] In researches,[15,16] it has been mentioned that blockchain seeks to create a revolution in the sharing and safe storage of information in such a way that it is possible to create a safe platform for information exchange in medical environments.

The one-level mechanism is much more useful than the multilevel mechanism. One of the most important reasons for this is that the cost of creating a multilevel mechanism is high.[17,18] Therefore, a cost-benefit analysis should be done to see if the creation of this multilevel mechanism can be done in any situation,[19] so it is recommended that researchers do this analysis and if the use of multilevel mechanism does not create a special necessity, use the one-level mechanism.

Ethereum is one of the most important platforms for creating blockchain mechanisms for telemedicine. In his

review, Vujičić pointed out that Ethereum is one of the most important blockchain platforms.[20] Also, Kushwah addressed the most important vulnerabilities of Ethereum. In his investigations, it was found that the vulnerabilities of Ethereum are divided into three main parts and seventeen subparts.[21] Given its expertise in security and decentralization, Ethereum respects the scalability trilemma while rejecting scalability. Adopting cutting-edge solutions like Plasma and Sharding, which partition data and eventually allow for parallel transaction processing, can help to avoid these limitations and significantly increase performance.[22]

Order-preserving encryption is one of the important mechanisms in the field of creating blockchain in telemedicine. Boldyreva pointed out that order-preserving encryption can improve security analysis and play an important role in improving security,[20] which is extremely important in telemedicine technology.

Study's limitations include:

a) It is probable that we overlooked some studies in our review because some close-access databases are not available in our nation.
b) This analysis took into account English-language papers. Other pertinent articles produced in other languages are therefore overlooked.

Conclusions

Blockchain plays an important role in creating security for telemedicine technology. Different countries, both developed and developing, use this technology. According to the investigations, a cost-benefit analysis should be done to use one-level or multilevel mechanism. Also, the discussion of electronic health record is one of the topics that blockchain can be very useful and by creating a suitable mechanism for data storage and sharing will provide the ability to use telemedicine technology. Ethereum is one of the most important platforms for creating blockchain, but it had lack of scalability. This problem can effect on using this system. In the future, the use of technology will have a significant and important leap, which will attract the attention of many researchers. The relation between internet of things and blockchain is the most important topics that considered in future.

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Conflicts of interest

There are no conflicts of interest.

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