Research on Infectious Disease Surveillance and Traceability System Based on Blockchain Technology

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Abstract: The current emergence of major infectious diseases has become a global problem and a serious threat to people's lives and health security. Although the current epidemic prevention and control work in China has achieved certain results, the existing infectious disease surveillance and traceability system still has problems such as poor information circulation that need to be solved. This paper firstly points out the drawbacks of the current infectious disease monitoring and early warning system, then combined with the characteristics of blockchain technology, the survey method is used to investigate, analyze, and justify relevant application examples at home and abroad. Finally, this paper proposes the general idea and infrastructure for the design of an infectious disease monitoring and traceability system constructed based on blockchain technology. The study of using blockchain technology to empower infectious disease surveillance and traceability system can realize efficient processing of data, which is the key to early prevention and control of infectious diseases and has important theoretical significance and practical value to improve the efficiency of epidemic prevention and control.

Keywords: Emerging major infectious diseases, Blockchain technology, Surveillance and early warning, Traceability, and tracking

1. Introduction

The outbreak of novel coronavirus pneumonia is a serious threat to people's life and health safety, which makes the surveillance and traceability system of infectious diseases an extremely critical part of the public health governance system.

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This means that once such a monitoring or early warning system has information barriers or other sudden information and technology-based failures, it is largely vulnerable to the nationwide infectious disease warning and epidemic prevention and control. Although there have been many studies on infectious disease monitoring and traceability systems based on blockchain technology, how to use blockchain technology to maintain the authenticity of the monitored data, how to use it to share intelligence quickly, and how to use its traceable quality for interdepartmental response in the context of new major infectious disease outbreaks still needs to be studied and explored in depth.

Based on the past research foundation and incorporating the features of decentralization, high availability, and high trustworthiness of blockchain technology, this paper proposes a feasible improvement plan for the specific application of blockchain technology in the existing infectious disease surveillance and early warning system, which has practical significance for the epidemic governance system.

2. Problems and challenges of the existing infectious disease surveillance and early warning technology system

Infectious disease early warning system generally refers to the early warning technology, based on clinical diagnosis and laboratory test data, to detect and identify abnormalities in the early outbreak of infectious diseases and issue early warning signals to alert the risk of their explosion and spread. Early warning of contagious diseases is a crucial part of prevention and control, and its quality often directly affects the timeliness and accuracy of infectious disease warning results. By analyzing the situation from the beginning of this year's new crown flu epidemic and the early outbreak, the existing monitoring and early warning system in the treatment of infectious diseases in China has revealed the following problems.

2.1 Isolated information and a single source of data in the early warning system

Each medical institution is divided and independent in China's current early warning system, and the CDC resources are relatively scattered. There is an information barrier between each other so that the information data between different medical institutions cannot be shared horizontally. At the same time, the current early warning system in China relies on infectious disease reports as the results of clinical diagnosis. Still, the infectious disease prevention and control and early warning system require a comprehensive analysis of clinical symptoms and other diversified data to function better. These reports are widely distributed, and the existing early warning system is challenging to collect and summarize, so all the current data analysis models and methods need to be improved and optimized. Otherwise, it will affect the prevention, early detection, and control of new infectious severe disease outbreaks.

2.2 The existing infectious disease reporting procedures are cumbersome and inefficient

New infectious diseases in China are currently detected, from clinical testing to reporting. They require manual prevention and approval processes at more than three levels, i.e., hospital, district, city, or province. This layer-by-layer review process consumes a longer time for the reviewer and requires professional judgment and a sense of risk-taking on the reviewer. Hence, the review process that currently exists often causes delays.

2.3 The lack of data to support the early stage of emerging infectious diseases, early warning is not timely

For the early stage of emerging infectious diseases that are not yet fully visible, on the one hand, local primary clinics and medical institutions are unable to correctly assess the risk and report it in the first place due to the lack of relevant data support. On the other hand, information on infection rate, transmission rate, case status, and disease are not available in time due to the lack of primary cases data. Thus, there is a lack of targeted and systematic treatment measures for infectious diseases caused by causes that are not yet fully visible. Related prevention and control initiatives and traceability efforts are also delayed.

3. Application of Blockchain Technology in the Traceability Process of Infectious Disease Surveillance

From the perspective of information management, blockchain is a kind of shared database in which a large amount of data or information is stored with decentralization, high availability, and high trustworthiness. On this basis, blockchain can establish an effective data mining, collection, and real-time tracking mechanism, which can support the highly logical association of physical "data islands" [1]and realize the chunking of information, "turning scatter into whole" and "turning points into surfaces", while enhancing the effective communication among subjects in the system. From the perspective of social governance, blockchain technology is a secure distributed computing network for building reliable collaborative partnerships and decentralized collaboration frameworks.

China's public health emergency response system has been in place for more than a decade and plays an important role in the daily management of public health emergencies and early warning of infectious diseases nationwide. Based on the existing real-time monitoring and early warning system, the blockchain model can be upgraded for the prevention and control of infectious diseases, which can achieve more targeted and multi-party shared monitoring and traceability of infectious diseases.

3.1 In infectious disease surveillance and early warning

The current early warning system for infectious disease prevention and control in China requires data to be aggregated and reported through layer-by-layer audits, and thus has obvious shortcomings in coping with unexpected infectious diseases. The use of blockchain technology to build a platform related to the prevention and control of infectious diseases can effectively produce monitoring and early warning of new major infectious diseases [2].

Domestic and foreign research and application of blockchain technology in infectious disease monitoring and early warning, combined with smart contracts and consensus mechanisms, as well as artificial intelligence and other technologies. For example, the Democratic Republic of Congo uses blockchain technology to monitor Ebola virus in the country using smart radio frequency electronic identification tags to collect surveillance data of possible and confirmed Ebola virus infection into SERIS and smart IoT to link telephone companies, Ebola virus surveillance departments, Ebola vaccine supply agencies, and transportation agencies to form a national outbreak surveillance network through blockchain [3] .This provides a good model

for building a major infectious disease outbreak surveillance in China.

In the domestic research on applications related to the field of infectious disease surveillance and early warning under blockchain technology, Zurui Li et al. proposed a federated infectious disease data blockchain system. The model integrates and shares big data resources using smart contracts to realize infectious disease early warning mechanism, which provides an infectious disease data sharing platform for the construction of China's sudden acute infectious disease surveillance and early warning model. However, it is found that the current domestic blockchain medical application research mainly focuses on medical data information sharing, while there is a lack of systematic research on early infectious disease data collection, regional early warning, and integration of government and social resources.

On this basis, Huang Rui et al. researched and proposed the idea of using blockchain technology to integrate four levels of infectious disease surveillance and early warning networks at district, city, provincial and national levels to build a four-level epidemic prevention chain network. The national CDC, the direct network reporting system, the national automated early warning system for infectious diseases, the national three-level public health data exchange platform, and primary care institutions (hospitals) are integrated in the four-level epidemic prevention chain to achieve encrypted data sharing and a two-level automated early warning mechanism at the national and regional levels.

3.2 In the traceability and tracking of infectious diseases

The technology of blockchain combined with cryptography can effectively protect the privacy of information data of patients and institutions and provide a safe and reliable information database and guarantee for improving the sharing system of medical service information. At the same time, the characteristics of non-deletion, non-overwritten modification and traceability of the uploaded information make blockchain have considerable advantages in traceability and tracking when applied to the prevention and control of infectious diseases [4]. Once there is a need to trace back, all information of any record can be traced. This will effectively reduce information falsification and ensure that information falsification can be accurately traced, thus ensuring the authenticity of information in the real-time monitoring traceability system.

Yuanhao Wu et al [5] proposed to combine distributed edge computing network and blockchain technology to realize the monitoring system of people movement information. This study uses the user's action records in the environment such as network platforms to reflect their corresponding location information, and establishes a big data fusion platform and stores it in the blockchain by, for example, base station data, payment data, travel data, urban public safety video surveillance, etc. The system uses the computing power of edge devices to make full use of resources, while the blockchain technology ensures the reliability of data in the transmission process and storage process, and Blockchain technology ensures the reliability of the data transmission and storage process, and automatically records the data in a certain area, which is more convenient.

Blockchain can provide the most basic guarantee for the authenticity of information in the infectious disease surveillance and traceability system. In addition, from the attribute of public health events, the prevention and control of infectious diseases is global, and with the further expansion of the "community of human destiny", real-time monitoring, early warning, and

traceability of public health events on a global scale will become the future development trend. This means that blockchain will develop from national to global layout, and the underlying technology architecture of public chain will be more suitable for the requirements of this development trend.

4. System Design

4.1 General design ideas

Cryptography in blockchain technology can effectively protect the privacy of the tested person and provide reliable data storage for the whole medical information sharing and preservation. Therefore, the system was born in the context of blockchain technology. Under the premise of fully protecting the privacy of the examined person and the construction of the face identity information face identity database collected by the national statistical database, the system can be regularly updated with the data of people's profile change search over a certain period. At the same time, the characteristics of non-deletion and traceability in blockchain technology can make it well applied to the traceability and tracking of infectious diseases, and if there exists a measured person who needs to be traced, all the information will have its corresponding way to follow.

In short, cryptography technology in blockchain technology can not only prevent privacy data leakage and effectively guarantee data security, but also solve the problem of user authentication and privacy protection of the tested personnel [6]. In addition, the distributed storage technology combined with the mechanism of consensus writing by multiple parties can avoid many attacks such as malicious tampering and information deletion by hackers to ensure the fault tolerance, reliability, and integrity of the system technology [7]. Therefore, the infectious disease surveillance and traceability system in the context of blockchain will avoid the problems of temperature measurement and registration in the original method that easily cause information asymmetry and will greatly improve the efficiency.

4.2 Basic design architecture

4.2.1 Establishing a digital system for the whole network distribution of patients, equipment, doctors, hospitals, etc.

The basic feature of blockchain technology is that the chain structure ensures that the data cannot be altered. Modern medicine is based on medical evidence and data trust and security. Blockchain technology solves the problem of credible deposition and unalterable deposition. The system is based on blockchain distributed digital certificates, constructs asymmetric key encryption and CA authentication system, and adopts elliptic curve encryption algorithm to realize identity verification, to achieve data privacy protection and network security transmission of personal electronic health records, electronic medical records, and infectious disease report data. Patients, doctors, medical institutions, devices, pharmacies, and other social disease control participants can realize digital identity management in cross-platform and multilingual systems or devices through the medical digital identity management software tool development kit (SDK) provided by the four-level epidemic prevention chain. Public health data will be securely transmitted under the guarantee of asymmetric encryption

algorithms.

4.2.2 Establishing a distributed infectious disease data encryption security sharing network

The essence of blockchain technology is a distributed database jointly maintained by multiple parties, which should adopt a decentralized data storage and management model so that all nodes can obtain a complete copy of the data and participate in the storage and maintenance of the data. A layer of multi-party secure computing (MPC) and data security sharing layer is constructed between the bottom layer of blockchain P2P network and data application layer, thus realizing the secure sharing of infectious disease data within the region and among multiple institutions under the premise of protecting personal privacy and institutional data security. At the same time, under the protection of key exchange algorithm and MPC architecture, data cipher text is stored, and smart contract is automatically warned, and after the outbreak of infectious disease, the cipher text is unlocked by regional warning smart contract and provided to medical institutions in the neighboring regions for sharing personal and medical data of the epidemic.

4.2.3 Using blockchain network to optimize infectious disease reporting process

Blockchain technology is also highly advantageous in the infectious disease reporting process. Currently, the national infectious disease reporting system requires too much completeness and accuracy of infectious disease reporting data. Although there is an option of "suspected cases", the initial symptoms of new infectious diseases may not be clear and cannot be diagnosed exactly, and doctors and hospitals are under great pressure to report, resulting in missing the warning time. Using blockchain technology, suspected cases are first reported directly to the blockchain network through surveillance sentinel sites for certificate storage. The sentinel application encrypts the suspected case information by digital signature and submits the patient's public key to the entire hospital node of the four-level epidemic prevention chain. The entire hospital node broadcasts the case ciphertext data via P2P network. The leader node in the regional epidemic prevention chain is responsible for initiating verification and consensus, and the final record is automatically synchronized to nodes throughout the network. Early warning will make full use of the regional epidemic prevention chain smart contract threshold judgment and big data analysis of the national automatic infectious disease warning system; at the same time, verification, regional consultation, pathogen analysis, expert consultation and final confirmation of infectious diseases will be carried out simultaneously. Parallel reporting of suspected and confirmed cases through the blockchain network will minimize epidemic decision-making.

5. Conclusions

The integration of blockchain with the existing infectious disease surveillance and traceability system can solve some problems existing in China's current monitoring and warning technology system.

Digital system for the whole network distribution ensures data security. Infectious disease data encryption security sharing network broadens the data source channels. Using blockchain

network to optimize infectious disease reporting process simplifies the reporting procedure of infectious diseases, improves efficiency, and minimizes epidemic decision-making. These advantages will make a significant contribution to the prevention and monitoring of infectious diseases in China and is worthy of in-depth study in the future.

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