



Communication

The Emerging Role of Blockchain Technology Applications in Routine Disease Surveillance Systems to Strengthen Global Health Security

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Received: 21 March 2019; Accepted: 4 May 2019; Published: 8 May 2019



Abstract: Blockchain technology has an enormous scope to revamp the healthcare system in many ways as it improves the quality of healthcare by data sharing among all the participants, selective privacy and ensuring data safety. This paper explores the basics of blockchain, its applications, quality of experience and advantages in disease surveillance over the other widely used real-time and machine learning techniques. The other real-time surveillance systems lack scalability, security, interoperability, thus making blockchain as a choice for surveillance. Blockchain offers the capability of enhancing global health security and also can ensure the anonymity of patient data thereby aiding in healthcare research. The recent epidemics of re-emerging infections such as Ebola and Zika have raised many concerns regarding health security which resulted in strengthening the surveillance systems. We also discuss how blockchains can help in identifying the threats early and reporting them to health authorities for taking early preventive measures. Since the Global Health Security Agenda addresses global public health threats (both infectious and NCDs); strengthen the workforce and the systems; detect and respond rapidly and effectively to the disease threats; and elevate global health security as a priority. The blockchain has enormous potential to disrupt many current practices in traditional disease surveillance and health care research.

Keywords: Blockchain; disease surveillance; infectious diseases; global health security; Epidemics; public health; health care; Quality of Experience

1. Introduction

In recent years, blockchain technology has gained significant attention among several diverse areas and domains, including healthcare, as it offers a safer and distributed database that can operate effectively without the need for a centralized administrator. Apart from that, blockchain has also gained a lot of attention and interest as an effective platform to improve both the authenticity and transparency of healthcare data in the institutions and hospitals ranging from maintaining permissions in electronic health records (EHR) to streamlining the processing of patient claims [1]. According to Angraal et al., the highlight of the blockchain environment is that once there is digital validation,

the network itself validates the transaction, secures the transaction history, and allows for assets to be transferred directly between parties [2]. This article aims to discuss (1) the basics of blockchain technology and its role in healthcare and disease surveillance, and (2) its application to improve global health security.

2. Understanding a Blockchain and Its Applications

2.1. Definition

A blockchain is a distributed system (decentralized) which performs the dual function of recording and storing the records of the transaction. In this blockchain, the data is located in a network of personal computers called 'nodes' without any central control as shown below (Figure 1).

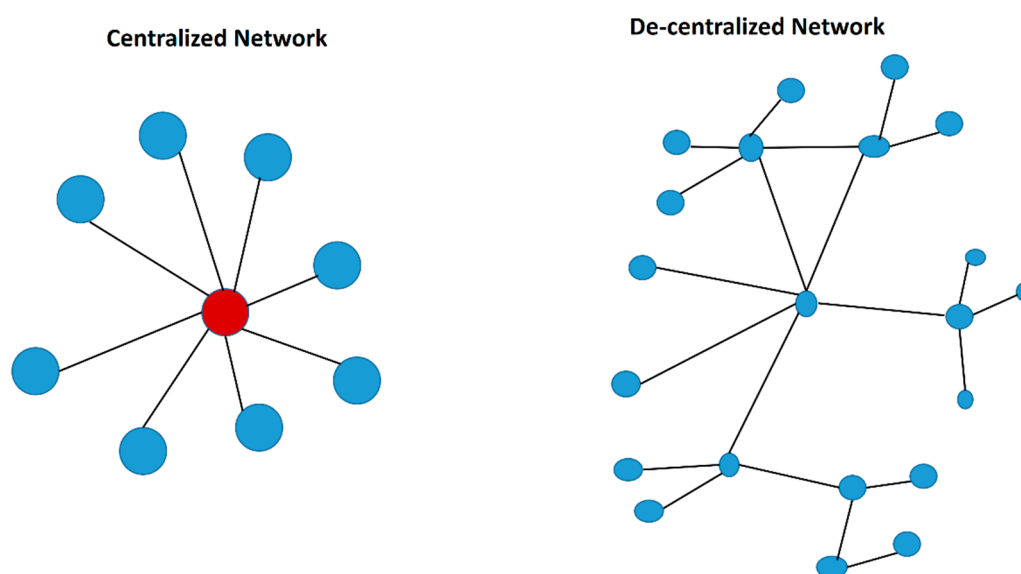


Figure 1. Centralized versus decentralized network.

All the transactions or changes in the data are recorded with real-time updates across the network. So the same information gets stored in each 'node.' This information is permanent; it cannot be deleted or modified [3]. The blockchain technology provides transparency, autonomy and has the potential to improve the quality of healthcare as data is shared among all the participants [4]. It is a system of creating an immutable, secure, distributed database of transactions where cryptographic algorithms are used to validate the transaction. This cryptographic proof is used instead of the "trust-in-the-third-party" mechanism for two willing parties to approve an online transaction which is protected by a digital signature [2]. Centralized healthcare systems have many disadvantages such as information sprawl, data insecurity, expensiveness, slowness, lack of transparency and ineffectiveness. However, decentralizing healthcare through blockchain integration will improve interoperability, immutability, tighter security, transparency, reduced costs, and faster care delivery.

2.2. Types and Uses of Blockchain

There are two main kinds of blockchains: (1) permissionless blockchains where all parties can view all the records, and (2) permissioned blockchains where there is the maintenance of privacy, that is, only select parties can view select information and can also be made nameless and presented [5]. Permissioned blockchains are more suited to the healthcare domain. Of the various available applications of blockchain technology, Bitcoin is the most popular example that uses this technology for cryptocurrency [6]. Other areas or industries where this technology is used are bank payments, money transfers, leasing, car sales, cybersecurity, voting, education, insurance, forecasting, etc.

A recent article published in the Harvard Business Review highlights various uses and applications of Blockchain technology from the validation of artwork to verification of voting records [7]. Many organizations have started to build on this technology for identity verification, settlements of trade/business and supply chain management.

2.3. Advantages and Limitations of Blockchain Technology

Based on the available research in this area, the advantages and limitations of blockchain technology are shown below (Table 1)

Table 1. Advantages and technical limitations of Blockchain technology.

Advantages	Limitations
1. Reduced costs and increased efficiency	1. Cost-effectiveness has yet to be proven
2. Healthcare information remains secure and easily accessible at the same time. Information is automatically updated in real time	2. Security mechanism to be built in to protect patient data from leaking
3. The transactions are processed by the network, so there is no need to trust a single computer, database, or institution	3. Regulatory issues and Technical challenges
4. Improved security by protecting confidential information and reliable protection against “phishing.”	4. The distributed access to the data set does have the risk for potential compromise although the data within the blockchain can be de-identified and encrypted
5. Provides interoperability to communicate the data to healthcare providers quickly in a meaningful way	5. The speed and scalability of a completely distributed system need to be addressed as smaller blockchain-based applications still pose some concerns

2.4. Role of Blockchain Technology in Healthcare

Blockchain technology, which has gained wide popularity among business and other sectors, has also started to get significant attention in the health management domain. The technological innovation has been applied to hospital and health sector activities such as medical records, insurance billing, and disease surveillance. Its application in the management of electronic health records is noteworthy, where vast information can be processed effectively [4]. Peterson et al. [8] argue that blockchains can solve all healthcare data exchange problems and it can revolutionize medical database interoperability. This unique feature of greater interoperability can revolutionize the health databases and helps in improving access to medical records, archives of images, scan reports, prescription databases, and surveillance systems globally. Also, there can be built-in authentication controls which lower the risk of data theft [9].

3. Disease Surveillance Systems

3.1. Definition of Surveillance

Last JM defined surveillance as a “Systematic, ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that the action can be taken” [10]. Surveillance is done for both infectious diseases and chronic noncommunicable diseases by all the national health systems, and according to the national priorities, the diseases under surveillance may be different through the nations must comply with the reporting of infections listed under WHO’s International Health Regulations. Effective disease surveillance and response systems are needed for infectious disease control and preventing the spread of epidemics [11]. If someone contracts Hepatitis A, for example, it is important to alert the CDC and local health departments and for these agencies to share data to identify the contaminant. By ensuring a reliable and active laboratory-based surveillance program which provides early warning about future epidemic transmission, we can have good control

of diseases and effective prevention strategies [12], which further helps in the adoption of appropriate vaccination policies.

3.2. Challenges of Current Surveillance Systems

The microbes have no boundaries, and any infectious disease threat at any part of the globe can be a threat everywhere in this interconnected, globalized world, as a pathogen can travel around the globe to major cities in as little as 36 hours [13]. The current challenge is the growing population, which has not only brought people closer to each other, but also animals, thereby increasing the chance for disease transmission between animals and humans. Due to climate change, it is easy for disease vectors like mosquitoes to cover more territories and transmit various vector-borne diseases to previously safe zones, thereby compromising health security. The concept of “One Health” with multisectoral approach holds a great promise in addressing such health security challenges. Infectious Disease surveillance is an ongoing, complex and inefficient process, as it involves a large number of independent agencies which must report to a centralized information system at the national level. Moreover, it is still a big challenge to keep the information flow timely and accurate, as there is a lack of incentives for the staff involved. The sequence of events after the reporting of a case by a health worker until the timely action is depicted in Figure 2 below.

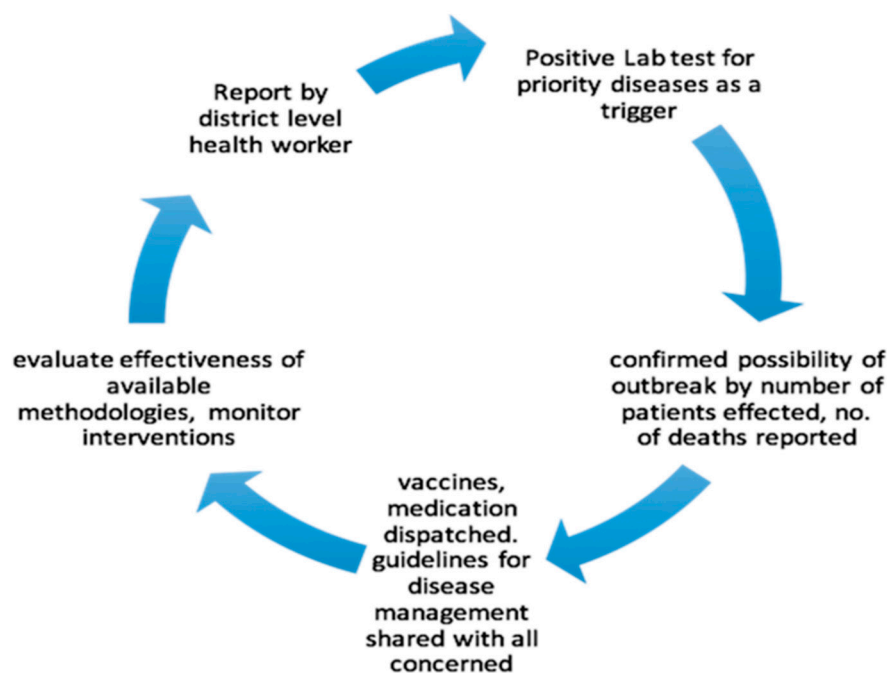


Figure 2. Sequence of events in an ideal disease surveillance systems.

3.3. Moving towards Real-Time Disease Surveillance through Blockchain

In regards to public health surveillance, blockchain could help agencies more efficiently manage data during a pandemic [14]. It could also help track information for ongoing public health emergencies, like opioid misuse [15]. Unlike a traditional centralized database that is maintained by one party, blockchain technology can be shared among a network of computers. When used in a public health initiative, these networks might be able to automate secure data sharing and storage for the national, state and local health agencies.

This technology, upon further research, has the potential to provide real-time disease surveillance, by identifying potential outbreaks or biological attacks and by sending immediate alerts for intervention. Massive casualties can be prevented if vaccinations, antibiotic treatments, and disease control measures are instituted promptly. The lack of timely detection has been repeatedly demonstrated in conventional

public health disease surveillance where manual reporting and data analysis is being done. In the existing system, the lone physician is blind to the cases being seen in nearby hospitals, thus unaware of valuable information which otherwise might lead him to consider uncommon diseases more strongly without missing them [16]. If there can be real-time data aggregation of total cases of priority disease conditions, then it is easy for rapid implementation of the necessary healthcare interventions in response to a potential evolving public health event or threat. Timely reporting of infectious diseases is needed in the early stages itself to guide action and prevent further spread.

3.4. Use of Blockchain over Other Widely Used Machine Learning Techniques

There are certain unique and added advantages of blockchain technology over other machine learning techniques that are widely used in surveillance. The blockchain particularly hinders two types of malicious activities, namely, record hacking and double-spending or duplication [17]. The blockchains are known for their key features such as being decentralized, deterministic, immutable, having data integrity and resilient to attacks [18].

Moreover, with the emergence of Artificial Intelligence (AI), the combination with blockchain technology adds progressive value to biomedical research and healthcare sector [19]. This combination could personalize medicine, quadruple treatments and health recommendations based on patient's medical history, hereditary factors and other external factors. This results in increasing trust in robotic decisions and the information can also be stored securely on a distributed, decentralized immutable patient record as well as a graph-based relationship database can be developed for storing unstructured data [20]. Apart from that, it was emphasized by Woods that this combination of AI with blockchain could tackle the security threats faced by the Internet [21].

3.5. Improving Disease Surveillance through Blockchain Applications

The blockchain applications help the disease surveillance systems in many ways as discussed in this section. The district-level surveillance becomes effective through prompt reporting by the district level health worker. By using the chief complaints and prescription data as input, a red flag can be created. Similarly, the laboratories can be integrated as a participating node when the certain positive test for a priority disease will act as a trigger so that timely public health action can be taken.

There is also scope for integration with other technologies like geographical information system to expedite the routine epidemic investigations, drug and vaccine supply chain systems can also be made efficient by supplying them on time. These blockchain applications can also evaluate the cost-effectiveness of various available treatment methodologies and share the information at a fast pace thereby saving time by reducing duplication in reporting. The other critical aspect is that by ensuring transparency and correct reporting, as in case of reporting deaths from the particular outbreak, the blockchain overcomes the limitations of already-present district health information systems

3.6. Quality of Experience Perspective

Quality of Experience (QoE) deals with the experience the end users are receiving from a service and their satisfaction with it. The user's quality of experience has become one of the most valued performance metrics and same can be applied for this blockchain technology and see various perspectives in healthcare applications. It was reported that by applying blockchain in the pharma supply chain, the quality of the medical products can be ensured by having the sensor devices monitoring the temperature of parcels during the shipment which are connected to blockchain [22]. It is also reported by Chen et al. that the supply chain quality management can be improved by adopting blockchain technology [23]. An interesting study by Anjomshoa et al. showed that application of continuous verification intelligence in smart devices could actually verify users with less than 10% false rejection probabilities, and users can use them for biometric authentication 90% of the time [24]. There are also other scenarios and examples from various countries where the blockchain technology is used in their health care systems (e.g., Taiwan, Estonia) which are discussed in detail in the next section.

4. Global Health Security and Global Health Security Agenda

4.1. Global Health Security

Global health security (GHS) is a shared responsibility which cannot be achieved by a single actor or government and needs the multi-sectoral collaboration of various departments of health, security, environment, and agriculture. In this globalized contemporary world, acute public health threats are at greater risk of crossing international borders and can create emergencies. The best and most effective way to tackle such situations is by providing technical assistance at the source so that the health of the local population is protected and at the same time supports global health security by preventing international public health emergencies [25]. Ebola virus, Yellow Fever, and Cholera in Africa, Avian influenza and Nipah in Asia [26], Middle East Respiratory Syndrome (MERS) Coronavirus in the Middle East, Zika virus are some of the new and recent re-emerging infections apart from the rising epidemic of NCDs globally [27–30]. In this context, the health systems also must be prepared to prevent, detect, and respond to the threat posed by accident or by bioterrorism. The key to success for such threats is by ensuring a robust real-time disease surveillance systems which share the information instantly ensure proper prevention, detection, and response.

4.2. What is the Global Health Security Agenda?

The Global Health Security Agenda (GHSA), which was launched in 2014, is aimed at addressing global public health threats, strengthening the workforce and the systems, detecting and responding rapidly and effectively to the infectious disease threats and elevating global health security as a national and global priority [31]. The GHSA is a multi-country partnership along with international organizations namely the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE).

4.3. Relevance of Blockchain in the Global Health Security Agenda

The application of blockchain technology will revamp the whole system and make it more robust provided GHSA advocates to use this technology based on the feasibility studies. Apart from that, it also drives the progress towards full implementation of the WHO's International Health Regulations (IHR) 2005, the OIE's Performance of Veterinary Services (PVS) pathway, and other relevant global health security frameworks [32]. To stop an outbreak at its source, it requires a multi-pronged approach with great collaboration among various sectors namely health, animal, agriculture, defense, security, development, and others. The recent 2014 Ebola epidemic, which claimed more than 11,000 lives, exposed major weaknesses in the global capability [33] for addressing biologic threats as it resulted in billions of economic losses, and posed a great threat to regional stability in West Africa. In this globalized world, it is essential that countries need to strengthen their health systems and be well equipped with safe, secure, and sensitive real-time disease surveillance systems; qualified and trained workforce; multi-sectoral collaboration; and an effective coordination for a prompt response.

The following schematic illustration (Figure 3) shows how the blockchain applications in surveillance systems enhance the activities for ensuring health security. By identifying the threats timely and reporting them to the concerned health authorities, many outbreaks can be avoided by preventing them early and responding to them effectively in a robust way.

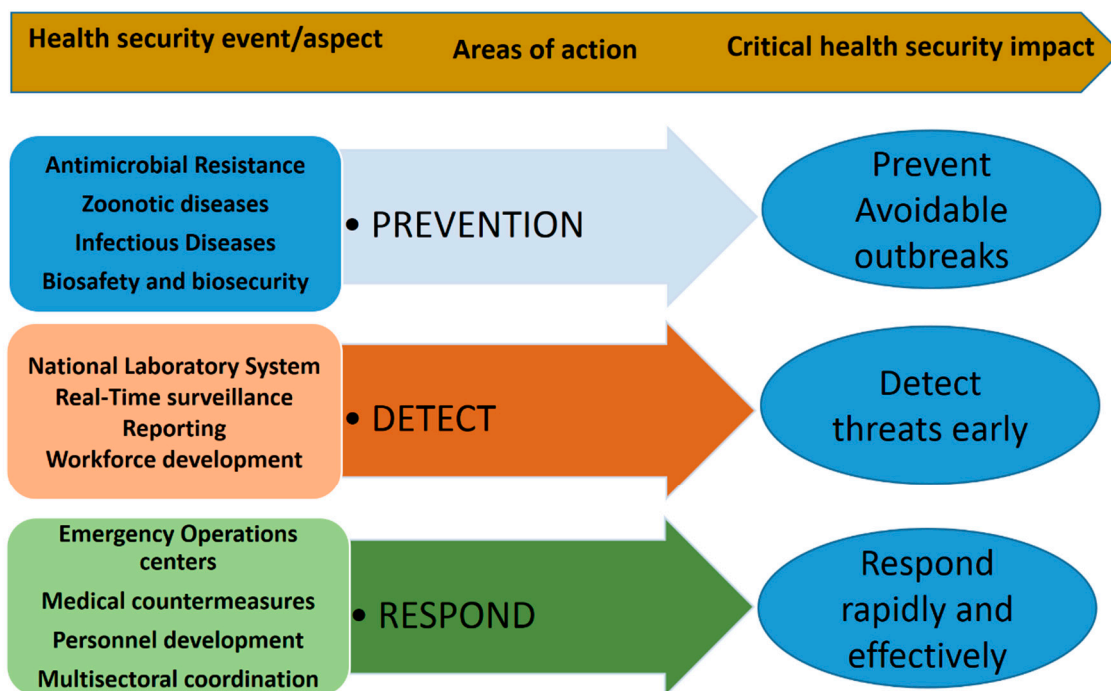


Figure 3. Blockchain application in surveillance systems in managing health threats.

Under these three broad categories of disease control namely prevent, detect and respond as shown in Figure 2, there is a great scope for real-time surveillance for detection of Non-Communicable Diseases (NCD) as well within the GHSA action packages.

4.4. Need for Real-Time Surveillance for Chronic Non-Communicable Diseases (NCDs)

The currently active and ongoing programs such as Field Epidemiology Training Programs (FETP), Global Hearts Initiative and Data for Health are good examples of NCD related activities related to the GHSA goals. By applying real-time surveillance, early detection can be ensured, and by capacity building of medical and health staff, the emergency response can be improvised through effective supply chain systems [34]. The summary of the NCD activities and GHSA action package activities are shown below (Table 2)

Table 2. Real-time surveillance for non-communicable diseases within the global health security agenda.

GHSA Category	GHSA Action Package	NCD-Related Activity to Support GHSA
Detect	Real-Time Surveillance	<ol style="list-style-type: none"> 1. Strengthen Cancer Registries 2. Support Tobacco use surveillance 3. Improve the birth defects surveillance due to Zika virus 4. Including NCD indicators in current surveillance systems 5. Support inclusion of Electronic Medical Records (EMR) 6. Implement Data for Health

5. Conclusions

The case of Taiwan is an excellent example of the application of this revolutionary blockchain technology. The capacity of this real-time surveillance was assessed by external experts and was found to have a demonstrated and sustainable capability which is quite promising [35]. In Estonia, the complete public health infrastructure is being operated using blockchain [36]. Every patient’s

interaction with any healthcare entity is recorded on the blockchain; this healthcare information is completely secure and accessible to only authorized individuals [37].

Other examples include countries such as the UK, USA, and Canada, where such real-time surveillance systems have been implemented in many of their departments. In England, at the national level, they have implemented in their Emergency Department Syndromic Surveillance System. Likewise, in the United States, they have incorporated this real-time surveillance in their National Retail Data Monitor. Canada has implemented the Emergency Department Syndromic Surveillance at the regional level. Another excellent example of this application is the European Antimicrobial Resistance Surveillance Network [38].

There are some essential characteristics of disease surveillance that are deemed necessary for an ideal surveillance system. The blockchain applications in disease surveillance can ensure the prime characteristics of ideal disease surveillance and can be more effective and prompt than the traditional surveillance in terms of coverage, durability, consensus, selective privacy, uniqueness and timing. The blockchain-based surveillance system is a robust, transparent and cheap solution can achieve all the desired characteristics mentioned above. It is very easy and simple to pack the blockchain client nodes in a mobile application at next to zero cost. Since it does not require centralized supervision, it can scale/measure without limits, even in places where connectivity is deficient as continuous connectivity is not required. As part of Global Health Security Agenda, an action package for disease detection and contribution to the Real-Time Surveillance Action package was initiated globally in different regions which includes South America (Argentina), Central America (Mexico), North America (United States), Africa (Azerbaijan, Cote d'Ivoire, Ethiopia, Ghana, Guinea-Bissau, Kenya, South Africa, Zimbabwe), Asia (Bangladesh, Mongolia, Indonesia, Yemen Israel) and Europe (Italy, Finland, Norway and United Kingdom).

Blockchain technology holds great promise for the future by strengthening the capacity of the countries with simplified early warning surveillance for diseases of epidemic potential by reducing the mortality, morbidity and economic costs. It enhances the abilities of the countries to detect events affecting public health threats to global health security. The advantages of immediate validation and availability of data can lead to faster responses of health systems during such emergencies. Finally, surveillance systems can reap countless benefits from a secure system for continuous release of data, but the scalability, security, and cost-effectiveness of blockchain technology will require further research before scaling up. The feedback from the countries implementing the real-time surveillance under GHSA action package would give more information on how this technology can be scaled up and used in shaping the disease surveillance systems. There is an excellent possibility for nationwide real-time disease surveillance, which can be adapted and extended to other nations for global surveillance and international collaboration to ensure global health security.

There is tremendous scope for this technology in healthcare research and clinical care in this contemporary globalized world.

Author Contributions: Conceptualization, V.K.C. and A.N.; Review of literature, V.K.C., A.N., S.K.C. and S.M.K.; Writing—Original Draft Preparation, V.K.C., A.N. and S.K.C.; Writing—Review & Editing, V.K.C., S.K.C., and A.K. All the authors have approved the final version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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