The way forward after COVID-19 vaccination: vaccine passports with blockchain to protect personal privacy

Kelvin K F Tsoi [1,2] Joseph J Y Sung,[3] Helen W Y Lee,[1] Karen K L Yiu,[2] Hong Fung,[1] Samuel Y S Wong[1]

[1]JC School of Public Health and Primary Care, The Chinese University of Hong Kong, Shatin, Hong Kong
[2]Stanley Ho Big Data Decision Analytics Research Centre, The Chinese University of Hong Kong, Shatin, Hong Kong
[3]Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

Correspondence to
Dr Kelvin K F Tsoi, JC School of Public Health and Primary Care, The Chinese University of Hong Kong, Shatin, Hong Kong; kelvintsoi@cuhk.edu.hk

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INTRODUCTION

The COVID-19 pandemic has been circulating in the world for over a year since 2019, resulting in over 80 million cases with almost 1.8 million deaths in 2020. The first vaccine that hit the global market is BNT162b2, given by Pfizer/BioNTech, which was approved in December 2020. Stepping into 2021, more COVID-19 vaccines are becoming accessible in the global market. Until February 2021, four vaccines have been approved for full use, while six more have been authorised for early or limited use in different countries around the world.

As vaccination programmes are gradually launched by various jurisdictions, post-trial surveillance with real-world evidence is of utter importance for close monitoring of their safety and effectiveness. This paper would introduce a vaccine passport concept implemented with blockchain technology. In the following, the methods of contact tracing and vaccine efficacy monitoring with intact personal privacy protection will be discussed.

VACCINATION FOR COVID-19

As SARS-CoV-2 infection can be asymptomatic, transmission is hard to stop. Despite various containment policies enacted, such as city lockdown, mandatory masking and QR (quick response) code contact tracing, COVID-19 vaccine presents new hope, another ammunition rather, combating the COVID-19 pandemic. Traditional vaccine development takes 10–15 years. With huge social and economic pressure, scientists around the world have been working on accelerated pace in vaccine development as authorised by government. SARS-CoV-2 vaccines are developed at an unprecedented rate with various types. In the face of a global public health crisis, vaccine development has been accelerated. This is accredited to the investigation years for the former severe acute respiratory syndrome coronavirus and Middle East respiratory syndrome coronavirus vaccine, helping identify the coronavirus spike protein as the antigenic target.[1]

Governments worldwide are rolling out mass vaccination programmes accordingly, with 40 million COVID-19 vaccine doses administered globally. A vaccine passport concept with data encryption, such as blockchain technology, could lead a forward way for continuous market surveillance that captures real-world evidence for safety and effectiveness.

VACCINE PASSPORTS WITH HEALTH RECORDS

Data are an indispensable and valuable commodity in dealing with global health crises. The COVID-19 pandemic, a global public health emergency as declared by the WHO on 30 January 2020,[2] has highlighted the importance of health data sharing. Data sharing at the early phase of an outbreak enabled healthcare professionals, researchers and policy makers in mastering information required for formulating strategies.[3 4] Trusted dissemination channels are primarily government official records, peer-reviewed journals and authorised open online databases. Capitalising on these dissemination channels,

governments and global scholars share important information for public health measures, from release of full viral genome sequences, pathological features and clinical phases of COVID-19 presentations, to development of diagnostic tests and potential medications,[5] [6] and potential therapeutic and prophylactic agents,[7] to name but a few. Contact tracing is a vital strategy in finding out potential and hidden cases. A convincing showcase was made by Taiwan, where the authorities have used PCR alongside contact tracing in assessing the COVID-19's transmission dynamics from the initial 100 confirmed cases.[8] This approach has much contributed to Taiwan's success in keeping its health system intact with less than 900 cases even after a year into the pandemic.

Aside from contact tracing for infected patients, daily monitoring among community dwellers could be useful in infection control and resumption of normal social activities. Vaccine passports and digital contact tracing applications (apps) could be widely adopted in recording personal health profiles, contacts, and more importantly vaccination status in later stages. Inevitably, the concept of a vaccine passport led to a heated debate among people from all walks of life over its scientific evidence and ethical concerns. From the scientific perspective, uncertainties remain over immunity responses and transmissibility after vaccination.[9] While COVID-19 vaccines have been developed at an unprecedented speed, data on short-term protection effectiveness and long-term immunity remain unclear. Clinical studies have indicated vaccines may have limited protection for upper respiratory tract as compared with higher efficacy for lower respiratory tract.[10] On the other hand, ethical concerns lie on intrusion of personal privacy of movement, discrimination towards unvaccinated people and the collection of personal data for non-medical purposes. These disputes posed challenges on the roll-out of vaccination programme and contact tracing methods worldwide. The other side of the coin, however, is that these arguments are also raising opportunities for high-technological solutions in resolving these doubts.

With the advent of technological advancement and reduced costs of telecommunications, ownership of smartphones and the use of various mobile apps are ubiquitous.[11] To illustrate, Australia has an app named COVIDSafe,[12] in which health officials would notify people with previous close contacts to infected people. Similar approach is used by Germany (Corona-Warn-App[13]) and Singapore (TraceTogether).[14] China was in fact the pioneer in using community-based health QR code system early in mid-February 2020,[15] in which the system relies on health self-declaration, contact tracing in identifying individuals' infection risk. Citizens without green code, as an indicated potential case of COVID-19, could be denied in travelling across cities and provinces or some designated public venues.

As we move into the postmarketing surveillance phase on vaccine performance in real-world scenarios, the issue of whether and how to implement vaccine passports is becoming more urgent. Documentation of vaccination and subsequent outcome serves as a robust tool that permits monitoring on the performances of vaccine over abovementioned scientific uncertainties concerning long-term immunity and transmissibility. Scientists and ethicists have stated that the launch of a vaccine passport creates more ethical benefits than concerns.[9] Owing to the high transmissibility of SARS-CoV-2 and the asymptomatic presentation of infected persons, city lockdown and ban of international travels have been the painful strategies used during the COVID-19 pandemic. Instead of limiting citizens' mobility, a vaccine passport may provide a gateway to free people from being 'grounded', normalising business and social activities.[16] [17] Children, pregnant women and people who are immunosuppressed or allergic to vaccines are not recommended for certain vaccines due to insufficient data and possible severe side effects, by the Strategic Advisory Group of Experts on Immunization of the WHO.[18] Discrimination towards unvaccinated population should not be a major issue with appropriate documentation and complementary measures to avoid contact. Indeed, using a vaccine passport can be a technological tool unravelling instead of complicating the global campaign against COVID-19. With these, data security is the remaining issue about which people are concerned.

Although data sharing is regarded as vital in fighting against COVID-19, people tend to be sensitive when personal data are exposed and exploited. Data privacy, storage and unauthorised use are the major concerns in widespread use of contact tracing apps.[12] Surveys have revealed that only 20% of Singaporeans[14] and 37.3% of Australians have installed and used their corresponding contact tracing apps.[12] Current data storage models adopted are either central storage by the governments, adopted by Australia, Singapore and the UK, or dispersed storage limited to users' devices only, adopted by Germany. Also, cross-border data communication between countries is not practised. In border control between Hong Kong and mainland China, the Guangdong provincial government launched a mutual recognition of health code with the Hong Kong government which allows uploading of COVID-19-negative test results and health declaration for visitors from both sides,[19] in facilitating cross-border check for passengers between two places. However, debate still exists on the host in storing all personal information.

APPLICATION OF BLOCKCHAIN
Data sharing as an infection control measure only works on wide acceptance and adoption among

citizens. Invariably, data security and integrity would come to the spotlight regarding data access and sharing issues; apart from data storage infrastructure, non-functional requirements[20] such as availability, confidentiality and integrity[21] are also fundamental to data storage, communication and mobilisation. Availability refers to the organised input of required data. Confidentiality is tantamount to authentic data access and usage authorisation, while data integrity ensures data safety against breaches.

Electronic health records and personal health records account for an immense portion of data in this digital era, with a 46% growth in 5 years.[22] Nevertheless, solutions for data protection remain limited, primarily stored via content management system with encryption, in designated host servers. According to the Department of Health and Human Services of the USA, at least 3054 healthcare data infringements were observed from 2009 to 2019, involving leakage of 230 954 151 electronic medical records.[23] A solution for data sharing with robust privacy protection is of paramount importance as well as urgently needed, and blockchain technology seems to be a qualified candidate.

Blockchain technology, which originated from financial technology in empowering virtual currency like bitcoin,[24] is a novel technology renowned for its decentralisation, transparency and anonymisation in data management properties.[25] In essence, blockchain is a distributed system for transactions recording and storage. Data stored via blockchain technology are shared yet impermeable, immutable and tamper-proof. Owing to the absence of central authority in governing the process, access to data is restricted and relies on well-established peer-reviewed cryptographic techniques, named hash key, in ensuring that any third parties' claims are verifiable.[26] This method does not require pre-existing trust between parties while keeping individuals' confidentiality intact.

As powered with these characteristics, blockchain technology is hailed as a promising tool for sensitive data management. It is capable in the application of health data handling and in the creation of a new ecosystem for health information exchanges,[27] with increased provenance, efficiency, privacy, security and interoperability, and therefore particularly useful in the global context in curbing COVID-19 transmission. Indeed, with reference to a review that provides an overview on blockchain applications in healthcare, electronic health records and personal health records are the main targets for using blockchain technology, with 23 out of 39 included articles demonstrating such system infrastructures.[27] Data collection, particularly when doing remotely, and data sharing and communication among health institutions are typically the purposes of blockchain technology utilisation. Ongoing investigations are targeted at polishing the techniques. For example, a hybrid system of applying blockchain and edge nodes is invented for attribute-based access control of health data[28] or multilevel authentication[29] (figure 1). Blockchain technology is becoming more and more mature in the healthcare sector, especially for health records processing.

Vaccine passport, as a form of portable health data, with adoption of blockchain technology, can be a promising tool for health monitoring and alerts while protecting personal privacy.[30] Furthermore, it can also be a pivotal tool for rapid intergovernmental data communication in the management of intelligence for infectious diseases. A vaccine passport concept, information regarding personal health conditions, visited places, vaccination status and related data would be logged in. Vaccine-related information of importance, say recipients' demographics, name and manufacturing details of the vaccine received, vaccination date, immediate side effects, duration of protection
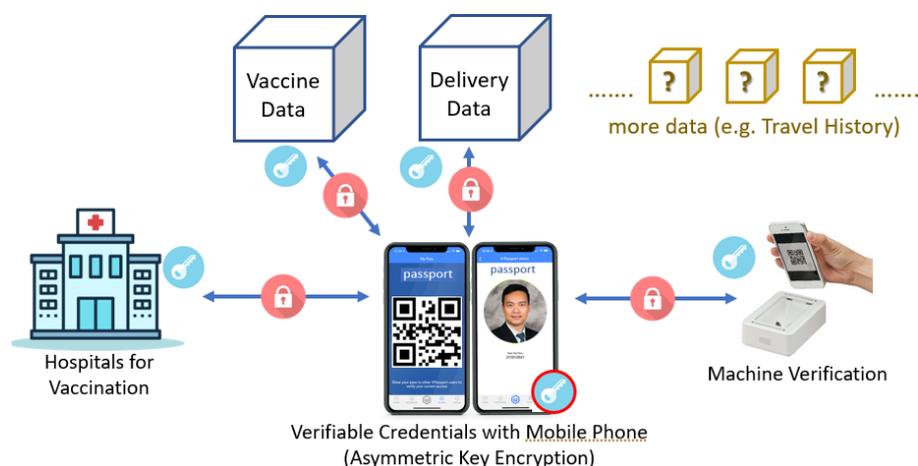

Figure 1 Vaccination data can be verified with multilevel authentication. Data can be stored in different organisations, including vaccine data from pharmaceutical companies, delivery data from logistic companies, and vaccination date and location from hospitals. Verifiable credentials can be installed in a mobile phone and connected to different data servers. Data can only be reviewed through cryptography mechanism, where different keys were used to encrypt and decrypt sensitive information. This is more secure than the traditional data system, where data are centralised in a single server and can be reviewed with a single login.

and so on, can also be included. Without excessive disclosure of personal identification, databases stored in blockchain are useful for data analytics.

GLOBAL COLLABORATION

Considering COVID-19 pandemic as an emerging, highly infectious and rapidly evolving condition, it affects the living of almost everyone around the world and is causing a high death toll and huge global economic recession. The world health community has periodically risen to the challenges of the pandemics and, in so doing, discovered an excess of opportunities for the improvement of healthcare system. For example, the 1854 cholera pandemic had flipped a new page for public health epidemiology,[31] whereas the 1919 Spanish influenza gave rise to an international bureau for fighting against epidemics in Vienna.[32] Now with the COVID-19 pandemic, the time has come for us to use data and advance technology as a way of controlling the spread of the disease and reducing the number of premature deaths.

Rapid data communication is of cardinal importance in dealing with larger infectious disease outbreak.[33] Nonetheless, scepticism in global data sharing and communication becomes a bottleneck for health technology development, but also an obstacle for global management of infectious diseases. As a way forward after COVID-19 vaccination, a vaccine passport constructed by blockchain technology should be used to overcome these hurdles, to improve data provenance, security, integrity, access control, and importantly interoperability. In this way, health information exchanges among institutions and governments could be much encouraged. Alongside portable health records, vaccine passports could be a breakthrough amidst the pandemic battle other than the successful development of vaccines. As a public health emergency of international concern, none of the countries could stand alone in the battle against the COVID-19 pandemic, which requires collective and organised efforts from the world community.

ORCID iD
Kelvin K F Tsoi http://orcid.org/0000-0001-5580-7686

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