COVID-19 Digital Vaccination Certificates and Digital Technologies: Lessons from Digital Contact Tracing Apps

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Abstract

The successful development of COVID-19 vaccines accelerates global post-pandemic recovery by vaccinating populations, targeting priority groups to reduce secondary transmission. This facilitates relaxation of imposed restrictions on international and regional travel, tourism industry, education sectors and other aspects of social life. The vaccination process is done by targeting priority groups to reduce secondary transmission and uncertainties triggered by emerging COVID-19 variants. Vaccinated people are given certificates (cards) that contain COVID-19 vaccination details and health facility. These traditional vaccination cards can be forged, altered, issued corruptly, sometimes difficult to read by non-health experts, and also they can easily get torn and lost. Hence, the relevance of robust, secure, tamper-proof, privacy-preserving and validated COVID-19 digital vaccination certificates is proliferating. However, just like contact tracing apps, COVID-19 digital vaccination certificates are not immune to emerging impediments that affect their adoption, acceptance and usage. Therefore, this paper presents opportunities and challenges pertaining to the adoption of COVID-19 digital vaccination certificates. Also, this paper provides a pioneering review of digital technologies that could be utilized to develop COVID-19 digital vaccination certificates while introspecting at their limitations. Based on this, the study proposes ethical values regard to the acceptable use of COVID-19 digital vaccination certificates.

Keywords: COVID-19; vaccination; digital certificates; contact tracing apps

1. Introduction

Though there is significant progress made towards the containment of novel coronavirus disease (2019), the pandemic continues to overwhelm health systems globally [1] and plunging economies into deep recessions. Governments are finding ways to lift restrictive measures gradually while minimizing public health risk. Lifting measures such as social distancing, face masking [2], blanket lockdown [3] and travelling ban [4] should be informed by the availability of vaccines, contact tracing effectiveness, epidemiological data, capacity for surveillance testing, quarantine and isolation of suspected and positive individuals and health system capacity [5]. Due to the successful development of COVID-19 vaccines, the emphasis now shifted towards vaccination of populations to accelerate post-pandemic recovery and safe relaxation of imposed restrictions[6]. Many countries started administering vaccines such as AstraZeneca, Johnson & Johnson, Moderna, Pfizer, Gamaleya, Sinopharm, Covax among others, to protect against the pandemic and preferably drive herd immunity [7]. However, the universal immunization of populations faces tremendous challenges such as inequitable vaccine distribution [8], weak health systems, shortage of healthcare professionals [9], lack of awareness. Also, impediments such as limited financial resources to secure vaccines, pre-existing health inequalities [10], historical biomedical and healthcare-related public mistrust, pre-existing vaccine hesitancy [11] retards vaccination progress. Lack of policies guiding immunization programmes, inequalities in vaccine coverage, ignorance, COVID-19 conspiracy theories [12] as well as short supply of vaccines and emerging of new variants that are partially resistant to vaccines [13] affect the distribution of vaccines. Also, scaling up the production of vaccines to meet the increasing global demand has been a daunting task for several manufacturing companies [7]. Despite all these impediments, vaccination is in progress in many countries, targeting priority groups including healthcare professionals[14]. Vaccinated people are given COVID-19 vaccination certificates that contain vaccination information, personal details and health facility [15]. However, traditional vaccination certificates (cards) can be forged [16], altered, issued corruptly, difficult to read by non-health experts and they can tear and easily get lost [14]. To counter the limitations of traditional vaccination cards, intense efforts are underway to develop applications (apps) that generate COVID-19 electronic-based vaccination certificates. Digital vaccination certificates should be tamper-proof, remotely accessible, secured and preserving privacy of people (design-by-ethics) because they store vaccination data, coronavirus test results and also act as proof of

vaccination. Also, COVID-19 digital vaccination certificates are not immune to emerging impediments that affect their adoption, acceptance and usage. Therefore, this paper presents opportunities and challenges pertaining to the adoption of COVID-19 digital vaccination certificates and also proposes ethical values regard to the acceptable use of COVID-19 digital vaccination certificates. Also, this paper provides a pioneering review of digital technologies that could be utilized to develop COVID-19 digital vaccination certificates.

2. The rise of COVID-19 digital vaccination certificates

Historically, vaccination cards have been used for people travelling to and from high endemic countries experiencing diseases such as rubella, yellow fever, smallpox, measles, diphtheria-tetanus-pertussis[14] and Bacillus Calmette-Guérin (BCG), especially for children. Various studies including [11,17–19] indicate that vaccination induces potent and nonspecific protection against other unrelated diseases which ultimately reduce infections and mortalities. Before vaccines, some European countries were issuing timed-immunity certifications (passports) to people after serological tests which allow holders to have some degree of mobility, time-work and attend social events during lockdown[20,21]. These immunity certificates experience ethical and scientific challenges. First, the extent of protection conferred by antibody-mediated and cell-mediated immune responses to COVID-19 must be well-understood with reliable indicators [5]. Second, the minimum length of immunity and its duration should be monitored over time to understand whether and when certificate holders need to reassess their immunity status. Lastly, the ethical concern regards the provision of services based on immunity certificates [22].

Notably, the successful development of COVID-19 vaccines prompts various countries to rollout different vaccination programmes based on phases, prioritizing healthcare professionals. Also, details of every dose of the COVID-19 vaccine are captured in a yellow card monitored and managed by the World Health Organization (WHO) through International Health Regulations (IHR). The purpose of IHR is to "*prevent, protect against, control and provide a public health response to the international spread of disease, while avoiding unnecessary interference with international traffic and trade*" [23]. Also, IHR monitors, through the World Health Organization, regional and international cross-border initiatives and control of infectious diseases including COVID-19. For instance, to reduce cross-border infections, COVID-19 antibody testing certificates are now part of the requirements for regional and international

travelling[5]. These traditional certificates can be altered and difficult to validate which subsequently lead to the illicit sale of fake negative COVID-19 test certificates. To counter this, the International Air Transport Association (IATA), the trade association for global airlines, launched the IATA travel pass app (but not yet adopted by many governments) to validate COVID-19 test certificates [24]. Since then, several initiatives are in progress to develop and roll-out COVID-19 digital vaccination certificates. For instance, WHO launched the Smart Vaccination Certificate consortium to monitor national COVID-19 vaccination programmes and facilitates cross-border vaccination activities guided by the International Health Regulations [25]. The United Kingdom (UK) developed a mobile phone application to document people that have been tested for COVID-19 and soon to be used to keep the track record of people immunized against the virus [26]. Also, China launched a digital COVID-19 vaccination certificate for its citizens planning for cross-border travels [27]. Table 1 shows countries, regions and regulators that have been developing COVID-19 electronic vaccination certificates apps as of March 2021.

Table 1: COVID-19 digital vaccination certificates Apps

COVID-19 digital vaccination certificates Apps	Country/ Region/Regulator
Digital COVID-19 vaccine passport	China
V-Health Passport	United Kingdom(UK)
Vacuna, SafeVac, VeriGO TrueSeal	Germany
COVID-19 Vaccine Certificates	Greece
Green Pass	Israel
COVID-19 vaccination card	Australia
Trusted Travel	Africa Centres for Disease Control and Prevention (Africa CDC)
Travel Pass Initiative	Global
Ink Digital Health Platform	Spain
Co-WIN	India
Smart Vaccination Certificate	World Health Organization
Travel Pass Initiative, CommonPass, COVID-19 Credentials Initiative	Global
SMART Health Cards, Digital Health Pass, Vacmobile, Vaccine Passport	United States of America(USA)

These COVID-19 digital vaccination certificates apps differ from region to region, in terms of data use, communication protocols and standards, data handling (centralized or decentralized) and data protection.

3. Digital technologies and COVID-19 Digital Vaccination Certificates

Since the outbreak of the pandemic, digital technologies have been utilized to tackle COVID-19 in different ways. Such technologies include artificial intelligence, smart applications, Internet of Things, Internet of Medical Things, big data, 5G/6G technology [28], geographical information systems(GIS), cloud computing and Blockchain technology. For instance, artificial intelligence models have been used for COVID-19 screening, detection, prediction, diagnosis, development of vaccines [29], while GIS tools have utilized for spatial modelling, mapping pandemic hotspots, monitoring, and migration mobility [30]. Therefore, these technologies could also be utilized to develop COVID-19 digital vaccination certificates in various ways as depicted in Table 2.

Table 2: Integration of Digital technologies into COVID -19 digital vaccination certificates

Digital technology	Function(s)
Artificial intelligence	• Detecting fake COVID-19 vaccination certificates. • Identify and map non-vaccinated regions or population and such information could be used for strategic planning. • Clustering migrants' migration patterns based on data stored in the verification app(s). • Data gathered could be used for contact tracing purposes.
Internet of Medical Things	• Remote access to vaccination certificates. • Support regional and international synchronization of health data and verification of COVID-19 digital vaccination certificates. • Additional health services such as remote counseling can be integrated into apps that generate electronic immunization certificates.
Blockchain Technology	• Verification and validation of COVID-19 electronic vaccination certificates. • Improves electronic health data and communication link security using blockchain-based systems especially when accessing and sharing

	COVID-19 data [31]. • Associates person's identification with blockchain records for authentication purposes [15]. • Securing of COVID-19 digital vaccination certificates.
5G cellular technology	• Supports high bandwidth and data transfer rate to support real-time verification of COVID-19 vaccination certificates and sharing of health data.
Big data	• Store and process COVID-19 certificates verification data • Supports remote access of COVID-19 digital immunization certificates • Allows real-time update of COVID-19 certificates verification data
Quick Response(QR) technology	• Allows authorities to check people's health status record by using quick response. For example, China issues health status certificate and travel pass using QR codes with different colours representing the degree of infection risk [32]. • QR codes can be used to verify COVID-19 digital immunization certificates by linking QR code generated by the mobile phone and the host or server applications. Australia created QR code-based COVID-19 digital vaccination certificate [33]. • By scanning the QR code, regulatory authorities may get access to a person's COVID-19 vaccination details, testing data and travel history. • Follow-up vaccination survey questionnaires can be developed and accessed through QR code systems [34].

4. Issues and challenges associated with COVID-19 digital vaccination certificates

Digital vaccine certificates can help business and society re-open, but complexities make a path forward less clear. Just like digital contact tracing apps, COVID-19 digital vaccination certificates are not immune to emerging impediments that challenges their wide-scale adoption, acceptance and usage by the affected population, vulnerable and disadvantaged countries. Hurried development and roll-out of COVID-19 digital vaccination certificates without proper engagement with stakeholders at the national, regional and international level could cause complexities and uncertainties to adopt and use the certificates, which subsequently lead to

experience the same fate as digital contact tracing apps. Contact tracing apps exposed the difficulty of coordinating, integrating and synchronizing a wide-scale digital response at regional and international level. For instance, a digital tool developed by WHO called Waze for COVID-19 failed to meet the expected outcomes due to lack of widespread adoption and Singapore's TraceTogether contact tracing app had more success but has recently seen public trust erode when it was reported that user data was shared with law enforcement[35]. COVID-19 digital vaccination certificates may face tremendous challenges as explained below.

a. **Lack of ICT supporting infrastructure** -It is not yet known whether the existing ICT infrastructure can handle the data management and security requirements needed for rolling out regional and international accessible COVID-19 digital vaccination certificates. Also, connecting the unconnected communities is another challenge attested by digital contact tracing apps.

b. **Socio-economic disparities** - Existing socio-economic disparities between developed and developing countries affects the roll-out of COVID-19 digital certificates due to poor internet connection and speed, infrastructure and computing devices. Disadvantaged communities might not have access to apps that generate digital certificates because of the digital divide [20]. Rolling out of COVID-19 digital vaccination certificates should not assume that the whole global populations have universal access to digital technologies, yet the gap still exists between ICT access and utilization among vulnerable populations [36].

c. **Lack of standardized COVID-19 vaccination certificates**- evidence from the literature reflect that countries and regions are developing and some have already deployed apps that generate and validate COVID-19 digital vaccinate certificates without regional and international standards. Multiple apps with different formats and designs could make interoperability between different frameworks difficult and may affect certificate acceptance in some regions. Hence the need for standardized COVID-19 vaccination certificates should not be overlooked.

d. **Inconsistency and heterogeneous digital solutions development standards**- Technology digital solutions providers should homogenize the development and deployment of digital solutions and standardization of regional and international COVID-19 electronic vaccination certificates. Harmonization of development standards for digital vaccination certificates apps and data formats.

e. **Security risks and Privacy**- the interconnectedness of apps makes the systems vulnerable to passive and active attacks. Hence security standards, data and communication link encryption should be clearly defined to ensure data confidentiality, integrity and availability of the systems. Also, data standardization, in terms of what data is acquired, how it's formatted and how it's exchanged is critical. Data use agreements may also be required to ensure health data protection. Regulators should encourage the use of consent-based COVID-19 digital vaccination records that are accessed in a secure, verifiable and privacy-preserving way.

f. **No framework, global standards and policies** guiding the integration and synchronization of digital solutions and data sharing such as COVID -19 digital vaccination certificates. There is a need for setting up global standards as a roadmap to the development and deployment of effective digital solutions in case of public health emergency such as COVID-19. Regional and international regulatory authorities should be involved in public and private sector initiatives, policy, guidelines and develop a framework guiding the implementation of COVID-19 digital certificates. Regular consultation with end-users, governments, and technology solution providers through regional public-private sector initiatives.

g. **Ethical concerns**- COVID-19 vaccination certificates pose considerable scientific, practical, equitable, ethical and legal concerns. Among other challenges, the issuance and sharing of COVID-19 vaccination certificate data raised ethical concerns since it will be accessed by many regulatory authorities in various jurisdictions without predefined standards and regulations. This may violate ethical values such as honesty, truthful consent, transparency, security and privacy [37]. The issuance of COVID-19 vaccination certificates raises the following ethical concerns:

- Will the privacy protections of people guaranteed?

- Will vaccination details used for their intended purpose?

- As countries re-open, what are international health standards and guidelines are needed for monitoring migrants, verification and validation of COVID-19 vaccination certificates (electronic or hardcopy)?

- How migrants' COVID-19 vaccination certificates and health data going to be shared among regional and international regulatory authorities as countries re-open?

- Are people without vaccinated against COVID-19 or lost COVID-19 vaccination certificates going to be deprived of their civil rights and access to services?

Nonetheless, privacy cannot be completely guaranteed considering that the vaccination data will be accessed and shared with regulatory authorities in various jurisdictions. However, considering the severity of the COVID-19 pandemic and the importance of COVID-19 digital vaccination certificates, infringements associated with a possible loss of privacy may appear to be justifiable in light of the enormous costs in terms of welfare, resuscitate the economy, liberty, health outcomes, and return to normalcy [38].

Conclusion

Even though the issuance of digital COVID-19 vaccination certificates is still debatable but such apps are inevitable especially when countries are expected to re-open to rejuvenate the economies and to ensure the safe movement of people[20]. COVID-19 electronic vaccination certificates may encounter several impediments such as heterogeneous communication protocols, lack of certificates (data) standardization and interoperability issues with other apps, privacy and security issues; lack of clear international regulations and policies guiding the use of electronic vaccination certificates amid COVID-19, data sharing without user-consent violates ethical issues. Also, there is no clear framework guiding the integration of blockchain technology in health systems and the issuance of electronic vaccination certificates [8]. The outbreak of pandemics in the future is imminent; therefore it is imperative to homogenize digital solutions and standardization of regional and international systems that document and validate COVID-19 vaccination certificates. Alternatives such as smart vaccination cards with digitally signed QR code should be available for people without access to digital devices such as smartphones and tablets.

However, to ensure successful implementation of COVID-19 digital vaccination certificates, there is a need for crafting global standards for vaccination certificates, standardization of communication protocols; data formats to avoid interoperability issues, regular engagement with stakeholders, privacy and security should be guaranteed. Also, the World Health Organization through International Health Regulations and Smart Vaccination Certificate consortium should develop clear international regulations and policies guiding the use of digital health tools such as electronic vaccination certificates that facilitates regional data sharing in case of public health emergency such as COVID-19. Such digital health tools should be developed and designed centred on ethical values.

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None

Competing interest

The author declares no competing interests.

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