A scoping review of global vaccine certificate solutions for COVID-19

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Research Article

Keywords: vaccination certificate, COVID-19, digital immunization passport, immunization passport

DOI: https://doi.org/10.21203/rs.3.rs-334258/v2

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Abstract

**Background:** Globally, measures such as lockdown, quarantining, and physical distancing have been implemented to curb the spread of COVID-19. As the vaccines are now available and reintegration into the society is beginning, measures such as vaccine certificates are being implemented around the world.

**Objective:** The objective of the scoping review is to identify the initial digital solutions available globally for COVID-19 vaccine certificates and evaluate them on the basis of purpose and use case, technological architecture, and ethical and legal implications.

**Methods:** We conducted a Google search on November 18 and 19, 2020 as well as a search of Embase on November 26, 2020, Ovid MEDLINE and preprint servers (MedRXIV, BioRXIV). The search terms used were “coronavirus”, “COVID-19”, “SARS COV2”, “immunization passport”, “immunization certificate”, “vaccine certificate”, “vaccination certificate” and “digital”. Articles were included for review if they included any discussion of a digital solution for vaccine certificates and English language. Data was extracted using an electronic data extraction form and included date, location, type of article, source, companies identified, technology used, type of evidence provided, digital architecture, security and privacy measures, and use cases. The articles were categorized based on the following six pre-identified themes: 1) legal, 2) technology, 3) ethics, 4) travel, 5) policy, and 6) science.

**Results:** A total of 70 articles were included in the final analysis. Technology emerged as the most dominant theme, appearing in 58.5% (n=41) articles followed by ethics (n=22, 31%), travel (n=21, 30%), legal concerns (n=10, 14%), public policy (n=9, 13%), and scientific concerns (n=1, 1.5%). Our review identified 8 global solutions that are working towards COVID-19 vaccine certificate, all optimizing blockchain technology. COVID-19 vaccine certificates are being considered in 13 countries and are in place in 3 countries. All the solutions we identified are using blockchain technology.

**Conclusion:** Several countries have implemented or are considering COVID-19 vaccine certificates. Many issues concerning the themes we identified remain to be addressed to facilitate successful implementation.

Introduction

Globally, unprecedented measures have been implemented to reduce the spread of the COVID-19 pandemic and prevent healthcare systems from being overwhelmed. These measures include states of lockdown, travel restrictions, work from home orders and quarantine of citizens. These have had serious psychological and socio-economic consequences. A key focus to mitigating and recovering from the economic impacts of COVID-19 will be safely reintegrating individuals into the workforce and society.

There are currently international travel requirements in place for Yellow Fever vaccine under the International Health Regulations and it is possible that similar requirements for COVID-19 vaccines may be added. Some airlines are requiring a negative COVID-19 test before boarding the plane, and travelers returning to Canada are required to isolate at their own expense while they await their COVID-19 test results. Beyond facilitating international travel, digital proof of vaccination is being considered as a mechanism to facilitate return to work and reopening of the economy.

The purpose of this scoping review is to identify and evaluate the initial digital solutions that were created globally for vaccine certificates for COVID-19. This lends particularly well to a scoping review as this is a rapidly evolving field. Digital solutions for vaccine certificates may be described on the websites of the groups who have developed them or in news articles or blogs. Therefore, we undertook a comprehensive Google Search of grey literature to identify existing vaccine certificates around the world. We identified key components of effective vaccine certificates and evaluated them with respect to (1) purpose and use case, (2) technological architecture, and (3) ethical, legal, and policy considerations.

Methods

**Search Strategy**

On November 18 and November 19, 2020 we followed the guidelines outlined by CADTH to conduct the google review. The search terms used were “coronavirus”, “COVID-19”, “SARS COV2”, “immunization passport”, “immunization certificate”, “vaccine certificate”, “vaccination certificate” and “digital”. All searches were conducted using privacy settings with location settings turned off. The specific search terms are presented in Supplementary Table 1. The first 150 results were reviewed, unless less than 150 results were obtained. Our Google search yielded a total of 1058 results, 641 after removing the duplicates. To ensure the comprehensiveness of our review, we conducted a search of Embase, Ovid MEDLINE and preprint servers (MedRXIV, BioRXIV) on November 26, 2020. The search strategy is available in supplementary materials. The academic search yielded 101 results. As it is an evolving area, we further augmented our results beyond the time of the search with additional solutions that emerged.

**Eligibility Criteria**

The scoping review inclusion criteria were articles in the English language that included any discussion of a digital solution for vaccine certificate/documentation or passport for the COVID-19 vaccine published from December 2019 to the search date. Articles were excluded if they did not meet the above inclusion criteria, if the links were broken or if the content was presented in video format.

**Screening process**

Two reviewers (SSM, ABB) independently screened titles and content (SSM, DZ) according to the inclusion and exclusion criteria. Data extraction was conducted in duplicate using an electronic data extraction form. Back searching of identified digital solutions was conducted to fill information gaps. Any
disagreements that arose during screening were resolved by consensus.

Data preparation and analysis

Following full-text screening, the two reviewers (SSM, DZ) charted each article chosen for inclusion using the data extraction form to gather common and comparable information on each study. Data extracted included date, location, type of article, source, companies identified, technology used, type of evidence provided, digital architecture, security and privacy measures, and use cases. We categorized articles based on the following six pre-identified themes: 1) legal, 2) technology, 3) ethics, 4) travel, 5) policy, and 6) science.

Results

Search Results

A total of 742 articles were identified for screening (Google n=641, academic literature n=101). Based on the title and headline screening, 551 articles were eliminated including 24 duplicates identified with the same heading or near similar content. One hundred and ninety-one articles remained for full text review, of which 70 were included in the final analysis (Figure 1).

Characteristics of included articles

Of the 70 relevant articles, nearly half were opinion/editorials (n=29, 41.4%), followed by news articles (n=25, 35.7%), research articles (n=7, 28.7%), company websites (n=3, 4.3%), and blogs (n=2, 2.9%). N=4, 5.7% were considered other (event description, guidelines etc.) (Table 1).

More than half (n=40, 57.1%) of the articles referred to “experts” as a source of evidence. Experts included academic thought leaders (n=12, 17%), federal leaders (n=16, 23%), and company CEO’s (n=16, 23%). Academic research was the source of evidence for 18% (n=11) of the articles. Approximately 26% (n=18) did not quote any source of evidence.

Table 1: Characteristics of the articles

| Article Type                                      | n  | Percentage (%) |
|--------------------------------------------------|----|----------------|
| Research paper                                   | 7  | 10.0           |
| News article                                     | 25 | 35.7           |
| Opinion/editorial                                | 29 | 41.4           |
| Company website                                  | 3  | 4.3            |
| Blog                                             | 2  | 2.9            |
| Other (event description, guidelines, concept paper etc.) | 4  | 5.7            |

Pre-identified themes

| Theme                        | n  | Percentage (%) |
|------------------------------|----|----------------|
| Travel                       | 21 | 30             |
| Ethics                       | 22 | 31             |
| Technology                   | 41 | 58.5           |
| Legal concerns               | 10 | 14             |
| Public policy                | 9  | 13             |
| Scientific concerns          | 1  | 1.5            |

Sub Themes

| Theme                      | n  | Percentage (%) |
|----------------------------|----|----------------|
| Reopening of economy       | 12 | 17             |
| Data security              | 9  | 13             |
| Transmission control       | 3  | 4.3            |
| Inequities                 | 3  | 4.3            |

Thematic Analysis
We evaluated the articles for six pre-identified themes. Technology emerged as the most dominant theme, appearing in 58.5% (n=41) articles. Ethics (n=22, 31%), travel (n=21, 30%), legal concerns (n=10, 14%), public policy (n=9, 13%), and scientific concerns (n=1, 1.5%) were also among the themes identified.

During our review we identified the following 4 sub themes: 1) reopening of economy, 2) data security, 3) COVID-19 infection prevention, and 4) inequities. Reopening of economy was the most common reason for introducing vaccine certificates (n=12, 17%). A lot of the discourse identified was around reopening of social events, gyms, and restaurants.

Issues around data security (n=9, 13%), COVID-19 infection prevention (n=3, 4.3%), and inequities (n=3, 4.3%) were also noted. More than half of the articles had no sub themes that were identified (n=43, 61%).

**Digital Solutions for COVID-19 Vaccination Certificates**

Table 2 identifies the countries which are considering or have implemented digital vaccine certificates and provides a brief summary of the details. To date, only Denmark and Estonia have implemented vaccine certificates. Estonia is piloting the VaccineGuard app in collaboration with the World Health Organization. USA, UK, Pakistan, India, Russia, Finland, Indonesia, Australia, Italy, and Sweden, Switzerland, Spain, and Italy are all considering vaccine certificates. Pakistan and India are considering the implementation of digital platforms under development, Vaccify and DigiLocker, respectively. Whereas Australia and Finland are considering the use of the existing health platforms, Express Plus Medicare app and My Kanta, respectively. Indonesia has identified several processes which must be put in place in order for the certificate to be considered halal which will allow it to be acceptable by their larger population. Canada has recently started to consider vaccine certificates for international travel. On March 17, 2021, the European Commission introduced a vaccine certificate to ensure free and safe travel within the European Union (EU) countries. The Digital Green Certificate, will be valid for all EU countries and available in both digital and paper formats. It is not known so far which EU countries will adopt the Green Certificate but to date France, Germany, and Luxembourg are rejecting the idea for the fear of inequities it will create. Israel's Green pass released on 21st Feb 2021 is also available in both digital and paper format. It displays proof that someone has recovered from COVID-19 or has a recent negative test.

**Table 2:** Approach of countries towards a vaccine certificate for COVID-19
| Country   | Government issuing immunization passport? | Approach |
|-----------|----------------------------------------|----------|
| Estonia10,11 | Implemented, In pilot stage | VaccineGuard developed in collaboration with the World Health Organization and Guardtime (See Table 3) |
| Denmark9 | Implemented | It has launched its own Corona passport. The passport grants the privilege to vaccinated citizens to travel beyond country borders. Vaccinated citizens are able to download the certificate from a government website. The government will soon be issuing digital certificates for business travellers. |
| USA12 | Considering it | Details are not yet released |
| UK13 | Considering it | The proposals are being discussed at the Cabinet's COVID operational committee. There is no final decision yet |
| Pakistan25,26 | Considering it, Work in progress | Vaccify by Trust Net Pakistan (See Table 3) |
| India23,24 | Considering it, Work in progress | DigiLocker - A government platform for issuing and verifying documents and vaccine certificate digitally (See Table 3) |
| Russia16,17 | Considering it, Work in progress | Covid passports would possibly be in a digital form |
| Finland19 | Considering it | The vaccine certificate would be available on "My Kanta" which is a nation-wide service platform for accessing health records |
| Indonesia18 | Considering it | There are several processes that must be passed for Indonesia's national agency BRJPH to issue a halal certificate: application, examination, determination, testing, checking, fatwa, and finally the issuance of the certificate |
| Australia22 | Considering it | It will allow people to access digital proof of vaccination via the Express Plus Medicare app and MyGov accounts. Approval is expected by March A paper form will also be available through Services Australia or through the vaccine provider |
| Italy21 | Considering it | Details not yet released |
| Sweden9 | Considering it | Details are not yet released |
| Canada27,28 | Considering it | Details are not yet released |
| Switzerland20 | Considering it | Details not yet released |
| Spain14 | Considering it | Spain supports the creation of a European Union document favouring vaccine certificate |
| Israel30 | Implemented | Green pass provides both digital and downloadable paper certificates. It shows whether the user is vaccinated and/or has a recent negative test |
| EU Commission29 | Implementing | Officially introducing Digital Green Certificate which will be available in both digital and paper format. Vaccine certificate will show details of inoculation and brand used, negative test certificates, and medical certificates for people who have recovered from COVID-19 in the last 180 days. Intended for travel between all EU countries. |

*Additional search identified the use or consideration of vaccine certificates. At this time, we do not have sufficient data about the EU countries that are in support of the EU commission's decision to implement vaccine certificates.

**Technological architecture**

The use of digital certifications was discussed in 78% of articles identified (n=53). Only one article mentioned the use of paper certificates for those who do not own a smartphone where in that situation, a printout of the Quick Response (QR) code would be given to them.

Our search identified 8 digital vaccine certificates in use or under development (Table 3). All solutions identified are using blockchain technology. The data privacy and security of the digital platforms identified were based on the fundamentals of blockchain, that is all personal identifiable information is kept...
encrypted and cannot be disclosed without the user’s consent\textsuperscript{31}. All solutions allow the verifier of the vaccine certificate to scan the QR code indicating presence or absence of a vaccine certificate and date and details of the vaccination without disclosing other personal identifiable information.

There are many major standard setting efforts underway out of which the following two were mentioned in our articles. 1) Worldwide Web Consortium (W3C) is an open, globally interoperable standard for data security\textsuperscript{32}. The body is also known for such standards as the early versions of HTML\textsuperscript{33}. COVID-19 Credential Initiative with 60 participating organizations globally, of which TrustNet Pakistan is also a part, works on W3C standard and looks for instances where Verifiable Credentials (VCs) can be used to address the public health crisis\textsuperscript{33,34}. CommonPass also uses W3C standards for their application\textsuperscript{35}. 2) HyperLedger is another standard which is an open-source community focused on developing a suite of stable frameworks, tools and libraries for enterprise-grade blockchain deployments with interoperability and tokens as their expertise\textsuperscript{32}. Quantum Materials Corp’s (QMC) blockchain-based QDX HealthID app, is based on the Hyperledger Sawtooth enterprise blockchain and for smart contracts, it’s using the Digital Asset Modeling Language (DAML)\textsuperscript{36}. Apart from it, WISekey has implemented standards such as OpenID Connect and OAUTH2 to enhance the security of their cloud applications\textsuperscript{37}.

\textbf{Table 3:} Digital solutions for COVID-19 vaccine certificates
| Product name | Company name | Objective | Product operation | Product Stage | Technology | Data privacy | Data security |
|--------------|--------------|-----------|------------------|---------------|------------|--------------|--------------|
| Vaccify (part of COVID-19 Credentials Initiative (CCI)) | TrustNet Pakistan | (1) To support safe domestic or international travel during COVID-19 pandemic. (2) To support return to work in-person. (3) To aid hospitals evaluate which staff/visitors are allowed into certain locations of the hospitals. | Users will be issued a vaccination certificate by the hospital/healthcare organization that administered the vaccine. The VC shows up as a QR code on the users' Vaccify app that can be scanned by officials (e.g., employers, border agents). | Demo | Decentralized block chain - (1) Uses the "Hyperledger INDY", "Hyperledger ARIES", and "VON" (Verifiable Organizations Network) blockchain. (2) Verifiable Digital Credential Technology (VDCT) preserves privacy; many international organizations including the United Nations approve VDCT use | No personal information is exchanged with officials. QR code identifies whether the user has a vaccination certificate or a positive/negative PCR/antibody test. | (1) App is accessible through biometrics or a passcode. Aligns with digital identity trust framework based on world wide web consortium (W3C) standards. Certificate can be issued (or revoked) rapidly, thus, potential for fraud is mitigated. |
| CommonPass | The Commons Project | To support safe domestic or international travel. | The Apple Health app (iOS) or CommonHealth app (Android), will assess whether the user's lab test results or vaccination records (a) come from a trusted source, and (b) satisfy the health screening requirements of the country they want to enter. | In trials by United Airlines and Cathy Pacific Airways | Block chain - details are not mentioned | CommonPass provides a yes/no answer to whether the user meets the current entry criteria (e.g., vaccination certificate, immunity status, or COVID-19 test result). QR code is generated that can be scanned by officials (e.g., airline staff). Underlying health information remains in the individual's control. | Uses open, globally interoperable standards (e.g., HL7 FHIR, W3C verifiable credentials). |
| QDX HealthID Immunization Passports | Quantum Materials Corp | Supporting return to work, social settings and society during COVID-19 pandemic. | App-based interface that provides a green, yellow or red indicator, as well as a scannable QR code. Green indicates the user is virus free and safe to return to work/socialize to some degree. Hosted on the Microsoft Azure cloud and can integrate with existing EMR system. | Beta testing | Block chain - Based on the Hyperledger Sawtooth enterprise blockchain | Verifiers of user's vaccine certificate scan the QR code. Personal information stays with the user except evidence of VC. | Implements distributed ledger applications via Digital Asset Modeling Language (DAML) which decreases fraud risk. |
| Covi-Pass | Tento Health | Supporting return to work, social settings, and society during COVID-19. | Considered in 15 countries including France, Canada and India. Currently, it only supports COVID-19 test results but there is a plan to expand the app to include vaccine certificates. | Available for download on the iOS and Android stores | Block chain - details are not mentioned | Verifiers of VC will scan the QR code which indicates presence/absence of VC. Personal information stays with the user. App is password-protected. | Not available |
| Platform                      | Owner/Developer | Features/Use Case                                                                 | Technology/Security Details                                                                 | Availability  |
|-------------------------------|-----------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------|
| DigiLocker                    | Government of India | Supporting return to work, social settings, and society during the COVID-19 pandemic. | A government platform for issuing and verifying documents and VC digitally. For dual-dosage vaccines, people are issued a provisional certificate. The full certificate will be issued after both doses, with dates of administration and vaccine information. Certificates are stored in DigiLocker. Available for download on the iOS and Android stores. | Not available |
| Digital Health Pass           | IBM             | Supporting return to work, social settings, and society during COVID-19 pandemic. | Currently supports COVID-19 test results but plans to add vaccination status and health records. | Demo         |
| WISeID                        | WIShelter SafePass | WISeKey International Holding | Vaccination certificate on WIShelter SafePass which ensures users’ privacy, security and safety while providing access to diagnostics, vaccine education and necessary medical services and data. | Block chain - details not available | To ensure data privacy, each user’s Personal Identifiable Information is kept encrypted and only disclosed with users consent. |
| VaccineGuard                  | Guardtime, OpenHealth, Sipca, WHO | To capture and protect proof of critical data accuracy, facilitate privacy-preserving global certificate verification and provide real-time insights on vaccination deployments for public health authorities. | It will provide proof of critical data accuracy, deliver automated aggregated reports from vaccination sites, automated monitoring of stock and vaccinations, and provide the ability to facilitate adverse effect reporting, supporting investigations around this more quickly. | Embedded decentralized privacy. |

| IBM Blockchain technology | Health Pass would be stored in digital wallet of the user. User has control over what health data they wish to share. | Not available |
Economic Forum, and IATA have also voiced the need for a single set of standards that can allow multiple platforms to interoperate data but when combined with personal data and globally unique identifiers like DIDs, it could be used for other activities. The leaders of IBM, the World Wide Web (an extension of the internet based on standards set by the W3C), with the goal of making data readable by machines Decentralized Identifiers (DIDs) and Verifiable Credentials (VCs) from the World Wide Web Consortium (W3C). The standards can be based on the Semantic technical foundations of vaccine certificate solutions

Although there is much ongoing debate about the medical and ethical issues surrounding vaccine certificates, there has been less inspection of the services and data already been working towards vaccine tracking used for other healthcare initiatives such as contact tracing among others essentially secure and cannot be tampered or changed technology is a distributed ledger technology (DLT) which stores copies of a document on nodes across the entire network. Blockchain is considered challenges it brings. This is a rapidly evolving area, and our study describes the initial exploration of this concept. The results of our scoping review point towards the different solutions that are being developed for vaccine certificates globally and the discourse about the discussion

As one of the largest mass immunization campaigns in history is underway, tracking of those who have been vaccinated could become essential as individuals return to work and international travel resumes. This review identified 8 early vaccine certificate technologies that were under development. At the time of this review 3 countries and the European Commission have adopted the use of vaccine certificates while at least 13 others are in the process of planning and implementation.

The results of our scoping review point towards the different solutions that are being developed for vaccine certificates globally and the discourse about the challenges it brings. This is a rapidly evolving area, and our study describes the initial exploration of this concept.

All vaccine certificates identified are using blockchain technology which provides a secure system where data control lies with the end-user. Blockchain technology is a distributed ledger technology (DLT) which stores copies of a document on nodes across the entire network. Blockchain is considered essentially secure and cannot be tampered or changed. In addition to their use in vaccine certificates, blockchain technology has also recently been used for other healthcare initiatives such as contact tracing among others Companies such as IBM, WiSekey, and Quantum Material Corp have already been working towards vaccine tracking, COVID-19 test results, and providing access to diagnostics, vaccine education and necessary medical services and data prior to introducing vaccine certificates. Currently, their solutions for vaccine certificates have reached the demo and beta testing trials.

Although there is much ongoing debate about the medical and ethical issues surrounding vaccine certificates, there has been less inspection of the technical foundations of vaccine certificate solutions. The majority of the digital solutions we identified have involved a stack of standards, such as Decentralized Identifiers (DIDs) and Verifiable Credentials (VCs) from the World Wide Web Consortium (W3C). The standards can be based on the Semantic Web (an extension of the internet based on standards set by the W3C), with the goal of making data readable by machines. This is useful for open public data but when combined with personal data and globally unique identifiers like DIDs, it could be used for other activities. The leaders of IBM, the World Economic Forum, and IATA have also voiced the need for a single set of standards that can allow multiple platforms to interoperate.
Counterfeit yellow fever vaccination certificates have previously been described as a concern. Fraud and counterfeit vaccine certificates also pose another challenge and undermine the biosecurity of a COVID-19 vaccine certificate. The model based on data integration can be exploited by signature exclusion and replacement attacks. A person can remove the signature of a signed message or a digital document and replace it with another signature, tricking the verifier into believing an invalid message as valid. In this case, it can cause vaccine certificates to be completely fabricated as well.

This study has several limitations. We chose to use a Google search for this review as the platforms we were evaluating were in the early development phase and not necessarily searchable in a traditional review platform. Although this allowed us to identify companies and platforms in production, we recognize that this is a rapidly evolving area and several new solutions will be emerging. Since many of the applications identified were in the beta testing or demo phase, further development will likely still occur. Finally, this review was limited to English language content. Since we are reviewing digital solutions around the world, it is likely that other relevant solutions were missed. As the conversations around vaccine certificate evolved, we conducted additional searching to identify countries approach towards vaccine certificates.

Conclusion

In summary, we have identified a number of early digital platforms under development for COVID-19 vaccine certificates around the world. A number of countries are moving forward with vaccine certificates in certain settings. The solutions we identified are based upon blockchain technology, which is considered the gold standard for securely storing personal information. It is important to take into consider limitations to blockchain-related healthcare implementations. Moreover, it is important when considering the implementation of vaccine certificates that it is taken up in an ethical manner that does not discriminate against those who do not have access to the technology. Therefore, it is integral to the success of these blockchain-based solutions for policymakers and government safety and privacy regulators to consider laws that detail appropriate risk management to put in place while still allowing the tool to work as intended.

Declarations

Funding: This research was supported by a Canadian Institutes of Health Research Operating grant, COVID-19 Rapid Research Funding Opportunity (VR5-173210)

Conflict of Interest: Kumanan Wilson is the Chief Executive Officer of CANImmunize Inc.

Acknowledgement: We would like to acknowledge our librarian, Risa Shorr at The Ottawa Hospital for conducting the academic search.

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Figure 1
Flow Chart

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- SupplementaryTable1.docx
- PRISMAcRFillableChecklist15MArch2021VC1.docx