

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

Salima S. Mithani

Ottawa Hospital Research Institute <https://orcid.org/0000-0002-9870-1504>

A. Brianne Bota

Ottawa Hospital Research Institute

David T. Zhu

Ottawa Hospital Research Institute

Kumanan Wilson (✉ kwilson@ohri.ca)

Ottawa Hospital Research Institute <https://orcid.org/0000-0002-1741-7705>

Research Article

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

Posted Date: March 18th, 2021

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

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Version of Record: A version of this preprint was published at Human Vaccines & Immunotherapeutics on October 6th, 2021. See the published version at <https://doi.org/10.1080/21645515.2021.1969849>.

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 consequences¹⁻³. 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 Regulations⁴ 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 plane⁵, and travelers returning to Canada are required to isolate at their own expense while they await their COVID-19 test results⁶. Beyond facilitating international travel, digital proof of vaccination is being considered as a mechanism to facilitate return to work and reopening of the economy⁷.

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 review⁸. 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	<i>n</i>	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		
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		
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 certificates⁹⁻¹¹. Estonia is piloting the VaccineGuard app in collaboration with the World Health Organization¹⁰. USA, UK, Pakistan, India, Russia, Finland, Indonesia, Australia, Italy, and Sweden, Switzerland, Spain, and Italy are all considering vaccine certificates^{9,12-22}. Pakistan and India are considering the implementation of digital platforms under development, Vaccify and DigiLocker, respectively²³⁻²⁶ (See Table 3 for more details). Whereas Australia and Finland are considering the use of the existing health platforms, Express Plus Medicare app and My Kanta, respectively^{19,22}. 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 population¹⁸. Canada has recently started to consider vaccine certificates for international travel^{27,28}. Following the date of our search, additional solutions have been announced. 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^{14,29}. 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 test³⁰.

Table 2: Approach of countries towards a vaccine certificate for COVID-19

Country	Government issuing immunization passport?	Approach
Estonia ^{10,11}	Implemented. In pilot stage	VaccineGuard developed in collaboration with the World Health Organization and Guardtime (See Table 3)
Denmark ⁹	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.
USA ¹²	Considering it	Details are not yet released
UK ¹³	Considering it	The proposals are being discussed at the Cabinet's COVID operational committee. There is no final decision yet
Pakistan ^{25,26}	Considering it. Work in progress	Vaccify by Trust Net Pakistan (See Table 3)
India ^{23,24}	Considering it. Work in progress	DigiLocker - A government platform for issuing and verifying documents and vaccine certificate digitally (See Table 3)
Russia ^{16,17}	Considering it. Work in progress	Covid passports would possibly be in a digital form
Finland ¹⁹	Considering it	The vaccine certificate would be available on "My Kanta" which is a nation-wide service platform for accessing health records
Indonesia ¹⁸	Considering it	There are several processes that must be passed for Indonesia's national agency BPJPH to issue a halal certificate: application, examination, determination, testing, checking, fatwa, and finally the issuance of the certificate
Australia ²²	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
Italy ²¹	Considering it	Details not yet released
Sweden ⁹	Considering it	Details are not yet released
Canada ^{*27,28}	Considering it	Details are not yet released
Switzerland ²⁰	Considering it	Details not yet released
Spain ^{*14}	Considering it	Spain supports the creation of a European Union document favouring vaccine certificate
Israel ^{*30}	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 Commission ^{*29}	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 consent³¹. 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 security³². The body is also known for such standards as the early versions of HTML³³. 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^{33,34}. CommonPass also uses W3C standards for their application³⁵. 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 expertise³². 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)³⁶. Apart from it, WISEkey has implemented standards such as OpenID Connect and OAUTH2 to enhance the security of their cloud applications³⁷.

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)) ^{25,26}	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 ³⁸⁻⁴⁰	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 ⁴¹	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 ⁴²	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

DigiLocker ^{23,24}	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	Block chain - details are not mentioned	Verifiers of the vaccine certificate scan the QR code indicating presence or absence of VC and date and details of the vaccination. Personal information remains with the user.	Not available
Digital Health Pass ⁴³	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	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
WIShelter SafePass ^{31,37}	WISeKey International Holding	Supporting return to work, social settings, and society during COVID-19 pandemic.	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.	Not available	Block chain - details not provided	To ensure data privacy, each user's Personal Identifiable Information is kept encrypted and only disclosed with users consent.	WISelD supports online KYC onboarding, OTP and digital certificate login, and an innovative "hands-free" secure login based on QR-Codes which users can read using WIShelter SafePass mobile app. WISelD implements standards such as OpenID Connect and OAUTH2, which enhances the security of their cloud applications.
VaccineGuard ^{10,11}	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.	In pilot stage with Estonia, Iceland, and Hungary	Blockchain - Keyless Signature Infrastructure (KSI)	Embedded decentralized privacy.	No data is registered into the KSI Blockchain itself - only hashes of data, any data movement is between known hosts in a point to point fashion using secure transport.

VC: Vaccination certificate

VDCT: Verifiable Digital Credential Technology

W3C: World wide web consortium

FHIR: Fast Healthcare Interoperability Resources

Purpose and Use Case

Some airlines are requiring a negative COVID-19 test prior to boarding a flight, and in future this may be adapted to a vaccine certificate for passengers and staff⁴⁴. The UK government has sought a proposal for digital health certificates for travel from the company Onfido⁴⁵. Health policy experts⁴⁶ envision vaccine mandates could be instituted and enforced by local governments or employers - similar to the current vaccine requirements for school-age children, military personnel, and hospital workers⁴⁶. CommonPass, a product of the Commons Project is one example which have been trialed out by United Airlines and Cathay Pacific Airways for showing COVID-19 test results and has been presented to over 37 governments. In the near future, it will integrate vaccine certificates³⁸. Germany, Indonesia, Italy, Israel, Colombia, Argentina, and the U.S. have considered implementing health passports like CommonPass³⁹. The company has proposed its use for travel, schools, hotels, and concert venues⁴⁰. Guardtime, a KSI blockchain technology company, in collaboration with the Estonian government and the WHO has piloted a digital vaccination certificate program⁴⁷. The platform is based on KSI blockchain, an EU-EIDAS certified trust service and X-Road, Estonia's data sharing platform, and out of its many objectives, one of them is to test the proof of vaccination, similar to the International Certificate of Vaccination or "yellow card". Covi-pass is another app that is now being considered in 15 countries including France, Canada, and India and is also supporting return to work and society. It is currently available for COVID-19 test results but plans to expand to incorporate vaccine certificates⁴². A secure COVID-19 vaccination certificate will play a critical role as economies reopen and international travel resumes⁴⁷.

Ethical, legal, and policy considerations

More than half of the articles combined (n=41, 58.5%) discussed legal, ethical, and policy concerns regarding COVID-19 vaccine certificate. The major concerns emerging from the ethical and legal perspective was that of inequities. Technology as much benefit as it brings, can also become a barrier for some, adding to existing inequities⁴⁸. Development of vaccine certificates may exclude vulnerable and marginalized populations who do not have access to smart phones⁴⁸. In terms of reopening the economy, including access to in-person social events, updating travel guidelines, or going to restaurants, gyms, and salons, one of the important questions will be to ask how society deals with the admission of non-vaccinated people. Alternatively, vaccine certificates may incentivize individuals to obtain vaccination against the virus, which is a social good⁴⁹.

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^{9,29,50} while at least 13 others are in the process of planning and implementation.^{9,10,19-28,11-18}.

The results of our scoping review point towards the different solutions that are being developed for vaccine certificate 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^{32,51}. In addition to their use in vaccine certificates, blockchain technology has also recently been used for other healthcare initiatives such as contact tracing among others⁵²⁻⁵⁴. Companies such as IBM, WISEkey, and Quantum Material Corp have already been working towards vaccine tracking⁴¹, COVID-19 test results^{43,55}, and providing access to diagnostics, vaccine education and necessary medical services and data³¹ prior to introducing vaccine certificates. Currently, their solutions for vaccine certificates have reached the demo and beta testing trials⁴³.

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^{33,56}. 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 machines³³. 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 interoperate⁵⁷.

Counterfeit yellow fever vaccination certificates have previously been described as a concern⁵⁸. Fraud and counterfeit vaccine certificates also posit another challenge and undermine the biosecurity of a COVID-19 vaccine certificate⁵⁸. 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 well³³.

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 consideration 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.

References

1. Nicola M, Alsaifi Z, Sohrabi C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *Int J Surg* 2020; 78: 185–193.
2. Chu IY-H, Alam P, Larson HJ, et al. Social consequences of mass quarantine during epidemics: a systematic review with implications for the COVID-19 response. *J Travel Med* 2020; 27: 7.
3. Brooks SK, Webster RK, Smith LE, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet* 2020; 395: 912–920.
4. World Health Organization. New yellow fever vaccination requirements for travellers. *International travel and health*, <https://www.who.int/ith/updates/20160727/en/> (2016, accessed 14 March 2021).
5. Kelleher RS. Get Ready For Needing A Negative Covid-19 Test To Fly Within The U.S. *Forbes*, <https://www.forbes.com/sites/suzannerowankelleher/2021/02/09/get-ready-for-needing-a-negative-covid-19-test-to-fly-within-the-us/?sh=297595282eed> (2021, accessed 14 March 2021).
6. Government of Canada. Flying to Canada: COVID-19 testing for travellers - Travel restrictions in Canada – Travel.gc.ca, https://travel.gc.ca/travel-covid/travel-restrictions/flying-canada-checklist/covid-19-testing-travellers-coming-into-canada?utm_campaign=gac-amc-covid-20-21&utm_source=travel-covid_travel-restrictions_flying_&utm_medium=redirect&utm_content=en (2021, accessed 14 March 2021).
7. Olijnyk Z. COVID-19 vaccine passport development must have legal and ethics expert input: medical journal | Canadian Lawyer. *Canadian Lawyer*, <https://www.canadianlawyermag.com/practice-areas/privacy-and-data/covid-19-vaccine-passport-development-must-have-legal-and-ethics-expert-input-medical-journal/353900> (2021, accessed 15 March 2021).
8. Grey Matters: a practical tool for searching health-related grey literature | CADTH.ca, <https://www.cadth.ca/resources/finding-evidence/grey-matters> (2019, accessed 15 March 2021).
9. COVID Vaccine Passport, the new trend being adopted by world nations | Times of India Travel, <https://timesofindia.indiatimes.com/travel/travel-news/covid-vaccine-passport-the-new-trend-being-adopted-by-world-nations/as80770025.cms> (2021, accessed 14 March 2021).
10. guardtime. Estonia, Hungary, and Iceland, together with AstraZeneca Estonia are participating in a pilot of Guardtime's VaccineGuard | Guardtime, <https://guardtime.com/blog/estonia-hungary-and-iceland-together-with-astrazeneca-estonia-are-participating-in-a-pilot-of-guardtime-s-vaccineguard> (2021, accessed 14 March 2021).
11. guardtime. Products, <https://guardtime.com/products> (2021, accessed 14 March 2021).
12. Mzezewa T. Coming Soon: The 'Vaccine Passport' - The New York Times. *The New York Times*, <https://www.nytimes.com/2021/02/04/travel/coronavirus-vaccine-passports.html?> (2021, accessed 14 March 2021).

13. Meyer D. Europe inches closer to COVID-19 vaccine passports | Fortune. *Fortune*, <https://fortune.com/2021/02/26/europe-covid-19-vaccine-passport-israel-greece-eu/> (2021, accessed 14 March 2021).
14. Mouzo J. Coronavirus: Covid passport: The new worlds opening up for the vaccinated | Society | EL PAÍS in English, https://english.elpais.com/spanish_news/2021-03-11/covid-passport-the-new-worlds-opening-up-for-the-vaccinated.html (2021, accessed 17 March 2021).
15. Hymas C. Vaccine certificates being developed to unlock international travel. *The Telegraph*, <https://www.telegraph.co.uk/politics/2021/02/12/government-develop-covid-vaccine-certificates-travel-abroad/> (2021, accessed 14 March 2021).
16. Kramer EA. Russia Mulls 'Covid-19 Passports' to Let People with Some Immunity Travel More Easily - The New York Times. *The New York Times*, <https://www.nytimes.com/2021/01/19/world/russia-covid-passports.html> (2021, accessed 14 March 2021).
17. Reuters. Russia considers COVID-19 vaccination certificates for cross-border travels | Reuters, <https://www.reuters.com/article/us-health-coronavirus-russia-cases-idUSKBN2991BI> (2021, accessed 14 March 2021).
18. Winosa Y. Indonesia to approve world's first halal-certified COVID-19 vaccine | Salaam Gateway - Global Islamic Economy Gateway, <https://salaamgateway.com/story/indonesia-to-approve-worlds-first-halal-certified-covid-19-vaccine> (2021, accessed 14 March 2021).
19. Finland planning to introduce coronavirus vaccine certificate | Yle Uutiset | yle.fi, https://yle.fi/uutiset/osasto/news/finland_planning_to_introduce_coronavirus_vaccine_certificate/11775698 (2021, accessed 14 March 2021).
20. Planetski. Will We Need a Vaccine Passport to Head to the Mountains Next Winter? - PlanetSKI, <https://planetski.eu/2021/02/25/will-we-need-a-vaccine-passport-to-head-to-the-mountains-next-winter/> (2021, accessed 14 March 2021).
21. Euronews. Growing number of Italians hesitant about taking COVID-19 vaccine | Euronews. *euronews*, <https://www.euronews.com/2020/11/26/growing-number-of-italians-hesitant-about-taking-covid-19-vaccine> (2020, accessed 14 March 2021).
22. Williams E. COVID-19 vaccine passports on the way via Services Australia | The Canberra Times | Canberra, ACT. *The Canberra Times*, <https://www.canberratimes.com.au/story/7117854/what-could-i-need-a-covid-19-passport-for/> (2021, accessed 14 March 2021).
23. Shehnaz. COVID19 Immunization Program: Schools can become Vaccine Booth, QR Code Certificate to be obtained after vaccination; Learn and prepare, <https://www.businesskhabar.com/business/industries/covid19-immunization-program-schools-can-become-vaccine-booth-qr-code-certificate-to-be-obtained-after-vaccination-learn-and-prepare/> (2020, accessed 14 March 2021).
24. Mumbai AP. Covid-19 vaccinated people may get a digital certificate: Report - The Hindu BusinessLine, <https://www.thehindubusinessline.com/news/covid-19-vaccinated-people-may-get-a-digital-certificate-report/article32652957.ece> (2020, accessed 14 March 2021).
25. Ahmed A. This Pakistani Company is Working on a Digital Vaccine Passport for COVID-19, <https://propakistani.pk/2020/06/26/this-pakistani-company-is-working-on-a-digital-vaccine-passport-for-covid-19/> (2020, accessed 14 March 2021).
26. *Vaccify. A Vaccination Passporting Ecosystem. Concept Paper*, <https://vaccify.s3.ap-south-1.amazonaws.com/Vaccify++Concept+Paper.pdf> (2020, accessed 14 March 2021).
27. Blatchford A. World moves to embrace vaccine passports. Trudeau's not so sure - POLITICO. *Politico*, <https://www.politico.com/news/2021/03/09/trudeau-covid-vaccine-passports-474789> (2021, accessed 14 March 2021).
28. MacCharles T. Justin Trudeau floats requiring proof of vaccines for international travellers | The Star. *Toronto Star*, <https://www.thestar.com/politics/federal/2021/03/12/justin-trudeau-muses-about-requiring-proof-of-vaccines-for-international-travellers.html> (2021, accessed 14 March 2021).
29. Euronews. European Commission outlines plans for Green Pass for freedom of travel within bloc | Euronews, <https://www.euronews.com/2021/03/17/european-commission-presents-plans-for-green-pass-for-freedom-of-travel-within-bloc> (2021, accessed 17 March 2021).
30. Ferguson C, Mitnick J. Israel's "green pass" vaccine passport is an early vision of how we leave lockdown | MIT Technology Review, <https://www.technologyreview.com/2021/03/01/1020154/israels-green-pass-is-an-early-vision-of-how-we-leave-lockdown/> (2021, accessed 17 March 2021).
31. WISEKey International : Digital Health Passport to Include a Trusted Vaccination Digital Certificate | MarketScreener, <https://www.marketscreener.com/quote/stock/WISEKEY-INTERNATIONAL-HOL-26786298/news/WISEKey-International-nbsp-Digital-Health-Passport-to-Include-a-Trusted-Vaccination-Digital-Certif-31729113/> (2020, accessed 14 March 2021).
32. *World Economic Forum. Global Standards Mapping Initiative: An overview of blockchain technical standards. White Paper*, http://www3.weforum.org/docs/WEF_GSMI_Technical_Standards_2020.pdf (October 2020, accessed 14 March 2021).
33. Powers B. Blockchain-Based Immunity Passports Don't End Privacy Issue - CoinDesk, <https://www.coindesk.com/blockchain-immunity-passports-core-privacy-issues> (2020, accessed 14 March 2021).
34. Allison I. COVID-19 'Immunity Passport' Unites 60 Firms on Self-Sovereign ID Project - CoinDesk, <https://www.coindesk.com/covid-19-immunity-passport-unites-60-firms-on-self-sovereign-id-project> (2020, accessed 14 March 2021).
35. CommonPass — The Commons Project, <https://thecommonsproject.org/commonpass> (accessed 27 January 2021).
36. Ledger Insights. US firm combines nanotechnology, blockchain for COVID-19 immunity passports - Ledger Insights - enterprise blockchain, <https://www.ledgerinsights.com/nanotechnology-blockchain-covid-19-immunity-passports/> (2020, accessed 14 March 2021).

37. WISEKey's Digital Health Passport to Include a Trusted Vaccination Digital Certificate Swiss Stock Exchange:WIHN, <https://www.globenewswire.com/news-release/2020/11/09/2123062/0/en/WISEKey-s-Digital-Health-Passport-to-Include-a-Trusted-Vaccination-Digital-Certificate.html> (2020, accessed 14 March 2021).
38. Khatib AN, Carvalho A-M, Primavesi R, et al. Navigating the risks of flying during COVID-19: a review for safe air travel. *J Travel Med*, 27. Epub ahead of print 23 December 2020. DOI: 10.1093/jtm/taaa212.
39. Martens B. Airlines introduce world's first immunity passport exempting travellers from quarantine | National Post, <https://nationalpost.com/travel/covid-19-screening-app-may-be-linchpin-for-travelling-during-the-pandemic> (2020, accessed 14 March 2021).
40. Walt V. COVID travel: Meet CommonPass, the startup trying to restore our faith in safe air travel | Fortune, <https://fortune.com/2020/10/06/commonpass-covid-air-travel-coronavirus-safety-tech-startup/> (2020, accessed 14 March 2021).
41. US Firm Integrates Nanotechnology, Blockchain For Covid-19 Immunity Passports! *BLOCKCHAIN MAGAZINE*, <https://blockchainmagazine.net/us-firm-integrates-nanotechnology-blockchain-for-covid-19-immunity-passports/> (2020, accessed 15 March 2021).
42. TENTO HEALTH, <https://covipass.com/faq/> (2021, accessed 15 March 2021).
43. IBM. Digital Health Pass - Overview | IBM, <https://www.ibm.com/products/digital-health-pass> (2021, accessed 15 March 2021).
44. Challenges posed with "immunity passports" and vaccination certificates for COVID-19 | Healthcare Purchasing News, <https://www.hpsonline.com/infection-prevention/screening-surveillance/article/21137049/challenges-posed-with-immunity-passports-and-vaccination-certificates-for-covid19> (2020, accessed 14 March 2021).
45. Higham A. Coronavirus vaccine: Can you be BANNED from work if you refuse vaccine | Express.co.uk. *Express*, <https://www.express.co.uk/life-style/health/1360782/coronavirus-vaccine-can-you-be-banned-from-work-refuse-covid-vaccine-EVG> (2020, accessed 14 March 2021).
46. Kramer J. COVID-19 vaccines could become mandatory. Here's how it might work. *National Geographic*, <https://www.nationalgeographic.com/science/article/how-coronavirus-covid-vaccine-mandate-would-actually-work-cvd> (2020, accessed 14 March 2021).
47. ERR news. Estonia and World Health Organization digitally sign cooperation agreement | News | ERR, <https://news.err.ee/1143517/estonia-and-world-health-organization-digitally-sign-cooperation-agreement> (2020, accessed 14 March 2021).
48. Chandran R. Back to work? Not without a check-in app, immunity passport | Reuters, <https://www.reuters.com/article/us-health-coronavirus-tech-idUSKBN24701B> (2020, accessed 14 March 2021).
49. Phelan AL. COVID-19 immunity passports and vaccination certificates: scientific, equitable, and legal challenges. *Lancet* 2020; 395: 1595–1598.
50. Iceland Becomes First Schengen Country to Grant COVID-19 Vaccination Certificates - SchengenVisaInfo.com, https://www.schengenvisa.info.com/news/iceland-becomes-first-schengen-country-to-grant-covid-19-vaccination-certificates/?fbclid=IwAR3gEm8dqHm_Cwb75IIYPTYs8jz3cme7dxql0_NJpMryq6B_s3e8IHnW-4 (2021, accessed 14 March 2021).
51. Chng E, Atherton J, Hyland. Blockchain and the Digital Passport | CDOTrends, <https://www.cdotrends.com/story/14852/blockchain-and-digital-passport> (2020, accessed 14 March 2021).
52. Abu-elezz I, Hassan A, Nazeemudeen A, et al. The benefits and threats of blockchain technology in healthcare: A scoping review. *Int J Med Inform* 2020; 142: 104246.
53. Abd-alrazaq AA, Alajlani M, Alhuwail D, et al. Blockchain technologies to mitigate COVID-19 challenges: A scoping review. *Comput Methods Programs Biomed Updat* 2020; 1: 100001.
54. Mackey TK, Kuo TT, Gummadi B, et al. 'Fit-for-purpose?' - Challenges and opportunities for applications of blockchain technology in the future of healthcare. *BMC Med* 2019; 17: 68.
55. D'Amore R. No coronavirus vaccine, no entry? Experts say it's possible in pandemic's next stage - National | Globalnews.ca. *Global News*, <https://globalnews.ca/news/7457999/ticketmaster-covid19-vaccine-canada/> (2020, accessed 15 March 2021).
56. Halpin H. Vision: A Critique of Immunity Passports and W3C Decentralized Identifiers. In: *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Springer Science and Business Media Deutschland GmbH, pp. 148–168.
57. Parker LJ. The Case For One Covid Passport. *Forbes*, <https://www.forbes.com/sites/jenniferleighbarker/2020/12/22/the-case-for-one-covid-passport/?sh=66ed0b3b301d> (2020, accessed 14 March 2021).
58. Liew CH, Flaherty GT. Immunity passports to travel during the COVID-19 pandemic: controversies and public health risks. *J Public Health (Bangkok)*. Epub ahead of print 5 August 2020. DOI: 10.1093/pubmed/fdaa125.

Figures

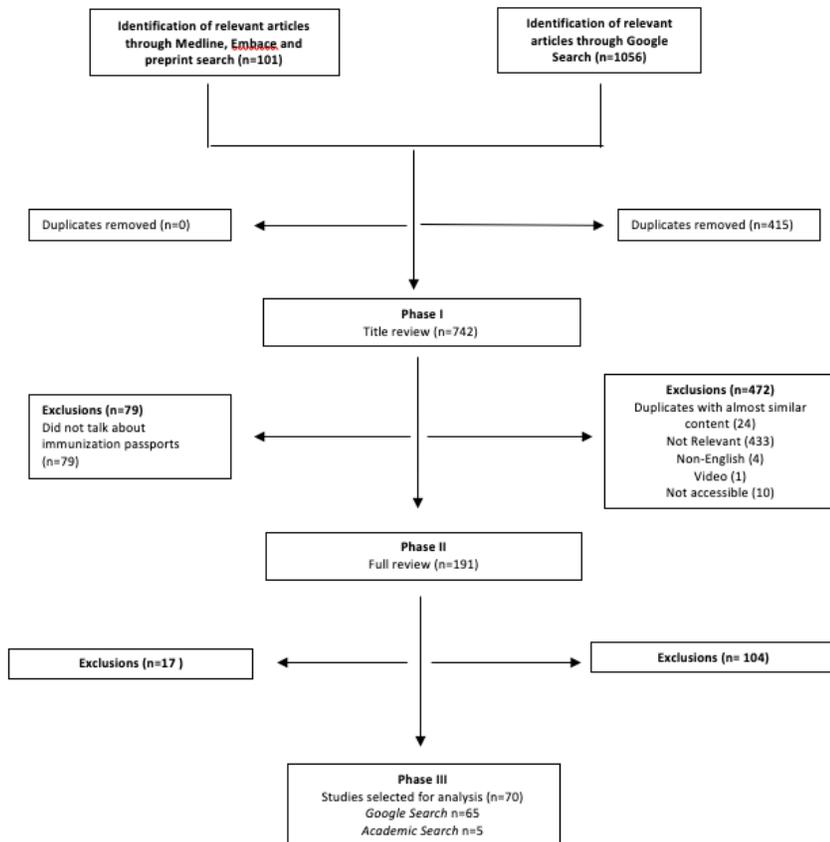


Figure 1

Flow Chart

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryTable1.docx](#)
- [PRISMAScrFillableChecklist15MArch2021VC1.docx](#)