Artificial Intelligence-based Disease Surveillance Amid COVID-19 and Beyond: A Systematic Review Protocol

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Protocol

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Abstract

Background: Infectious diseases are dangerous and deadly. As the leading causes of morbidity and mortality in all demographics across the world, infectious diseases carry substantial social, economic, and healthcare costs. Unlike previous global health crises, health experts now have access to more advanced tools and techniques to understand pandemics like COVID-19 better and faster; one such class of tools is artificial intelligence (AI) enabled disease surveillance systems. AI-based surveillance systems allow health experts to perform rapid mass infection prediction to identify potential disease cases, which is integral to understanding transmission and curbing the spread of the pandemic. However, while the importance of AI-based disease surveillance mechanisms in pandemic control is clear, what is less known is the state-of-the-art application of these mechanisms in countries across the world. Therefore, to bridge this gap, we aim to systematically review the literature to identify (1) how AI-based disease surveillance systems have been applied in counties worldwide amid COVID-19, (2) the characteristics and effects of these applications regarding the control of the spread of COVID-19, and (3) what additional disease surveillance resources such as database, AI-based tools and techniques that can be further added to the current toolbox in the fight against COVID-19.

Methods: To locate research on AI-based disease surveillance amid COVID-19, we will search databases including PubMed, IEEE Explore, ACM Digital Library, and Science Direct to identify all potential records. Titles, abstracts, and full-text articles were screened against eligibility criteria developed *a priori*. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses procedures was adopted as the reporting framework.

Results: NA for now

Conclusions: Findings of our study will fill an important void in the literature, as no research has systematically reviewed available AI-based disease surveillance in the context of COVID-19. As the world continues to reel from COVID-19, it is important to identify cost-effective AI-based disease surveillance mechanisms that can detect COVID-19 cases and explain how one COVID-19 case turns into many cases, so that better prevention measures can be established to curb the spread of the COVID pandemic in a timely manner.

Study Protocol Registration: PROSPERO CRD42020204992

Background

Infectious diseases are extremely dangerous and deadly [1–3]. From the Black Death to the 1918 influenza pandemic, to the recent coronavirus pandemics, infectious diseases have caused the deadliest events in the human history [4–10]. Humans have witnessed the level of indiscriminate destruction infectious diseases can cause, both in terms of lives decimated and livelihoods destroyed, including the ones that are caused by coronaviruses, like the severe acute respiratory syndrome (SARS) pandemic, the Middle East respiratory syndrome (MERS) epidemic, and the COVID-19 pandemic [11–15]. It is estimated that the 1918 influenza pandemic alone is responsible for infecting one third of the world population at the time with the influenza virus, among which, approximately 50 million people died of the infection [9]. What is more harrowing is that, according to one estimate, the COVID-19 pandemic is expected to infect at least 40% of the world's 7.6 billion population before it fades out [16]. As the virus is still evolving, epidemiological models may fall short in generating accurate estimates in terms of how many deaths COVID-19 will claim [17–19].

Partially owing to its unique viral characteristics and epidemiological properties, though COVID-19 has a relatively inconspicuous case fatality rate, its high transmissibility has elevated its global impact [20–24]. Adding potential deaths COVID-19 could cause before it fades out to the casualties previous epidemics and pandemics have already claimed [11–14, 16], it is safe to assume that the degree of impact of infectious diseases might be more daunting than previously estimated [25]. However, not all of the news is grim [26]. In contrast to global health crises in previous decades, recent advances in molecular biology, epidemiological modeling, health informatics, and data analytics, have all greatly enhanced the ability of researchers to understand the underlying mechanisms behind infectious diseases [27–30]. Some of the most promising evidence-based and practical solutions that are particularly useful in the face of COVID-19 are technology-enabled public health solutions [31–36].

In the context of pandemics caused by infectious diseases (as opposed to non-communicable disease (NCD) pandemics, such as the obesity pandemic), where physical contact or close proximity can result in transmission, technology-based solutions using contactless or remote sensing are ideal tools to adopt in the fight against pandemics [37–40]. Adding the fact that global health crises can often cause economic fallout and resources constraints, the cost-effective nature of technological solutions increases their potential as candidate solutions for solving various healthcare issues [37, 41–43]. Lastly, and perhaps most importantly, the potential for some technological-based solutions, such as artificial intelligence (AI) powered disease surveillance systems, in identifying infection cases with high accuracy, may be the most desirable quality governments need to effectively control the spread of diseases [44–50].

AI can be understood as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception ... and decision- making" [51]. Overall, surveillance is often used interchangeably with the term biosurveillance, which could be understood as "the science and practice of managing human, animal, plant, food, and environmental health-related data and information for early warning of threats and hazards, early detection of events, and rapid characterization of the event so that effective actions can be taken to mitigate adverse health, social, and economic effects" [52]. In the context of this study, simply put, surveillance is defined as the use of technology to rapidly and continuously monitor and screen populations, with the aim of predicting and tracking infectious diseases in a real time and nonintrusive fashion.

One key facilitating factor that further popularized AI-based disease surveillance is the availability of large datasets, mainly coming from (1) data actively generated by netizens (e.g., social media user generated data, news reports, etc.), (2) data collected about the individuals' passive human-computer interaction (e.g., background data collected by apps and electronic devices), and (3) data collated independent of individuals' human-computer interactions (e.g., video surveillance footage) [48, 53–55]. BlueDot, the data analytics company that first identified and reported an unusual cluster of pneumonia cases (i.e., the COVID-19 outbreak) eight days before the World Health Organization issued a global warning about a potential global crisis in the making [56], adopted data actively generated by netizens (e.g., social media posts, newsfeeds) and data collated independent of individuals' human-computer interactions (e.g., information obtained from airline ticketing systems) to feed into their AI systems to generate insights [57].

Another more sophisticated way to use data collated independent of individuals' human-computer interactions is to combine all relevant information to detect infectious diseases in real time [49]. In previous work, AI-systems that synthesize multiple measures such as respiration rate, heart rate, and facial temperature, have been successfully applied to influenza surveillance with high detection accuracy [49]. In other words, AI-based disease surveillance can accomplish, essentially, the ability to swiftly identify individuals who have been infected with or exposed to infectious agents, a challenge that remains to be one of the deadliest problems that health experts face in the fight against COVID-19 [44–48]. Lacking the ability to discern potential COVID-19 infected individuals from the rest of the population is also a key reason why governments chose to lockdown entire populations in early days of COVID-19 outbreak [58–60], with significant economic cost. AI-based disease surveillance techniques have the potential to preserve the economy or slow down the rates of economic fallout, partially owing to their ability to negate the necessity to require a large population to stay at home and limit their contributions to the economy [45].

Even though the city of Shenzhen, a well-developed city in China, has deep economic connections with the city of Wuhan, a relationship that is manifested in the convoluted transportation ties between these two cities, Shenzhen survived the onslaught of COVID-19 without issuing a citywide lockdown, owning largely to its network of surveillance systems, which include multiple AI-based surveillance mechanisms that were made available as early as January, 2020 [45]. However, while the importance of AI-based disease surveillance systems in pandemic control is clear [61–63], what is less known are the applications, characteristics, and effects of these systems in countries across the world. Therefore, to bridge this gap, we aim to systematically review the literature to identify (1) how AI-based disease surveillance systems have been applied in counties worldwide amid COVID-19, (2) the characteristics and effects of these applications regarding the control of the spread of COVID-19, and (3) what additional disease surveillance resources, such as database, AI-based tools and techniques that can be further added to the current toolbox in the fight against COVID-19.

In addition to focusing on what is currently being used for COVID-19, we also aim to investigate potential AI-based surveillance tools and techniques that could provide insights into what could be done more effectively with current COVID-19 monitoring and surveillance. Infectious diseases are universal and ubiquitous [1–3], both in terms of space and time [4–10]. It is also important to note that infectious diseases are highly underestimated: though they have maintained to be an oversized problem faced by humanity throughout history, the level of preparedness currently in place by governments across the world for an equivalent of 1918 influenza pandemic or a Disease X is miserably minuscule at best [64]. As early as 2018, the World Health Organization has already issued a warning that a Disease X is looming on the horizon [65], an infectious disease that has the potential to replicate the 1918 influenza pandemic or the Black Death in the 21st century [66]. Disease X could be understood as a highly infectious disease powered by a pathogen that is unknown or unfamiliar to the human race [65]. In addition to high transmissibility and unpredictability [66, 67], based on existing evidence, it is highly possible that the power of destruction of Disease X will be compounded by systematic issues such as government incompetence and lack of preparedness in public health sectors.

A systematic review of AI-based disease surveillance systems in use as well as those that elevate society's current response towards COVID-19 have the potential to help people better cope with COVID-19 and prepare for Disease X [61]. In other words, the best timing for government officials and health experts to prepare for Disease X is now—most epidemiologists in the world would agree that the perfect opportunity to study infectious diseases and develop effective responses towards them is when they are ongoing [68]. It is almost impossible for any laboratory, even the top ones in the world, to create an infectious disease experiment condition like COVID-19—a natural experiment condition which also happens to be an unprecedented global health crisis [69]. Therefore, with a disaster preparedness mindset, we set out to not only identify the characteristics and effects of existing AI-based disease surveillance systems, we aim also to explore and excavate AI-based disease surveillance tools and techniques that have the potential to be applied in the current COVID-19 context as well as approaching reality of Disease X.

Methods

Aiming to avoid unnecessary study duplication [70, 71], increase study rigor [72, 73], improve study comparability and replicability [74], and ultimately, promote quality and transparency in research [75], the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedures will be adhered to in the reporting process [76]. This systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO) system (CRD42020204992).

Inclusion and exclusion criteria

Based on research aim and insights from preliminary search results, inclusion and exclusion criteria were developed *a priori*. Detailed information on inclusion criteria is listed in Table 1. In the context of this study, artificial intelligence is considered as an umbrella concept that encompasses techniques like machine learning and deep learning. As, in theory, all of these mechanisms can be used for mass screening and identification of diseases, we include all of them in the operational definition of AI-based disease surveillance systems. Articles will be excluded if (1) they did not report the use of AI-based surveillance systems, (2) they did not report the use of AI-based surveillance systems in the context of

COVID-19, (3) they did not report detailed characteristics of AI-based COVID-19 surveillance systems, and (4) they did not report the effects of these systems on the control and containment of the spread of COVID-19.

Table 1
Study inclusion criteria

Data type	Inclusion criteria
Participants	People who are 18 years younger of older
Language	English
Study type	Peer-reviewed full-text article
Study design	Focus on AI-based disease surveillance in the context of COVID-19
Technology	Report detailed description of the AI-based disease surveillance discussed in the study
Outcome	Report results or effects of the AI-based disease surveillance mechanism on personal or population health in the context of COVID-19

Search strategy

To locate research on AI-based disease surveillance amid COVID-19, we will administer our search in databases including PubMed, IEEE Explore, ACM Digital Library, and Science Direct to identify all potential records. Search strategies were developed based on a preliminary review of the literature [50, 62, 63, 77, 78]. Overall, our search terms were developed based on three concepts: AI, disease, and surveillance. Detailed search strings will be used for PubMed are illustrated in Table 2.

Table 2
Example PubMed search strings

Concept	Search string
Artificial intelligence	“Artificial intelligence” OR “Machine intelligence” OR “artificial neutral network*” OR “Machine learning” OR “Deep learn*” OR “Natural language process*” OR “Robotic*” OR “thinking computer system” OR “fuzzy expert system*” OR “evolutionary computation” OR “hybrid intelligent system*”
Disease	COVID-19 OR “COVID 19” OR “novel coronavirus” OR disease* OR illness OR health-related OR medic* OR “medical diagnosis” OR treatment OR health* OR wellness OR well-being
Surveillance	“digital disease surveillance” OR “population surveillance” OR “population monitor*” OR “public health surveillance” OR “public health monitor*” OR “risk factor* surveillance” OR “behavior* surveillance” OR “automated surveillance” OR “disease surveillance” OR “population screening” OR “public health reporting” OR biosurveillance OR “syndromic surveillance” OR “sentinel surveillance” OR “epidemiological monitoring”

Study selection

All search records will be updated to Rayyan [79], with the replicate items automatically removed by the system. Titles, abstracts, and full-text articles were screened against eligibility criteria developed *a priori*: (1) after screening titles and abstracts, two main reviewers will reconvene to discuss potential discrepancies, which will be resolved via group discussion till a consensus is reached; (2) full-text articles of the remaining records will be downloaded and screened against the eligibility criteria, following the same discrepancy resolution. All group discussions will be administered via email or videoconferencing.

Study quality assessment

When applicable, the Cochrane Collaboration evaluation framework will be adopted to examine potential risk of bias of the included study [80]. Overall, seven domains of the included articles will be examined: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and any other source of bias. Only scores of the first five items will be utilized in assessing the quality of included study: if a study is rated as “low” on three or more of these five items, then this study will be deemed as having a low level of risk [80, 81]. The risk of bias will be evaluated independently by two reviewers. Any discrepancy regarding the risk of bias will be resolved by email- or videoconferencing-based group discussions till a consensus is reached. All team members will be involved in the group discussions.

Data extraction and synthesis

Data on study attributes (e.g., country of origin), participant characteristics (e.g., sample size), type of AI technique adopted (e.g., AI, machine learning, or deep learning), type of disease studies (e.g., COVID-19, flu, or chronic conditions), and outcomes (e.g., effects of the AI-based disease surveillance system on the spread of COVID-19). Data will be extracted by two reviewers. To shed light on the extracted data, both descriptive analysis (e.g., percentage of mechanisms studied in low-income country vs. high-income countries) and narrative synthesis (e.g., the database adopted to enable the AI technique) will be used to identify useful insights from the data. Descriptive analysis will be used to identify patterns, as it can give the audience a clear and connected picture of the state of art development of existing AI-based disease surveillance techniques. While narrative synthesis can help researchers to identify key information needed to better understand the characteristics as well as effects of the disease surveillance approach studied. Due to the perceived heterogeneity within the tentative eligible articles, meta-analyses are not considered for the current study at the moment.

Results

NA for now—This is a protocol study

Discussion

Infectious diseases have been wreaking havoc on humanity throughout history [1–6]. Ranging from the Black Death, the 1918 influenza pandemic, the SARS pandemic, the Ebola outbreak, to the current COVID-19 pandemic, infectious diseases have traumatized generation after generation of humans, leaving numerous lives lost and countless livelihoods irreparably damaged [4–15]. Situations might become worse as COVID-19 evolves and spreads across the world. One estimate indicates that at least 40% of the world’s 7.6 billion people will be infected with COVID-19 [16]. However, not all hope is lost. One of the most promising tools that can help health experts better curb and control the spread of COVID-19 is AI-based disease surveillance systems [44–48].

AI-based disease surveillance systems have the advantages over traditional monitoring of allowing rapid mass monitoring of populations and potential COVID-19 infections in a timely and cost-effective manner, advantages that can save lives and effectively negate the necessity of social distancing measures like lockdowns. However, while the importance of AI-based disease surveillance mechanisms in pandemic control is clear, what is less known is the state-of-the-art application of these mechanisms in countries across the world. Therefore, to bridge this gap, we aim to systematically review the literature to identify

(1) how AI-based disease surveillance systems have been applied in counties worldwide amid COVID-19 and (2) the characteristics and effects of these applications regarding the control of the spread of COVID-19.

Findings of our study will fill an important void in the literature, considering that no research has systematically reviewed available AI-based disease surveillance in the context of COVID-19. As the world keeps reeling from COVID-19, it is important to identify cost-effective AI-based disease surveillance mechanisms that can detect COVID-19 cases and explain how one COVID-19 case turns into many cases in a timely manner, so that better prevention measures can be established to curb the spread of the COVID pandemic in a timely manner. In addition to lives and livelihoods saved, with a comprehensive understanding of options and opportunities available in the context of AI-based COVID-19 surveillance systems, data scientists and health experts will obtain insights needed to develop AI-based surveillance systems that can better help the society understand AI-based surveillance systems to tackle infectious diseases above and beyond COVID-19.

Conclusions

NA for now—This is a protocol study

List Of Acronyms

AI: artificial intelligence

COVID-19: coronavirus disease 2019

SARS: severe acute respiratory syndrome

MERS: Middle East respiratory syndrome

NCD: Non-communicable diseases

Declarations

- # Ethics approval and consent to participate

Not applicable.

- # Consent for publication

Not applicable.

- # Availability of data and materials

No

- ## Competing interests

None

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None

- ## Authors' contributions

ZS developed the research idea and drafted the manuscript, BB and FS reviewed and revised the manuscript.

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Supplementary Files

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