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Review Article

Preventing Pandemics and Containing Disease: A Proposed Symptoms-Based Syndromic Surveillance System

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Abstract

Background: Due to globalization, spread of a pandemic is inevitable as we have seen with COVID-19. Further, increased ease of travel increases the potential and frequency of pandemics. Hence, it is imperative to find solutions to stop the spread of future pandemics at onset. The proposed solution is a self-reported, symptoms-based syndromic surveillance system that is universal, interactive, integrative, and combined with artificial intelligence. Once developed, this framework has the potential to stop any future epidemics and pandemic in urban and rural areas worldwide.

Methods: We conducted a thorough literature review of existing short message service (SMS, text messaging) and interactive voice response (IVR, calling) surveillance systems, identified and addressed the shortcomings. We considered artificial intelligence applicability in this paradigm and cost-versus-benefit analysis in a myriad of economies.

Results: Utilizing social psychology studies regarding user compliance, high-quality systematic analyses of SMS/IVR-based reporting tools, artificial intelligence prediction models, and a review of data-sharing laws, we have found that many of the previous syndromic surveillance models suffer from data fragmentation, thus hindering their scalability to a global setting.

Conclusions: This proposal will allow decision-making officials and healthcare professionals to robustly identify local disease outbreaks, thus thwarting unchecked spread while preventing a breakdown in the supply chain. Since communicable pathogens can cause high morbidity and mortality as well as a negative impact on economies, we call upon today's high-tech companies as well as governmental bodies to be the impetus for the change that will decrease the multifaceted burdens on our global society.

Keywords: COVID-19, SARS-CoV-2, Syndromic Surveillance, Pandemic, Epidemic, Prevention

Introduction

Syndromic surveillance refers to the collection of individual and population information regarding clinical features, signs, and symptoms to provide an early means of outbreak detection in the public health landscape [1]. The central objective of the initially developed syndromic surveillance systems was to identify outbreaks, hotspots, and disease clusters early, and to mobilize a rapid response, thereby reducing morbidity and mortality [2].

Using machine learning (ML) algorithms, future syndromic surveillance systems can be trained on datasets that include previous disease outbreaks to be able to detect and predict any such future outbreaks [3]. The monitoring and prediction of disease trends will continue to grow and improve as longitudinal data accumulates and as syndrome definitions are refined. There are many resources, brilliant minds, and accurate systems in place to track increase in existing as well as novel disease incidence [4-8] (Table 1); however, the current 2020 global landscape concerning the spread of coronavirus disease (SARS-CoV-2; COVID-19) has highlighted the weaknesses in our syndromic surveillance efficacy. Hence, it is essential to develop a robust, worldwide surveillance system that would curb any future epidemic or pandemic at the outset. Here, we propose an adaptable and timeless model which, in the future, could be developed on a global scale to accurately identify disease outbreaks in different parts of the world, predict a pandemic and stop its spread in a timely manner.

Table 1: Resources that Provide a Proof-of-Concept.

Resource	Description	Is concept specifically mentioned in our model? Does current literature show promising results?	Considers useful parameter(s) in development of proposed model? If so, how?
Blue Dot [11,52]	Artificial intelligence driven, algorithm-based health monitoring platform that quantifies exposure risk and helps to detect outbreaks early.	Y, Y	Y, predicts based on airline itinerary, mobile device data, climate conditions, animal and insect populations. Successfully predicted and validated the COVID-19, Zika (Florida, 2016), and Ebola (West Africa, 2014) outbreaks.
China Infectious Diseases Automated-alert and Response System (CIDARS) [53]	Utilizes the Internet, computers, and mobile phones to accomplish rapid signal generation and dissemination (SMS), timely reporting, and reviewing of signal response results at the county, prefecture, provincial, and national levels to assist in early outbreak detection at local levels. Prompts reporting of unusual disease occurrences or potential outbreaks to CDCs throughout the country.	Y, -	Y, SMS delivery of unusual disease occurrences and potential outbreaks utilizing available means for early detection and prevention
COVID Worldwide Symptom Tracker [22]	Finland-based developer. Allows individual to report symptoms. Individuals using this program are given a unique identification number allowing them to update their symptoms in the future.	Y, N	Y, allows individuals to update their symptoms in the program based on their de-identified ID number. Mostly used in Finland and neighboring countries, limitations include high falsepositives due to self-reporting without further verification. Project is largely in its infancy.
COVID Symptom Study (Previously COVID Symptom Tracker) [3]	Developed by Zoe Global in collaboration with King's College London and Massachusetts General Hospital. Enables the capture of self-reported information related to COVID-19. Mobile application based, therefore user logs into app to report symptom status (age: 18+ and must provide consent).	Y, -	Y, same as above. Added current applicability in US and UK (2.6 million participants). Accurately predicted that 17.4% tested positive for COVID-19. High false positives,but has means to verify COVID-19 status suspicion. Very interactive and highly user-friendly. Application based, therefore limitations where smartphones do not exist.
Early Warning, Alert, and Response System (EWARS) [55,56]	Mobile phone field-based reporting and management system. Is deployed in remote and challenging field settings where there is no access to reliable internet or electricity. The system is available in a prepackaged box that contains mobile phones, laptops, solar generators and chargers, and a local server. Phones are distributed in rural, remote areas. Data is collected and temporarily saved and stored off-line. Once the data is added to the server it is synced and uploaded for real-time analysis.	Y, Y	Y, allows for on-site investigation of rise in disease incidence. Evaluation by healthcare professionals verifies whether potential patient has communicable disease.

Mobile-Based Surveillance Quest Using IT (MoSQuIT) [57]	Digital, mobile phone-based system in place for Malaria surveillance. This system offers real-time tracking of disease, identification, and management of outbreaks, and is run on a central server. It also allows for data collection from rural and slum areas via health activists. Information reported to this system is made immediately available to public health officials, in database form, for analysis. Decisions can then be made to enforce quarantine in those areas, send out mass-messages to warn others about potential outbreaks, and allocate medical supplies.	Y, Y	Y, streamlines information via digitalization from underserved areas to a centralized platform and enabled faster generation of information critical to disease prevention. Addressed underreporting issues that burdened India with economical latencies as a manifestation of unchecked/unknown disease spread/active cases.
ProMED Mail (PMM) [63]	worldwide, online, email-based system put on by the International Society for Infectious Disease.	Y, Y	Y, reported many outbreaks before the World Health Organization (WHO) did. Addresses privacy concerns by de-identifying reported information for quicker turnover of data acquisition and meaningful usage. Open and free to use for global surveillance. Notably, PMM caught a Cholera outbreak in the Philippines almost three weeks before the WHO, Yellow Fever in Brazil days before the WHO, Cholera in Peru eight weeks before the WHO, and the SARS outbreak even before governments were able to issue reports [30]. PMM has also been the first system to detect and report on numerous major and minor disease outbreaks including SARS, MERS, Ebola, and Zika. PMM is an open and free to use global surveillance system [31].
Sproxil [65]	System that helps identify counterfeit medicine hotspots in Ghana, Nigeria, Kenya, and India. It is supported by regulatory bodies and governments and utilizes a mobile, text-message based reporting system to a central database.	N, Y	Y, parameters may be repurposed in terms of coding to lend wisdom in identification of hacking or malicious utilization of healthcare information.
Well Vis COVID-19 Triaging [23]	This is an internet-based, self-reporting system that assesses an individual's risk and helps that individual decide on the next steps to take (whether that person should go to the doctor, call the disease control hotline, etc.)	Y, N	Y, in our current global landscape and due to reliance on current syndromic surveillance models, triaging algorithm may be useful until shifting is fully implemented into practice.
Zenysis [54]	Emergency response and disease surveillance system that is mobile based. It Utilizes a centralized, integrated virtual control room. Based on individual reporting their system can accurately make predictions of future outbreak areas and medical supply shortages. These predictions can be used to catch problems early on.	Y, Y	Y, utilizes machine learning algorithms to inform decision making officials of evidence based prediction and near-real-time reporting of cases. AI enhancement made false positive prevalence lower than technology that did not use it. Integrated data sets into a single platform (virtual workspace), established a high-quality information flow to the public and partnering organizations, and allowed decision makers (government officials and healthcare professionals) to reduce cholera cases from 400 to 0 in three weeks (Sofala, Africa, 2019)

A conglomeration of resources with concepts that are either well-studied, applicable to our proposal, or both. Legend: Y = Yes, N = No, - =significantly documented limitations that must be considered, and furtherly researched before definitive "yes".

The Problems

Firstly, current national and international surveillance methods only track provider-reported symptoms and disease cases [4,9] where symptom reporting is dependent on a healthcare provider seeing the patient. Further, delay of care is a persistent and undesirable feature of current health care systems where nearly 33% of Americans report an inability to receive timely care for urgent needs [10]. Symptomatic patients hesitate to seek care for weeks and travel rates among asymptomatic patients allow for unchecked disease spread to others [11-15]. A second problem with current disease surveillance methods is access to healthcare. With global healthcare inaccessibility, people in afflicted communities either must wait days to weeks before healthcare professional's assessment or do not receive healthcare altogether and community transmission of disease goes unchecked [16-19]. Especially relevant in developing countries, lack of geographic accessibility hinders the distribution of healthcare-related items (i.e., drugs and vaccines) [16].

Limited access to electricity, supply-chain, internet, and cellular network further contribute to underreporting of true case volume via the current surveillance system structures [3,15]. The third problem with current methods is fragmented communication and integration [4-8]. When datasets are centralized, predictive power, detection, and prevention are greatly increased [3,20]. Overall, current methods do not allow for robust early containment of geographical hotspots, thus allowing future outbreaks and pandemics. With current methods, we can pair retrospective analytical tools with prospective, predictive software to develop an early notification system.

Addressing Healthcare Provider-Dependent Reporting

While several countries have previously implemented small-scale, local, mobile-based health surveillance systems in urban and rural areas (Table 1), the lack of central integration misses early detection of outbreaks at-large. Despite the current need for central integration, there is a place for mobile-based practice in public health. A systematic review in 2015 that looked at many high-quality meta-analyses and systematic research reviews substantially supports the value of integrating text-messaging interventions into public health practice, especially since the interactivity in the SMS format facilitated and correlated positively with use and health outcomes [21]. Open-access symptom tracker tools equip users with unique identification numbers and resources to guide their “next-steps” [3,22,23]. Our proposal seeks to utilize the useful insights from these surveillance systems as it is mentioned in (Table 1).

User Compliance

While SMS-mediated communication allows for great penetrance [24,25] a limitation with user (i.e., patient) compliance must be addressed in governmental initiatives that empower the patient through SMS/IVR. One group showed that intrinsically and extrinsically motivated individuals (self-determination theory) are more likely to participate in governmental initiatives when users deemed it “fun and enjoyable” [26]. Therefore, a quintessential aspect in the development of our AI’s interactivity function would be the cornerstone that it is exceptionally user-friendly.

Furthermore, it has been reported that negative emotions (i.e., fear and anxiety) in response to the current pandemic are protective and account for adaptive public health-compliant behavior change [27]. However, over-sensationalized media coverage and fear of infection during health clinic visits have contributed to maladaptive levels of anxiety, which helps explain why some patients do not seek healthcare services [28,29]. As negative emotions can facilitate user compliance, especially in our proposal’s governmental, public-health initiative paradigm, we strongly recommend that media outlets responsibly report findings from evidence-based institutions.

Increasing Predictivity Power, Integrating Deep Learning, and Saving Money

As SARS-CoV-2 has inspired the advent of open-access symptom tracker tools [3,22], a mainstay limitation is a high rate of false-negatives and -positives in the database (attributed to leading questions and mainstream media influence). Nonetheless, when one group paired disease-specific symptoms (i.e., loss of taste and smell) with otherwise general symptoms (i.e., fatigue, persistent cough, and loss of appetite), they yielded a prediction model that most accurately determined true-positives [3]. Another group showed that ML and cloud computing end-user data can predict disease spread in real-time using the Robust Weibull model (e.g., allows user to weigh parameters to robustly deal with contaminated data), which made statistically better predictions than the baseline Gaussian model (e.g., a model that assumes a parabolic behavior near the origin of coordinates) [30]. These more accurate predictions allow for a better proactive governmental and citizen response to an emergence of disease in a country specific manner.

As notorious overfilling of hospitals occurred in the face of the 2020 COVID-19 pandemic in countries across the world, a better system for triaging was made evident. In the clinical setting, a fully automated Deep Learning (DL) system for COVID-19 diagnosis and prognosis may better triage patients based on computed tomographic images of their lungs, thus optimizing medical resource usage in the clinical setting. Additionally, this DL system is also able to differentiate pneumonias (COVID-19 vs. other viral vs. bacterial), thus substantially decreasing the generation of false-positives [31]. As ML predictive models are developed, DL methods may be employed to amplify important inputs that discriminate and suppress irrelevant variations [32]. On a geographical scale, Blue Dot and Zenysis (Table 1) are AI-based healthcare companies that have utilized aggregated data in thwarting previous epidemics. Their concepts provide prediction models based on meta-data parameters (airline itinerary, disease-carrying vector[s], and cellphone data). Analysis offered by Oxford Insights details the readiness index by which various countries’ governments have the capacity to implement AI technology into their daily practice [33-37]. In a cost-versus-benefit analysis, financially limited countries may benefit the most in a universally accessible syndromic surveillance paradigm [32]. As larger datasets are integrated, ML and DL-associated costs are expected to increase; however, mitigating economic devastations warrant the investment.

Applicability in Global Communities (Urban & Rural)

Smartphone-based applications are powerful, but there is concern that their scalability is limited to affluent areas in developed countries, and the concept cannot be extrapolated to rural areas, impoverished cities, or developing countries [38]. Unavailability of transportation is associated with a lack of regular medical care and less use of healthcare services, therefore leading to adverse health outcomes that may be otherwise prevented [39]. Rural populations are less likely to have online access to health information [40], less access to information from primary care physicians and specialists [41], and lower levels of health literacy [42] compared to urban residents. Rural populations, especially minorities, are more unlikely to be able to see a physician for at least one year due to the related costs [43]. In (Table 2), we show extensive global utilization in both urban and rural demographics that have SMS and IVR technologies currently employed. We summarized these findings to show the current successes in utilizing the SMS/IVR route as a means for data collection and information distribution done in an accurate manner. Taken together, user compliance may be enhanced by an automated, streamlined, and digitalized SMS/IVR syndromic surveillance model, therefore leading to the early detection and prevention of epidemic and pandemic pathogens.

Table 2: Feasibility of Proposed Program Worldwide based on Similarly Employed Technologies.

(Urban/Rural) Country	SMS, IVR, or Both?	Category	Results
Philippines [34]	Both	Crime	- 20% of population with cellphones subscribed - Overall reduction of crime
India [57]	SMS	Health (Malaria)	- Decreased time of data transfer (21 days to instantaneous) - Decreased time of lab results (7 days to 1 day) - Increased medical stock visibility (7 days to instantaneous) - Increased epidemiological report generation (1 month to 1 hour)
Ireland [35]	SMS	Health (COVID-19)	- 82.9% of text messages sent received a response Referred 9% of asymptomatic close contacts for testing (from 14.6% of total asymptomatic close contacts) - 2.6% of total text message recipients tested positive for COVID-19
Sierra Leone [36]	Both	Health (Ebola)	- 85.8% of cell phone alerts were followed-up within 24 hours
Rural Nepal [37]	SMS	Health (Diarrheal & Respiratory Diseases)	- Data collected via SMS modestly correlated with clinical/hospital data - Effectively provided a snapshot at current health state before reaching the hospital
Rural Western Uganda [45]	SMS	Health (General)	- Reporting of symptoms was found to be 75.2% accurate
Rural Madagascar [46]	SMS	Health	- 86.7% of the data was analyzed in "real-time" of 24 hours
Rural Ghana [47]	IVR	(Influenza- Like Diseases) Health (General)	- Caregivers were able to triage children's symptoms effectively based on severity - Reporting of symptoms was found to be 95% accurate for fever and 87% accurate for diarrhea

Examples of countries utilizing SMS and IVR technologies to mitigate a variety of issues (i.e, crime, specific- and general-health issues). Results are summarized from primary literature sources. Countries considered were those of both urban and rural geographical location.

Proposed Solution

Our proposed symptoms-based syndromic surveillance addresses three main objectives:

- Focus on early detection of known and unknown diseases to improve overall health surveillance.
- Prevent potential disease transmission within the community, thereby mitigating outbreaks at-large.
- Consider mass distribution and market penetration through current economic and medical landscape.

The proposed solution (Figure 1) is a self-reported, symptoms-based syndromic surveillance system that is universal, interactive, integrative, and combined with artificial intelligence. The system aims to be integrated, meaning data input and analysis is handled by one central system. It utilizes short message service (SMS; text-messaging) and interactive voice response (IVR; calling; for those unable to text) to identify and contain hot spots during the early stages of an outbreak. Our proposed system interacts with users (educating them on evidence based/recommended "next-steps") and with the virtual workspace (communicating findings in [near]-real-time) using an artificial intelligence (AI)-enhanced communication pipeline.

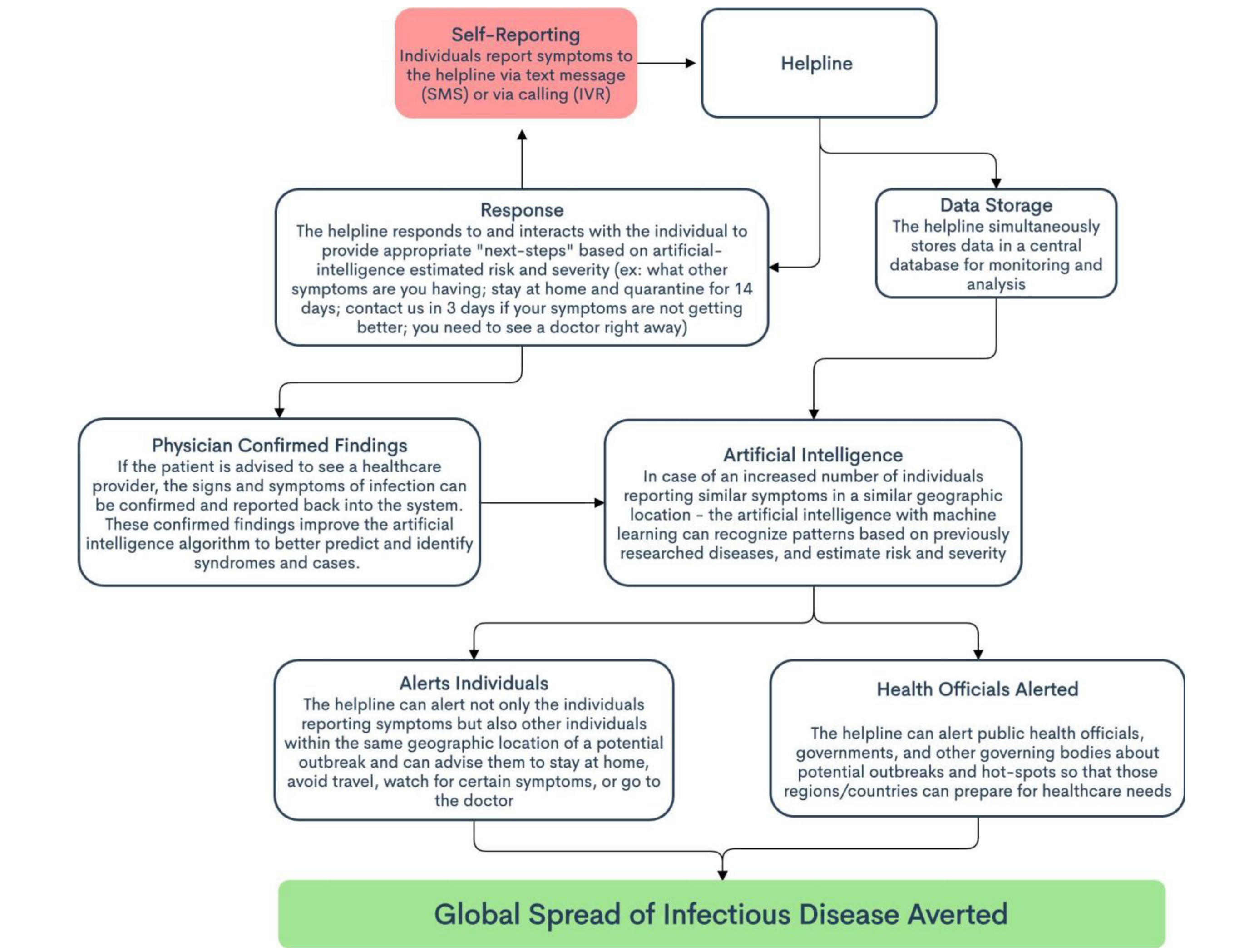

Figure 1.

The key to the success of our solution is funding provided by international health agencies and legislative bodies. The proposal includes collaboration between different regional, national, and global, governing bodies to construct a centralized, mobile-based reporting network. Previous success has been shown with disease-outbreak prevention systems utilizing cellphones at local and regional levels. Two groups have successfully used similar ideas in the United States and United Kingdom. The first was used to predict geographical hotspots of COVID-19 incidence five to seven days before public health reports, and the second to predict COVID-19 cases, based on self-reported symptoms, before patients were seen and diagnosed [3,44]. In the United States, contact tracing is done via SMS, telephone, or in-person follow-ups. When compared to the robust SMS system in Ireland, the United States had a significantly lower yield of 0.5% positive COVID-19 cases from 445 close contacts [45-48]. Therefore, while cognizant of its current limitations, we consider a system based in mobile technology best suited for the early detection needs of a pandemic.

AI has equipped its users with robust predictive power which provides accurate case reporting while simultaneously mitigating false-positive cases. It also offers low-cost alternatives such as virtual, data-integrated workspaces to ease the workload by any single individual that can work in both urban and rural settings. In an artificial intelligence (AI)-based manner, big-data companies, such as Blue Dot and Zenysis (Table 1), have increased the availability of the technology's benefits to entire regions despite economic shortage. By having an AI-enhanced SMS/IVR system, we exponentially strengthen our otherwise lacking financial resources, human ability to manage big datasets, and disease prevention and mitigation strategies. By utilizing an SMS/IVR reporting system to obtain initial data in a potential public health crisis scenario, our proposal would be able to pre-screen users and effectively lessen the rapid demand on healthcare professionals and resources. Our end-users assigned an identification number and partnering health agencies can de-identify patient information since the user only needs a cellphone number when giving self-reported symptoms and demographic information. Users are then triaged and advised on follow-up that mitigates psychological distress and functional impairment among citizens, thus increasing user compliance. As AI-based technology to detect disease-causing agents is expected to increase, its current and expected applications on various levels may help to decrease inherent costs and curtail expenditures associated with a breakdown of the supply chain.

In a centralized manner, our proposal empowers legislative bodies, healthcare professionals, and individual decision-making citizens informatively on the proper next steps. Mobile-based tools have previously been rapidly deployed in pandemic settings to address disease reporting and treatment needs [3,44]. Our proposal allows for the greatest market penetration in the current technological landscape and provides vital access to healthcare to vulnerable populations. In emerging economies, 78% of the population own mobile phones [49]. In advanced economies and the United States, 94% [50] and 96% [49] of the population own mobile phones, respectively. By relying on the current hardware distribution of cellphones allocated to individuals in the world, we drastically decrease the need for new hardware. Developing a syndromic surveillance network that relies on the utilization of existing hardware, combined with its expansive present-day utilization in both rural and urban societies, allows our proposed system to be highly scalable. Combined with AI and ML, a system like this would identify emerging patterns of disease exposure, symptom onset, disease trajectory, and clinical prognosis [51].

Remaining Challenges

Secondary Costs

Costs related to further engineering of software for AI, ML, and DL that seeks to integrate information from country-based syndromic surveillance systems into a centralized system will both need to be funded. Additionally, expanding EWARS-like systems (Table 1) so that they are readily available may require additional investment from the WHO. If the long-term feasibility of this program is adopted and governments wish to equip every individual with a mobile phone (smart or not), they may need additional funding for hardware needs if sensitivity is to be maximized. This may not be required as a smaller percentage of local populations rise in symptoms may be enough to alert of unusual disease activity.

Altruistic Behavior

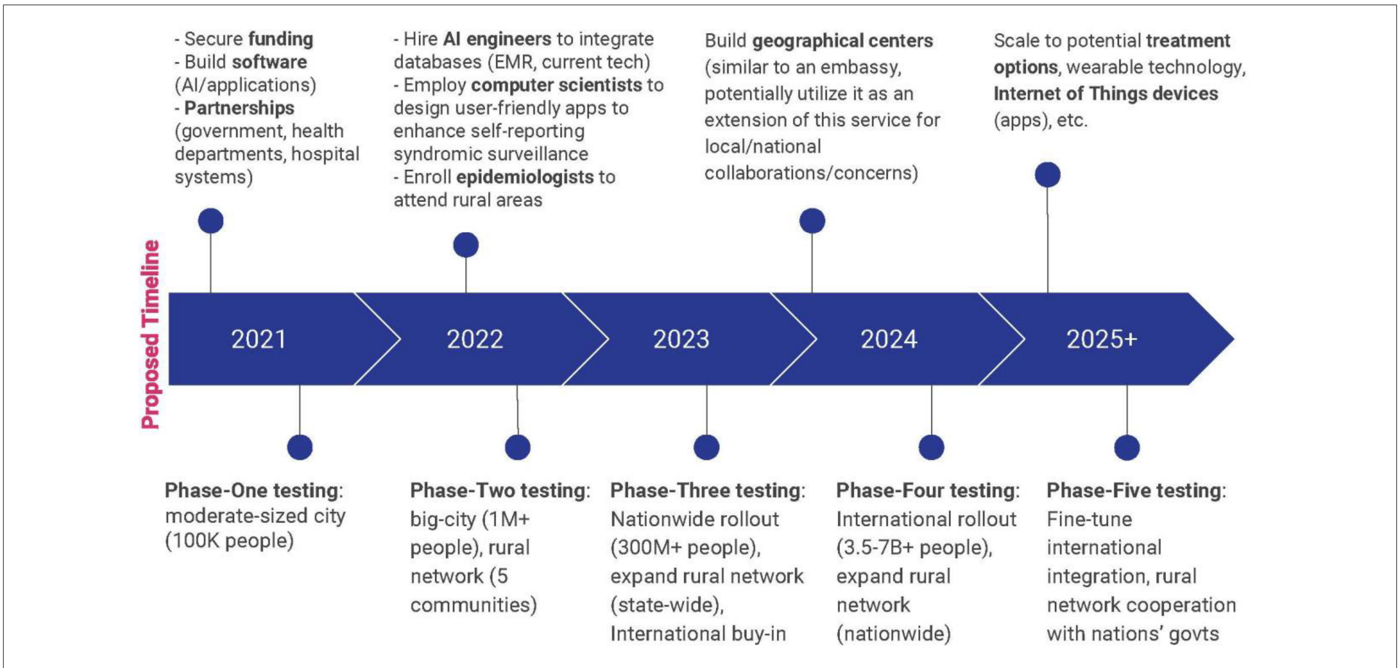

Figure 2.

Perhaps the greatest limitation of them all will be the desire for companies, governments, and other resources to work together if this idea would be proposed over the next five years (Figure 2). While organizations like the WHO may obtain individual governmental backing, we will need governmental contracts promising financial compensation for lasting partnerships. In addition, we will need a group of computer and AI engineers to collaborate in developing the algorithm and code for this centralized system. We may utilize algorithms like Blue Dot's [52,53] or Zenysis' [54] that will help setup the program for widespread distribution. Once developed, it can be deployed by individual local and national governments and increase the robustness of this system. With the added benefit of ML and DL, this system will be adaptable over time without needing to start from scratch [55-57].

Privacy Concerns

One of the biggest concerns with big data communication networks is that only data that are meant to be transferred are obtained by the organizing bodies. This emphasizes the need for institutional regulations regarding the issues of privacy at all levels - patient and individual governments. Current legal precedents may help guide privacy rights and data sharing in our syndromic surveillance model. Importantly, all information collected from users is de-identified and HIPAA compliant, which is achievable if users are provided with a unique identification number that then redacts their personal information. United States federal law allows the sharing of healthcare-related information to those conducting public health surveillance [58].

International Health Regulations implemented by the Global Outbreak Alert and Response Network (GOARN) also permit the sharing of health information among countries [59]. These legislative bodies may be useful in checking that information cannot be linked to personal health information of any individual and ensure privacy compliance to ensure ethical utilization and enhanced privacy of the patient data that will be collected, guidelines such as Singapore's Model Artificial Intelligence Governance Framework [60] can be used. Other guidelines were also established to encourage the use of data collected via public funds to be a public good [61]. However, these guidelines were not universally adopted due to privacy concerns. Blockchain, a distributed ledger system most commonly used for cryptocurrencies, can be used to combat these privacy issues and ultimately maintain confidentiality of health data [61]. De-identifying data or performing meta-analysis can be other ways to protect patient data while continuing to benefit from the valuable health information [62].

The use of ML will build prospective analyses, which then can be retrospectively verified to enhance future predictive power. Utilizing current datasets that do not require official clearance may curtail disease detection, and respect privacy concerns as data is inherently de-identified before reporting. Pro MED Mail (PMM) is a worldwide, online, email-based system put on by the International Society for Infectious Disease [63-65]. In contrast to the World Health Organization, PMM does not need clearance from officials before reporting on disease. Thus, by also sending this information to the AI-enhanced proposal we describe, we may afford national governments the preliminary preventative decision-making information before cases break into epidemic magnitude.

Taken together, many legal avenues and resources allow for meaningful information to be aggregated while respecting patient privacy. Still, however, breaches in personal health information should be vigorously overseen to ensure this standard is being met. In the technological era of data sharing, safeguards that prevent malicious utilization of information and hacking should be active areas of research moving forward.

Future Applications

Due to the extensive applicability and reach of this proposal, there are several ways this system can be utilized in the future. Patients in rural areas can easily be seen and assessed by a provider through a central, virtual, "telephone box-like" telemedicine room. This method can also allow for remote monitoring of patients. Offering and providing a virtual system to receive healthcare may be an essential approach to reducing health disparities among rural and underserved populations [66,67]. Based on our proposal, more complex robotic telemedicine carts with cameras, interactive screens, and on-board medical equipment can be developed for these populations as well [66]. There is also potential to interact and treat disease hot spots without risking healthcare workers or additional exposure. Our system can also be used as a mass messaging system that provides health alerts or warnings and health or disease-related education [66,68]. Millions of people can be informed simultaneously via a simple text message, thereby increasing their health literacy. Regarding the COVID-19 pandemic and for future use, our system can also provide an enhanced contact tracing technique. The information can be easily attained and analyzed from patients who have reported symptoms in an efficient, timely manner.

Conclusion

Design and development of an automated, AI-enhanced SMS/IVR syndromic surveillance system is of great interest to the global scientific and medical community and an active area of research. While some areas are better studied than others, the integration of associated technologies can be started locally and subsequently incorporated into a more centralized database as data and positive outcomes accumulate. With strong evidence showing the beauty in a system that increases communication and workflow through an AI-enhanced manner, healthcare and the medical landscape will inevitably progress in this direction. In our proposed solution to thwart any future epidemic and pandemic, we offer a conglomeration of evidence-based reports, real-life examples, and potential funding sources to perpetuate the beginning of what may just change the future of healthcare as we know it. While current economic constraints, altruistic-dependent behavior, and privacy concerns are considered, the proposal offers future savings, positive public health outcomes, and patient privacy protection as mainstays in our development toward its feasibility, applicability, sustainability, and scalability into the greater medical landscape. We describe current and future appliances of our solution that truly increase healthcare for all. In an integrated manner, we have essentially taken proficient pieces of the metaphorical puzzle and assembled them to offer a novel concept in stopping epidemics and pandemics in their tracks.

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None.

Conflicts of interest

No Conflicts of interest.

References

1. Mandl KD, Overhage JM, Wagner MM, Lober WB, Sebastiani P, et al. (2004) Implementing syndromic surveillance: a practical guide informed by the early experience. J Am Med Inform Ass 11(2): 141-150.
2. Henning K (2004) What is Syndromic Surveillance? In: Syndromic Surveillance: Reports from a National Conference. MMWR, 2003 (53): 7-11.
3. Menni C, Valdes AM, Freidin MB, Sudre CH, Nguyen LH, et al. (2020) Real-time tracking of self-reported symptoms to predict potential COVID19. Nat med 26(7): 1037-1040.
4. (2020) Centers for Disease Control and Prevention. FAQ: COVID-19 Data and Surveillance.
5. (2020) GitHub. nytimes/covid-19-data.
6. Johns Hopkins University & Medicine. COVID-19 United States Cases by County. Coronavirus Resource Center 2020.
7. (2020) GitHub. Be out break prepared/nCoV2019.
8. (2020) HealthMap. COVID-19. Novel Coronavirus (COVID-19).
9. Hope K, David Durrheim N, Edouard Tursan d Espaignet (2006) Craig Dalton, Syndromic Surveillance: is it a useful tool for local outbreak detection? J epidemiol commun health 60(5): 374-375.
10. Strunk B, Cunningham P (2002) Treading Water: Americans Access to Needed Medical Care, 1997-2001. Track Rep (1): 1-6.
11. Menkir TF, Chin T, Hay JA, Surface E, Martinez de Salazar P, et al. (2020) Estimating the number of undetected COVID-19 cases exported internationally from all of China. medRxiv: the preprint ser health sci.
12. Taber JM, Leyva B, Persoskie A (2015) Why do people avoid medical care? A qualitative study using national data. J gen int med 30(3): 290-297.
13. Green CA, Johnson KM, Yarborough BJ (2014) Seeking, delaying, and avoiding routine health care services: patient perspectives. Am j health promot 28(5): 286-293.
14. Moghadas SM, Fitzpatrick MC, Sah P, Pandey A, Shoukat A, et al. (2020) The implications of silent transmission for the control of COVID-19 outbreaks. Proc Nati Acad Sci 117(30): 17513-17515.
15. Havers FP, Reed C, Lim, T, Montgomery JM, Klena JD, et al. (2020) Seroprevalence of antibodies to SARS-CoV-2 in 10 sites in the United States. JAMA Intern Med.
16. Peters DH, Garg A, Bloom G, Walker DG, Brieger WR, et al. (2008) Poverty and access to health care in developing countries. Ann N Y Acad Sci 1136: 161-171.
17. Frye I (2020) The Impact of Underserved Communities in Times of Crisis. Healthcare Info Manage Sys Soci.
18. (2020) U.S Department of Health and Human Services. Soci Deter Health.
19. (2018) Centers for Disease Control and Prevention. Table 29. Delay or nonreceipt of needed medical care, nonreceipt of needed prescription drugs, or nonreceipt of needed dental care during the past 12 months due to cost, by selected characteristics: United States, selected years 1997-2017.
20. Hruby GW, McKiernan J, Bakken S, Weng C (2013) A centralized research data repository enhances retrospective outcomes research capacity: a case report. J Am Med Info Ass 20(3): 563-567.
21. Hall AK, Cole Lewis H, Bernhardt JM (2015) Mobile text messaging for health: a systematic review of reviews. Ann Rev Pub Health 36: 393-415.
22. (2020) COVID Worldwide Realtime Symptom Tracker.
23. (2020) The Wellviser Company. Wellvis COVID-19 Triaging App.
24. (2014) Weinschenk S, are you addicted to texting? in Psychology Today Blog.
25. Johnson D (2013) SMS open rates exceed 99%, in Tatango.
26. Schmidthuber L, Frank Piller, Marcel Bogers, Dennis Hilgers (2019) Citizen participation in public administration: investigating open government for social innovation. R&D Management 49(3): 343-355.
27. Harper CA, Liam Satchell P, Dean Fido, Robert Latzman D (2020) Functional Fear Predicts Public Health Compliance in the COVID19 Pandemic. Int J Mental Health Add 1-14.
28. Thompson RR, Dana Rose Garfin, E Alison Holman, Roxane Cohen Silver (2017) Distress, Worry, and Functioning Following a Global Health Crisis: A National Study of Americans' Responses to Ebola. Clin Psychol Sci 5(3): 513-521.
29. Chang H J, Nicole Huang, Cheng Hua Lee, Yea Jen Hsu, Chi Jeng Hsieh, et al. (2004) The Impact of the SARS Epidemic on the Utilization of Medical Services: SARS and the Fear of SARS. Am J Pub Health 94(4): 562-564.
30. Tuli S, Shikhar Tuli, Rakesh Tuli, Sukhpal Singh Gill (2020) Predicting the growth and trend of COVID-19 pandemic using machine learning and cloud computing. Int Things 11: 100222.
31. Wang S, Yunfei Zha, Weimin Li, Qingxia Wu, Xiaohu Li, et al. (2020) A fully automatic deep learning system for COVID-19 diagnostic and prognostic analysis. Eur Resp J 56(2): 2000775.
32. Panch T, Szolovits P, Atun R (2018) Artificial intelligence, machine learning and health systems. J Glob Health 8(2): 020303.

33. (2018) Oxford Insights. Government AI Readiness Index 2017.

34. Alampay E (2003) Reporting Police Wrongdoing via SMS in the Philippines. University of Manchester: eGovernment for Development Information Exchange.

35. Barrett PM, Niamh Bambury, Louise Kelly, Rosalind Condon, Janice Crompton, et al. (2020) Measuring the effectiveness of an automated text messaging active surveillance system for COVID-19 in the south of Ireland, March to April 2020. Euro surveill 25(23): 2000972.

36. Jia K, MK (2015) Evaluating the use of cell phone messaging for community Ebola syndromic surveillance in high risked settings in Southern Sierra Leone. Afr Health Sci 15(3): 797-802.

37. Meyers DJ, Ozonoff Al, Ashma Baruwal, Sami Pande, Alex Harsha, et al. (2016) Combining Healthcare-Based and Participatory Approaches to Surveillance: Trends in Diarrheal and Respiratory Conditions Collected by a Mobile Phone System by Community Health Workers in Rural Nepal. PLoS One 11(4): e0152738.

38. (2020) O Dea S, Smartphone penetration rate by country 2018.

39. Syed ST, Gerber BS, Sharp LK (2013) Traveling towards disease: transportation barriers to health care access. J commun health 38(5): 976-993.

40. Lustria MLA, Smith SA, Hinnant CC (2011) Exploring digital divides: An examination of eHealth technology use in health information seeking, communication and personal health information management in the USA. Health Info J 17(3): 224-243.

41. Chen X, Heather Orom, Jennifer Hay L, Erika Waters A, Elizabeth Schofield, et al. (2019) Differences in Rural and Urban Health Information Access and Use. J rural health 35(3): 405-417.

42. Golboni F, Haidar Nadrian, Sarisa Najafi, Shayesteh Shirzadi, Hassan Mahmoodi (2018) Urban–rural differences in health literacy and its determinants in Iran: A community-based study. Aust J Rural Health 26(2): 98-105.

43. James CV, Ramal Moonesinghe, Shondelle Wilson Frederick M, Jeffrey Hall E, Ana Penman Aguilar et al. (2017) Racial/Ethnic Health Disparities Among Rural Adults-United States, 2012-2015. Morbidity and mortality weekly report. Surveillance summaries. 66(23): 1-9.

44. Drew DA, Nguyen LH, Steves CJ, Menni C, Freydin M, et al. (2020) Rapid implementation of mobile technology for real-time epidemiology of COVID19. Sci 368(6497): 1362-1367.

45. Lester J, Sarah Paige, Colin A Chapman, Mhairi Gibson, James Holland Jones, et al. (2016) Assessing Commitment and Reporting Fidelity to a Text Message-Based Participatory Surveillance in Rural Western Uganda. PLoS One 11(6): e0155971.

46. Rajatonirina S, Jean Michel Heraud, Laurence Randrianasolo, Arnaud Orelle, Norosoa Harline Razanajatovo, et al. (2012) Short message service sentinel surveillance of influenza-like illness in Madagascar, 2008-2012. Bull World Health Organ 90(5): 385-389.

47. Aliyu M, Konstantin Franke, Portia Boakye Okyere, Johanna Brinkel, Axel Bonačić Marinovic, et al. (2018) Feasibility of Electronic Health Information and Surveillance System (eHISS) for disease symptom monitoring: A case of rural Ghana. PLoS One 13(5).

48. Burke RM, Claire Midgley M, Alissa Dratch, Marty Fenstersheib, Thomas Haupt, et al. (2020) Active monitoring of persons exposed to patients with confirmed COVID-19 - United States, January-February 2020. Cen Dis Control Preven 69(9): 245-246.

49. Silver L (2019) Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally.

50. (2019) Pew Research Center. Mobile Fact Sheet.

51. Yang Z, Zeng Z, Wang K, Wong SS, Liang W, et al. (2020) Modified SEIR and AI prediction of the epidemics trend of COVID 19 in China under public health interventions. J Thora Dis 12(3): 165-174.

52. Blue Dot. Available from: https://bluedot.global.

53. Yang W, Zhongjie Li, Yajia Lan, Jinfeng Wang, Jiaqi Ma, et al. (2011) A nationwide web-based automated system for early outbreak detection and rapid response in China. West Pac Surveill Resp J 2(1): 10-15.

54. (2020) Zenysis. Available from: https://medium.com/zenysis.

55. (2020) Global EWARS. Available from: http://ewars-project.org/index.html.

56. (2020) World Health Organization. Early Warning, Alert, and Response System (EWARS).

57. (2016) Naydenova E, Mobile-based Surveillance Quest using IT (MoSQuIT), India. Social Innovation in Health Initiative Case Collection: WHO, Geneva: Social Innovation in Health Initiative.

58. (2003) Code of Federal Regulations (CFR), Uses and Disclosures for Which an Authorization or Opportunity to Agree or Object is Not Required, in 45 CFR 164.512.

59. Mackenzie JS, Patrick Drury, Ray Arthur R, Michael Ryan J, Thomas Grein, et al. (2014) The Global Outbreak Alert and Response Network. Glob Public Health 9(9): 1023-1039.

60. (2019) Personal Data Protection Commission, A Proposed model artificial intelligence governance framework.

61. Wahl B, Aline Cossy Gantner, Stefan Germann, Nina Schwalbe (2018) Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings? BMJ global health 3(4): e000798-e000798.

62. Noorbakhsh Sabet N, Ramin Zand, Yanfei Zhang, Vida Abedi (2019) Artificial Intelligence Transforms the Future of Health Care. Am j med 132(7): p. 795-801.

63. Madof LC, Woodall JP (2005) The internet and the global monitoring of emerging diseases: lessons from the first 10 years of ProMED-mail. Archi Med Res 36(6): 724-730.

64. Carrion M, Madoff LC (2017) ProMED-mail: 22 years of digital surveillance of emerging infectious diseases. Int Health 9(3): 177-183.

65. Kshetri N (2014) Global entrepreneurship: environment and strategy.

66. Kapoor A, Santanu Guha, Mrinal Kanti Das, Kewal C Goswami, Rakesh Yadav (2020) Digital healthcare: The only solution for better healthcare during COVID-19 pandemic? Indian Heart J 72(2): 61-64.

67. (2020) Food and Drug Administration (FDA), Enforcement Policy for Non-Invasive Remote Monitoring Devices Used to Support Patient Monitoring During the Coronavirus Disease 2019 (COVID-19) Public Health Emergency: U.S. Department of Health and Human Services.

68. (2020) Turn.io; Available from: https://www.turn.io/.