

Review Article

New Ways to Manage Pandemics: Using Technologies in the Era of COVID-19: A Narrative Review

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Abstract

Objective: Health care systems and professionals worldwide are relying on technology as an essential partner to manage the COVID-19 epidemic. This paper explains how digital technologies can benefit the public, medical workers, and health care systems.

Method: This nonsystematic literature review was conducted on different technologies and their impact and applications in the COVID-19 epidemic using proper search keywords on the PubMed, Google Scholar, and Science Direct databases.

Results: We found various helpful technologies, which can help us to appropriately contain and manage the COVID-19 pandemic through broad areas of clinical care, logistics, maintenance of socioeconomic activities, and inspection. However, main challenges still need to be addressed for obtaining the full capacities of the technologies to support health care systems.

Conclusion: Technologies can offer many innovative ideas and solutions against global and local emergencies. In this time of great vagueness and danger, we require all the resources we can collect to rescue ourselves and our patients. Barriers and challenges, such as lack of technology proficiency, confidentiality requirements, and reimbursement matters, need to be recognized and resolved rapidly, accurately, and compassionately.

Key words: COVID-19; Health Care; Informatics; Robotics; Technology; Telehealth

In January 2020, the world health organization announced the Coronavirus disease 2019, called COVID-19, outbreak as a public health emergency of international concern. This outbreak was classified as a pandemic about 6 weeks later. The prevalence of COVID-19 to date is several times than that of the previous Coronavirus outbreak-the 2002 to 2003 SARS-and the number of new cases continues to rise. However, the COVID-19 pandemic is happening in a much more digital world that is equipped with advanced technologies, including internet and various methods of telemedicine and robotics, intelligent analytics and big data. In fact, unlike previous outbreaks, health care management of the COVID-19 can take advantage of new technologies for different practices from prevention, self-isolation and quarantine, and initial symptoms triage

to return the social interaction. The use of digital data from digital devices, such as cell phone, is of particular importance in a public health crisis arising from newly discovered pathogens (1). A recent research has indicated the feasibility of predicting the spread of the COVID-19 virus by integrating data from a great provider of digital flight information with data from a popular social media app and other digital devices on human mobility (2). The possibility of forecasting the spread of cholera using cell phone data has already been shown in the 2010 Haiti cholera epidemic (3). Also, big data analytics have effectively been used during the 2014-2016 African Ebola crisis (4). However, today more data are available from cell phones and other digital devices, and more advances have been made in smart analytics and artificial intelligence (AI).

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Furthermore, during those recent outbreaks, there were serious concerns about the privacy and data protection, when using mobile phone records and social media data, due to lack of proper guidelines and regulations (1).

To continue working, institutions of higher education and private companies have abruptly changed their routine to videoconferencing and other digital solutions, whereas the health care system is still coping with this crisis mainly through high risk visits. Health care as an analogue system is ill-equipped to manage this rapidly emerging epidemic. The health care system in most parts of the world, especially in Iran, is organized on the inevitable model of physical interactions between clinicians and their patients in a historical manner. Clinical workflows have primarily been developed to sustain and support a face to face model of care, causing the congregation of patients and people in emergency departments and lobby areas during this crisis. This care model promotes the spread of the new Coronavirus to uninfected people who are requesting evaluation. Vulnerable people, such as patients with chronic conditions and immunosuppression, will encounter a difficult decision between risk taking iatrogenic virus exposure during a visit and delaying needed care. Furthermore, pandemics cause panic, fear, anxiety, stress, and other severe problems related to mental health (5-7). We need to have an organized system to manage this situation and to improve the public mental health through providing inclusive and timely services and right education. In the global health crisis, the medical community is in dire need of new technologies to monitor and manage the spread of COVID-19 pandemic. Therefore, it is necessary to leverage different advanced technologies and put them to proper use for public health. In this narrative review and perspective paper, we draw new experiences with technologies, digital tools and telehealth, and review the impressive global researches and innovations in the management of the current pandemic.

Health Informatics

Health informatics cope with the information and computer technologies, resources, systems, devices, and different approaches to organize and analyze information in medicine and health for the sake of improvement in health care outcomes (8). In addition to medical actions, nonmedical measures have been proven to be essential for postponing the spread of the COVID-19, including strict national and international mobility restrictions (9). However, appropriate and timely decision-making during different stages of the outbreak requires reliable data not only about infected patients, but also about their behavior, such as mobility and physical interactions of people. The COVID-19 crisis severely endangers human health, life, social interactions, economy and international relations. However, big data, geographic information systems (GIS), and AI technologies have played a prominent role in various directions: the fast gathering of multisource big data; visualization of

epidemic information; online tracking of infected cases; forecasting spatial transmission; regional segmentation of the infection risk and prevention level; counterbalancing and administration of the supply and demand of resources; and social education and stress management. They all have provided reliable regional information support for proper decision-making, planning, and effective evaluation of COVID-19 prevention and control. Zhou et al (10) constructed a rapid analysis platform through GIS and big data technologies and assessed the spatial representations of the patients, material resources, population, social psychology and Chinese behaviors at 3 individual, group, and regional scales. This platform yielded epidemic maps to provide distribution of epidemic dynamic information and population flow, which recognized the problems in the main risk regions and the spatial inconsistency of medical resources in an opportune manner. They also developed a knowledge database through data obtained from social media to monitor social psychology and public opinion, which yielded very important information on public attitude to guide the government. Other seminal works on human mobility have also demonstrated that cell phone data can help for modeling the geographical dissemination of epidemics (11). Local authorities and researchers in Italy are working together to assess the efficacy of mobility and travel restrictions to tackle the spread of the COVID-19 virus through a database of cell phone information (12). Other European governments, such as Germany, France, Austria, Spain and Belgium, are collaborating with researchers as well as mobile network operators to estimate the conformance and consequences of the social distancing measures to fight the COVID-19 crisis and to recognize and predict potential key risk areas (13). In the United States, researchers collected location data from over 180 apps and developed a contact network with 3 layers (households, schools, and community) to estimate the contact patterns of 100 000 agents in the city of Boston during a 4-month period. They evaluated different scenarios of social distancing using SIR and SEIR epidemiological models and reported interesting results about the impacts of different policies on the spread of the virus (14). South Korea and Taiwan, which have done well to control and contain the spread of the virus, have taken effective measures by constructing integrated information technology systems and big data analytics. They have drawn information technology-based tracing strategies by aggregating data from different sources, including location data from cell phones and other digital devices, personal identification information, prescription and medical records, immigration and travel records, card transaction data, public transportation records, and closed-circuit television scenes. The information is categorized through big data analytics and is made available near real-time to the related organizations for containment of the COVID-19 as well as to the public for the

observance of health protocols in accordance with the specific privacy laws (15, 16). A group of Chinese researchers developed an intelligent detection and treatment assistant platform based on the Internet of Things technology. This automated platform recognizes the confirmed, suspected or suspicious cases of the COVID-19 infection and classifies patients into severe, moderate, or mild pneumonia based on questionnaires and existing data. It can update itself according to the latest real world data and can be helpful in the long-term follow-up of patients (17).

Another technology that can improve our planning, treatment, and reporting processes against the COVID-19 is AI (18-20). In addition to contact tracing, AI has been used for diagnosis and treatment of the disease (21). In the detection stage, it can be useful in the detection of the infected cases through analyzing data from medical imaging methods of the chest, such as computed tomography (CT) and magnetic resonance imaging (MRI). A recent research proposed neural network-based classifiers for the screening of patients with COVID-19 at large scale according to their distinct respiratory pattern (22). Furthermore, several studies developed AI models through different deep learning approaches, such as convolutional neural network architecture, for early automatic detection and temporal monitoring of patients with COVID-19 pneumonia on high resolution x-ray and CT chest images and achieved comparable performances to expert radiologists (23-29). These deep learning-based AI methods allow for high precision analysis of many chest images almost simultaneously. They have a great potential to improve early detection of the COVID-19 and to relieve the exhaustive workload of front-line radiologists. Therefore, AI based automated diagnostic systems not only contribute to improved diagnostic speed and accuracy, but also keep healthcare workers safe by reducing their working time in polluted environments. Moreover, a high accuracy machine learning-based prognostic model has been developed to predict the survival for critically ill COVID-19 patients with 3 main clinical data, including lymphocyte, lactic dehydrogenase, and high-sensitivity C-reactive protein, which are the representatives of immunity-, injury- and inflammation-typed indices, respectively (30).

Furthermore, no effective drug has yet been approved for the treatment of COVID-19, and there is an urgent need for an effective therapeutic strategy to treat rapidly spreading COVID-19 patients worldwide. Therefore, it is important to develop efficient and systematic approaches for repurposing existing clinically approved drugs or designing new drugs against COVID-19. A repurposing and repositioning framework has been developed based on AI and machine learning to set priorities for existing drug candidates against COVID-19 for clinical trials (31). A drug discovery pipeline based on machine learning has been used to design and develop new drug like compounds against COVID-19

(32). Moreover, a new Vaxign reverse vaccinology tool merged with machine learning has been developed to predict and propose COVID-19 vaccine candidates (33). Moreover, a deep learning system, AlphaFold, has been developed by Google DeepMind to reveal protein structures and genomic signatures associated with COVID-19, serving as valuable and useful information for vaccine preparation (34). An alignment free whole genome machine learning approach has also been proposed for rapid classification of the COVID-19 pathogens in a reliable and real time manner (35).

Telehealth and Robotics

Healthcare providers are faced with serious challenges in delivery of care because of preventing measures, such as social distancing, for the expansion of the COVID-19 pandemic. This global crisis has highlighted the important role of telehealth and telemedicine to provide medical services. Telehealth is a perfect solution for controlling communicable diseases. Many clinicians and health care seekers now understand the full capabilities of medical digital tools for the first time, as they are forced to, and use them for timely connection while in-person visits are impossible. On the other hand, for individuals not infected with the virus, particularly those at higher risk (eg, elderly people with preexisting conditions), telehealth can propose an appropriate access to regular care with no risk of the COVID-19 exposure in a clinic. Telehealth has several strengths that can reinforce an emergency response during biological or environmental hazards. It can allow remote triaging of care and yield easily obtainable information via technology tools, such as chatbots, as experienced in Singapore and USA during COVID-19 pandemic (36, 37). Currently, more than 50 health systems in the USA, such as Cleveland Clinic, Jefferson Health and Mount Sinai, leverage telehealth technologies to deliver timely care and follow-up of infected patients (37). The Australian Department of Health is equipping medical workers to deliver services through telemedicine. Similarly, the National Health Service in the United Kingdom is offering online consultation in specific areas to limit unnecessary health systems visits (38). Telehealth can also help us for disease diagnosis through video consultations with experts (39, 40). Clinical trials have demonstrated that clinical video consultations resulted in high satisfaction among health care providers and patients, independent of disease progression, with lower costs compared to traditional visits (41-44).

Other telemedicine tools to identify and track infected cases and allow self-assessment practices are telemedicine apps. 'Coronavirus SUS' app is a telemedicine Brazilian tool, which integrates prevention, triage and information by identifying possible infected cases and referring them to the nearest emergency department, and providing evidence-based insights and appropriate health advices. A similar innovation is explored in the USA. Also, a telemedicine UK app asks citizens to self-report their health condition daily in 1

minute. Citizens must declare information about their location, gender, age, and medical condition (38).

As a result of swiftly growing numbers of infected cases and deaths, both medical personnel and the public have been encountering psychological problems, including stress, anxiety, obsessive-compulsive traits, and depression. Accordingly, more than 72 online surveys associated with mental health aspects of the COVID-19 pandemic have been conducted in different Chinese and Iranian populations (45, 46). One such survey involving 1563 medical personnel reported 73.4% prevalence for stress related symptoms, 44.7% for anxiety, 50.7% for depression, and 36.1% for insomnia (47). As a result, the National Health Commission of China has provided several guidelines for emergency psychological crisis intervention and psychological assistance hotlines during the COVID-19 pandemic (48). Online mental health education through communication programs and social media has been extensively used during the pandemic for medical personnel and the public. Moreover, online psychological consultation services have been widely delivered by mental health professionals in China, USA, Australia, and other countries (49). Online psychological intervention systems in a self-help manner, including online cognitive behavioral therapy for anxiety, insomnia, and depression have also been established (50, 51). Furthermore, several AI programs have been developed during the COVID-19 epidemic as timely interventions for psychological crises through monitoring and analyzing posted messages on social networks and alerting specified volunteers to act accordingly (45).

The question may arise that how can robots help us in this era? Robots are effective resources with great potentials to be utilized for disinfection, quick production of gloves and face masks, measuring vital signs, delivering medications and food, and contributing to border controls (52). COVID-19 can persist on different surfaces, such as plastic, glass, or metal for days and remote controlled noncontact ultraviolet robots are effective and fast intelligent systems for autonomous navigation, recognition of high risk and high touch surfaces, and disinfection (53). Furthermore, mobile robots can continually work for temperature measurement in ports of entry as well as public places. Incorporating vision algorithms, automated camera systems and thermal sensors onto autonomous robots could improve the effectiveness and coverage of screening. Such mobile robots can be used to monitor temperatures of the medical staff and patients in different areas of the hospitals repetitively with data and measurements linked to hospital information systems. Most countries used oropharyngeal and nasopharyngeal swabs for initial diagnostic testing of COVID-19 (54). Sample collection, transfer, and testing are involved in this process. However, lack of qualified personnel or imposing too much workload on them is a main challenge during a pandemic. Automated or robot-

assisted oropharyngeal and nasopharyngeal swabbing may accelerate this process, decrease the risk of staff infection, and free up personnel for other tasks. Also, researchers are working on robotic systems through ultrasound imaging technology to recognize peripheral forearm veins for mechanized venipuncture to check for COVID-19 antibodies in a blood test (52).

Discussion

Challenges Ahead and the Roadmap

COVID-19 crisis has made a surge demand for necessary health care equipment and advanced information technologies along with efficient medicine. This review and perspective paper presented different technological solutions for management of the COVID-19 pandemic. These innovative technologies can fulfill the customized requirements of health care systems for appropriate management of COVID-19. AI and big data analytics are useful and are imminent tools to recognize early infections and treat and monitor the infected cases with COVID-19. They can track the outbreak at different scales, including molecular, medical, and epidemiological applications. They are also useful in promoting the innovative researches on the virus through analyzing the available data. Machine learning methods can help in suggesting treatment solutions, preventive strategies, and drug and vaccine development. However, in evaluating the contribution of AI and big data technologies to the containment of the infectious virus, several challenges remain to be investigated. For instance, the restriction regulations for big data sources in local governments and commercial enterprises may limit the data availability for effective social management, cause an immature design for big data aggregation, and result in difficulty of swift online application of deep merging. In data acquisition step, we face difficulties of heterogeneous data integration, which requires governments, academic institutions, and enterprises to jointly develop the formulation of relevant applicable policies. Currently, strategies for an appropriate technical system of knowledge acquisition according to the big spatial data with emphasis on social operations are existing challenges. Moreover, from the perspective of result presentation, we need a multiscale data-driven dynamic presentation.

Telehealth and telemedicine offer a new approach for broader digital health care to help fight the COVID-19 crisis. As healthcare systems prepare for a second wave of COVID-19 cases, urgent measures are required to remodel health care delivery and to upgrade our systems by releasing the power of digital technologies. Although some technologies such as telemedicine have been around for years, their presence in the market and health care systems has been poor due to burdensome regulations and few supportive financial structures. In fact, there is no digital component in the overall strategic plan of many health care systems in the world. For example, the Federal Medical Council in Brazil has

supposed the practices of telemedicine as not legal (38). Likewise, in most states of the USA, the utilization of telemedicine is gravely limited by regulatory bodies. About 38% of American health care systems reported having no digital element in their strategic plan (55). Furthermore, the use of telemedicine requires proper infrastructures for effective implementation in health care systems. Sufficient bandwidth to enable the transmission of data, videos, images and sound is a key feature of technologies for telehealth. Thus, access to broadband is crucial for telemedicine applications. This prerequisite causes challenges in serving rural areas that do not have access to the Internet adequately (56). Furthermore, the use of new technologies and software requires proper training for both providers and users (57). Data protection and privacy is also a crucial problem in successfully implementing telehealth and telemedicine. This issue causes main challenges for both practitioners and authorities and requires strict regulations and proper measures (13). Therefore, at this critical time, we need to draw a broad strategy to address the main 3 challenges: reimbursement for new digital and electronic services, extended regulatory relief, and assessment of clinical care provided through these technologies. Remote treatment delivery requires appropriate payment structures to support its widespread applications, including text, email, mobile phone, video visits, and even wearable devices and chatbots applications. Reimbursement can be structured through fixed pay for service payments or time-based models. Technical wage to supply essential technology infrastructure can also be developed based on existing software as service models.

An urgent update of regulations for privacy and communication would have to attend the implementation of the reimbursement models for new digital services. Policy-makers and stakeholders should consider temporary and new incentive policies with minimum strict regulations to encourage health care providers to adopt digital solutions for patient care. With the passage of this critical time, regulations can be revised, and after reforming the telehealth services provided in the duration of the emergency, they can be presented as permanent solutions. However, we need to accurately assess the quality of care services provided during and after this emergency period to achieve the desired reforms. It is important to understand whether the new digital approaches assist in improving clinical productivity during the COVID-19 epidemic as well as whether these emergency expansions should become permanent once the crisis has resolved.

According to the actions taken in the field of robotics during this crisis, 4 broad applicable areas can be identified to make a difference by robots: clinical care (eg, disinfection and telemedicine), logistics (eg, delivery services and managing contaminated waste), maintenance of socioeconomic activities (eg, teleoperation and telecommunicating through robotic

avatars and social robots), and inspection (eg, monitoring conformance with voluntary quarantines and isolations). COVID-19 could be a great opportunity to develop robotic systems that can be quickly utilized with remote access by professionals and service providers without the need to attend the front lines. Robots have been historically developed for handling dirty, dull, and dangerous operations, similar to current actions to combat infectious virus that are difficult for human workers but are appropriate for robots. However, without systematic and sustained researches, robots will not be ready for the next crisis. By supporting an integration of infectious disease and engineering experts with dedicated funding resources, we can be ready in time of the next pandemic.

Conclusion

We need an urgent digital revolution in the health care practices to face this crisis. Technologies can offer many innovative ideas and solutions against global and local emergencies. In this time of great vagueness and danger, we require all the resources we can collect and utilize to rescue ourselves and our patients. Old and new technologies need to be gathered with no delay and put into practice. Barriers and challenges, such as lack of technology proficiency, confidentiality requirements, and reimbursement matters need to be recognized and resolved rapidly, accurately, and compassionately. Now more than ever, we should join together in our battle to deliver highly needed medical and psychiatric treatments.

Conflict of Interest

The authors declare that they have no conflict of interest.

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