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Technology and its Solutions in the Era of COVID-19 Crisis: A Review of Literature

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ABSTRACT

Background: An important feature of novel coronavirus disease 2019 (COVID-19) is its rapid human to human transfer.Technologies can play an important role in controlling this disease. Therefore, this study aims to investigate the technologies that have been applied to solve the COVID-19 crisis. Besides, the approaches used by these technologies are surveyed.

Methods: In this narrative review, international databases were searched for papers investigating the role of various technologies in the management of COVID-19 from December 2019 to 20 April 2020. The keywords searchedwere "Technology", "COVID-19", "nCOV-19", Diagnostic Technologies", "Therapeutic technologies", "Telemedicine", "Internet of Things", "Big data", "Blockchain", "Robots", and "Drones". Forty-seven articles were found to meet the inclusion criteria after the title, abstract, and full text were reviewed.

Results: Two major categories of technology were found to be applied to combat COVID-19. The first category involves technologies that have the potential to support the diagnostic process and case-finding including non-contact thermometers, artificial intelligence, drones, self-assessment applications, and virus genome sequencing. The second category includes technologies with therapeutic and logistic applications searching for medicines or vaccines, and provide support services such as pharmaceutical tech, robots, telemedicine, Geographic Information System (GIS), Internet of Things, and big data and blockchain.

Conclusion: It can be concluded that technologies with the ability to reduce human contacts through teleservices as well as those that quickly enable decision-making via in-depth analysis received more attention among the health authorities and organizations.

Key words: Technology solutions, COVID-19, Internet of Things, Artificial intelligence, Telemedicine

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Introduction

Coronaviruses are a large group of viruses causing mild to severe diseases from the common cold to Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS) (1). In December 2019, a new type of coronaviruses named COVID-19 emerged in Wuhan, China, and rapidly spread throughout China and other countries all around the world (2).

An increase in the number of patients (2,774,135 confirmed cases) andthe number of deaths (over 190,871confirmed deaths) in 213 countries on April 26th of 2020 has caused the healthcare stakeholders and key players to search for tools and solutions to tackle the COVID-19 crisis (3, 4). Given the current situation, not only relying on traditional tools and methods is ineffective but also is costly and dangerous for people's health (5).Technology can be considered as a practical approach that helpsto overcome the current crisis (6) and manage iteasier compared to previous outbreaks (7).

In different countries, especially in China, many technologies with various applications have been developed (6). By enhancing existing capabilities or adding new capacities, technologies allow the governments and health authorities to take smarter approaches to overcome this pandemic. In the COVID-19 era, global conversations are being stimulated to innovate in technologies to combat this crisis (8) and as the spread of COVID-19, advances in technology have also developed the ability of societies to respond to this crisis. The current situation is the true benchmark for technologies (9). Also, data extracted from these technologies can be aggregated into databases, and provide accurate and real-time information on COVID-19 for making evidence-based decisions (2, 10). Therefore, given the vital role of technology in the fight against COVID-19, the purpose of the current study was to determine the types of technologies applied and the methods they have taken to manage this disease.

Materials and Methods

In this review study, the literature on various technologies in the management of COVID-19 was searched in international databases (PubMed, Science Direct and Scopus databases as well as Google Scholar and specific websites of related organizations) from December 2019 to April 2020 using key words including technology, COVID-19, nCOV-19, diagnostic technologies, therapeutic technologies, telemedicine, Internet of Things, big data, blockchain, robots, and drones. Only articles in English with their available full text as well as covering aspects of technology in the management of COVID-19 were included in this study.

The initial search identified 133 potentially relevant studies of which 47 records were excluded due to duplication. The abstracts of the remained articles were screened by two authors. Ten articles were removed due to lack of relevance (3 articles) and inaccessibility to the full-text articles which were almost 7 articles. Sixty-five full-text articles were assessed for eligibilityfrom which 18 articles were removed due to poor content. Forty-sevenstudies were subsequently included in the analysis and synthesis (Figure 1). The contents of selected articles were carefully reviewed and the technologiesapplied in the COVID-19 management and control were analyzed and interpreted.

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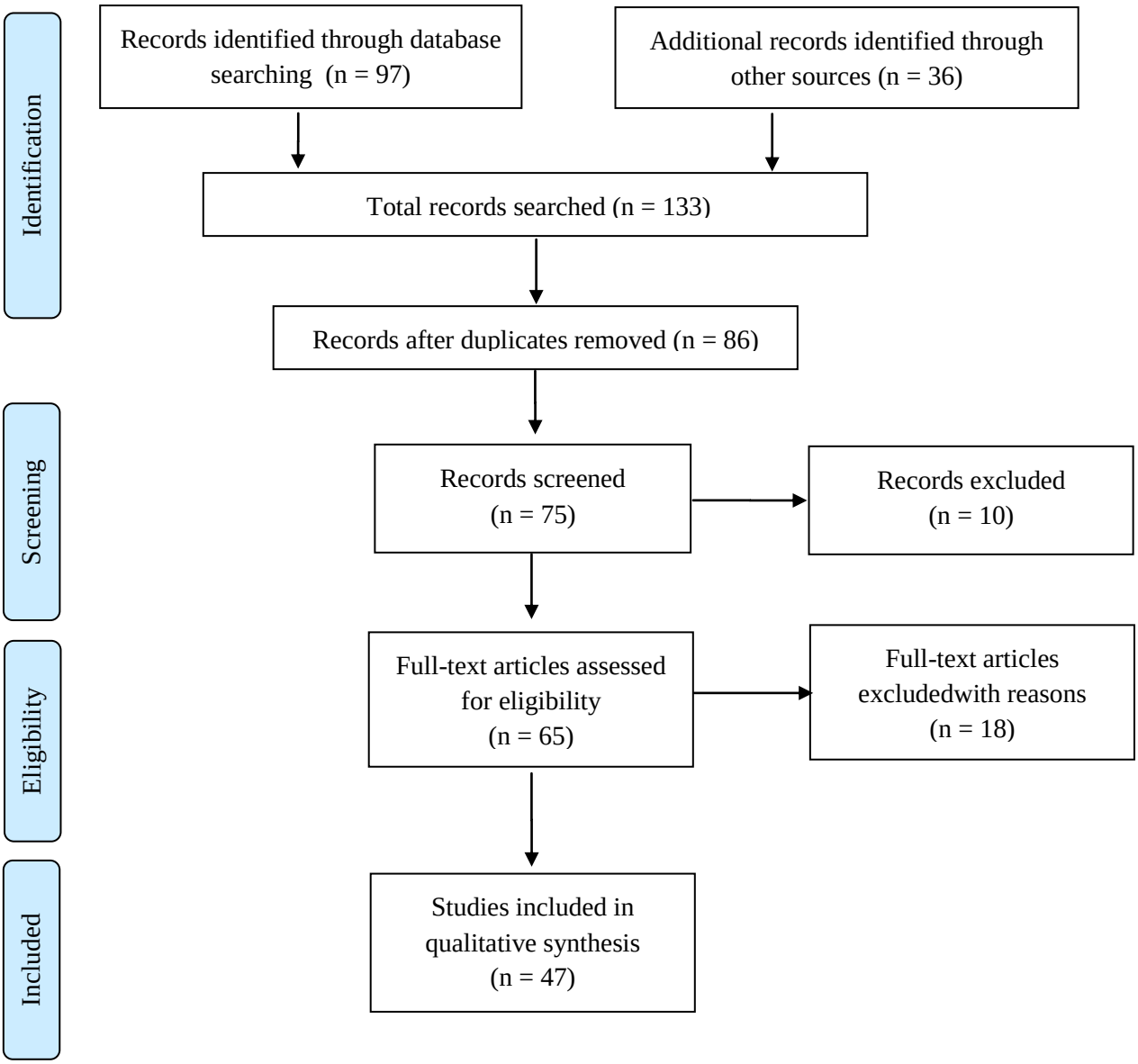

Figure 1.The process of selecting resources

Results

The application of technology in epidemics management has a long history (4). In epidemics like the Ebola virus, a variety of technologies were used. Protective technologies such as smart bands assisting healthcare workers in monitoring hand hygiene and detective technologies like different versions of smartphone thermal imaging applications identifying potential Ebola patients weretwo main categories of these technologies (11). Also, as influenza spreads in the United States in 2018, the use of smart connected thermometersmade it possible to indicate the spread of the virus among the population (4).Technology has been integrated with epidemics (11).

In terms of COVID-19,increased use of different technologies has been observed (4). This fact can be explained by the nature of this pandemic on one hand, and the growth of technology overtime on the other hand. Given the high transmission capabilityof the COVID-19, the use of technologies can reduce communication and contacts between people and subsequently slow down the transmission of this disease(12). Since

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the outbreak of COVID-19, a variety of technologies have been developed by several large companies around the world as well as governments. These technologies summarized in Table 1 are classified into two categories based on the type of servicesthat they provided.

1. Case-finding and diagnostic technologies

1.1. Thermometers. Because of the high prevalence of the coronavirus and the high risk of contamination, close contact of people should be avoided as much as possible. Therefore, the use of handheld touch thermometers is not a good alternative to use in fever screening. Given that thermometers are applied to determine the body temperature of suspicious individuals at high-risk entrances such as airports and train stations, non-contact technology can be very helpful in achieving this goal(13). Heretofore, a variety of non-contact thermometers have been applied in which different technologies such as infrared thermal systems, thermal imaging cameras (14), smartphone thermal sensors (15), and telemonitoring technologies have been used (5).

1.2. Artificial Intelligence (AI). Given the capabilities of AI, it can be applied to overcome the medical and social challenges created by COVID-19. The main applications of AI in the context of COVID-19 are diagnosing new coronavirus infection and differentiatingit from other infectious pulmonary diseases estimating the structure of coronavirus proteins to determine the effectiveness of existing drugs or to propose a new component, epidemiological modeling of the number of patients, andthe analysis of information related to COVID-19 (16).

In the field of diagnosis, given the high spread of the coronavirus, it is essential to identify infected individuals as soon as possible.One of the diagnostic methods is chest Computed Tomography (CT scan). Although it can usually help to identify suspected cases of COVID-19, its overlap with images of other infectious pulmonary diseases makes it difficult to havea differential diagnosis of the COVID-19. In this situation, using other technologies can be helpful. AIthrough machine learning can enable medical staff to identify patientsquickly by extracting the features of the image such as shape, color, and texture (17).In this regard, a Shanghai-based AI startup launched the Intelligent Evaluation System of CT for COVID-19. This system can evaluate CT scans through algorithms identifying image features and determine the type of lung lesions and the severity of their involvement (4, 16).

1.3. Drones. In the COVID-19 pandemic, drones play an important role in managing the disease due to their various applications.Some countries use drones to identify patients and people with high-risk situations and behaviors in large population groups.These tools can monitor people's temperature, heart rate, and respiratory rate using specialized sensors, high-resolution cameras, and powerful computer systems.They also display the activities of people such as sneezing and coughing which helps to detect suspicious cases (18).Another application of drones is for logistic services. Due to the need for social distancing, water and food, medicine, laboratory samples of patients, and other essential items are transported quickly using drones. Drones are also being used for broad disinfection operations and aerialspray (19). Health advises for people with high-risk behaviors as well as government announcements during quarantine are provided by drones (2, 18, 20).

1.4. Self-assessment applications. In different countries, to reduce unnecessary referrals to hospitals and corona specialized centers, a variety of self-assessment applications has been designed.These applications ask several questions such as general information, geographic location, recent travel history, underlying diseases, and the symptoms of the corona. By receiving the person's answers, his/her condition is determined in terms of infection with the smart diagnostic algorithms.Based on the individual's situation, basic suggestions are provided (21).

In most countries, self-assessment applications are nationally implemented and have become the tools for general screening and early case-finding (21).Examples of these applications include the StarTimes ON app, which is provided by the

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Chinese StarTimes Group which can be used by 45 countries in the region (22).Correspondingly, the self-assessment application has been designed and implemented by the Ministry of Health in Iran, which aims to prevent, identify, and take care of people in the community against the COVID-19. By answering the questions, suspicious individuals are identified, followed up, and received the necessary care by the health and medical centers (23).

1.5. Virus genome sequencing technology. Sequencing of the virus genome in clinical cases and patients can help to determine the genome sequence pattern and to monitor the genome mutation of the virus.In this regard, the formation of databases that can provide big data on the genome sequence will provide a great opportunity for detecting the virus behavior, preventing the virus spread, anddestructing the virus. Several databases register data on all types of influenza, including GISAID (Global Initiative on Sharing All Influenza Data) and NCBI GenBank (24, 25).

2. Medical and logistic services technologies

2.1. Pharmaceutical technology. International health authorities as well as countries around the world are looking for ways to find a cure or a vaccine for COVID-19. Some of these efforts have been done based on previous treatments for coronaviruses (26). Also, several clinical trials are being carried out by pharmaceutical research groups to stop the activity of viruses with various mechanisms and to be a therapeutic method to deal with the severe effects of COVID-19.CAS has compiled a special report of various patents. According to this report, antivirus strategies of small molecules targeting complex molecular interactions are emphasized. More than 500 patents also described the methodologies of four types of biological substances, including antibodies, cytokines, RNA therapies, and vaccines that could be useful for COVID-19 control and prevention(27).

2.2. Robots. Robots, due to their widespread applications during the COVID-19 outbreak, are considered as one of the most important technological tools. In some countries, robots with measuring vital signs and performing lab tests reduce direct contact with the patients and prevent the spread of the disease to the health care providers (28, 29). Cleaning and disinfecting of hospitals, delivery of medicine and food to patients' rooms, distributing medicines and personal protective equipment, controlling of contaminated waste, and distributing food among quarantined people are logistical applications of robots during the COVID-19. Some social robots also play a role in controlling social interactions and training individuals to deal with new coronavirus (16).

2.3. Telemedicine. Special attention is paid to telemedicineduring the COVID-19 pandemic which is due to the chance to provide servicesfor people without having any contact with these people through the Information and Communication Technology (ICT) platform. Providing teleconsultation by telephone or video is the simplest application of telemedicine as the best tool for answering people’s questions as well as case-finding (30, 31).

Another application of telemedicine in this period is tele-triage to monitor people, especially in quarantine conditions. People can send their health information to an information system via IT-based devices on smartphones or other devices.So,the system can provide the necessary alarms to care providers based on the individual's situation.This capability can be useful for identifying suspicious individuals as well as monitoring and demonstrating an overview of the state of the population. This connection can also be made by physicians who can communicate visually with their patients (32, 33).

In some countries, for people who do not have access to medical centers for different reasons, or to prevent unnecessary referrals to hospitals, mobile health centers are designed to identify suspected cases of COVID-19.By referring to these centers, people express their symptoms to physicianssynchronously, and based on their instructions, the necessary procedures will be taken by the nurses in the center. Physicians can also

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diagnose and treat patients by accessingpatients' data, such as the results of lab data and chest CT scans asynchronously.Through telemedicine training capacities, people can also be provided with the necessary training to prevent COVID-19.Due to limited resources, follow-up of the patients after discharging from the hospital can also be done using telemedicine capabilities (34, 35).

2.4. Geographic Information System (GIS). Monitoring the prevalence of COVID-19 as well as getting prepared for diagnostic and therapeutic services require information about the state of contagion, and the exact location involved. The development of GIS technology has provided a platform for the production of spatial data. Providing data such as the location of people infected with the virus and those suspected of having coronavirus, hospitals to which patients with corona have been referred to, the route of travel that patients have taken daily and weekly, the place of the distribution of masks and disinfectants can make GIS a helpful tool for managers to combat the COVID-19 crisis effectively. GIS also makes it possible to perform complex spatial analyzes that can be applied to extract the geographical distribution of coronavirus transmission in the world and the country (2, 36).

World Health Organization (WHO) has extensively applied GIS to illustrate the distribution of COVID-19 cases and deaths by country in the world. For this purpose, on January 26th in 2020, the WHO unveiled its ArcGIS Operations Dashboard for COVID-19 (2). Another application of GIS in the COVID-19 crisis is the ability to prioritize service delivery based on the characteristics of each area according to the prevalence of the disease or the need for medical services (37).

2.5. Internet of Things (IoT). In COVID-19, at a high level, IoT provides a platform foraccess to real-time data of peopleknown to have COVID-19, daily new cases, disease distribution by countries, and severity of disease (recovered, critical condition or death). This allows public health authorities to monitor the COVID-19 pandemic and plan based on live data to better manage this crisis (38). At the community level, IoT technology creates a network of electronic communications among various tools that can play a vital role in preventing the spread of disease due to reduced physical communications. Through connecting remote medical devices to the internet, they can share their information within a network and facilitate the identification of COVID-19 cases (39). A successful example happened in Hong Kong that the internet-connected remote sensors were embedded in individuals' arm examining vital signs and blood oxygen levels andsendingthem to a digital platform for real-time monitoring and analysis (40). Therefore, by strengthening the infrastructures of the IoT, it is possible to provide conditions with limited physical communications (38).

2.6. Big data and blockchain. A lot of data on coronavirus are available in a variety of sources including official websites, scientific databases, hospitals, social networks, telecom operators, and travel and tourism sites (41). These data include the number of people infected to COVID-19 or died of this disease, epidemiological reports, the structure and activity of the coronavirus, howthe virus is transmitted, the population at risk, the infection clusters, the symptoms of infected people, patients' travel history, health guidelines, and essential preventive guidance (42). By aggregating this big data into a secure platform such as blockchain, different organizations can access large amounts of real case data, perform various analyzes, andextract models of virus behavior. The results help the health system authorities of each country to enhance their preparation for the outbreak (38). It is also possible to identify the unknown aspects of this new virus and find the appropriate vaccine and drugs to fight against it (43).

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Table 1. Type of technologies used to fight the new coronavirus and their applications

Tech classification	Tech solutions	Applications
Case-finding and diagnostic technologies	Thermometers	Fever screening without contact
	Artificial Intelligence	- Diagnosing new coronavirus infection - Differentiating COVID-19 from other infectious pulmonary diseases - Estimating the structure of coronavirus proteins - Epidemiological modeling of the number of patients - Analyzing the information related to COVID-19
	Drones	- Identifying people with high-risk behaviors and guiding them - Transporting water and food, medicine, and laboratory samples of patients - Disinfecting places such as hospitals
	Self-assessment applications	Tools for general screening and early case-finding by receiving a person's information
	Virus genome sequencing technology	- Determining the genome sequence pattern and monitoring the genome mutation of the virus - Detecting the virus behavior for its controlling
	Pharmaceutical technology	Looking for ways to find a cure or a vaccine for COVID-19 by various mechanisms
Medical and logistic services technologies	Robots	- Reducing direct contact with the patients by measuring vital signs, performing lab tests, etc. - Cleaning and disinfecting hospitals - Distributing medicines and personal protective equipment - Controlling contaminated waste - Distributing food among quarantined people - Controlling social interactions and training individuals to deal with the new coronavirus
	Telemedicine	- Providing services without contact through the ICT platform - Tele-consulting for answering questions from people and case-finding - Tele-triage to monitor people, especially in quarantine conditions -Tele-monitoring synchronously in mobile health centers - Distance learning to prevent COVID-19 - Post-discharge follow-up
	Geographic Information System	- Performing complex spatial analyses to extract the geographical distribution of coronavirus transmission in the world and by country - Prioritizing service delivery according to the prevalence of the disease or the need for medical services
	Internet of Things	-Gathering real-time data from people who are known to have COVID-19 - Creating a network of electronic communications between various tools and reducing physical communications
	Big data and blockchain	- Aggregating large amounts of real data into a secure platform - Performing various analyses,extracting models of virus behavior and finding the appropriate vaccine and drugs

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Discussion

The findings showed that different technologies with various applications facilitate the conditions for fighting against the COVID-19 crisis. It can even be considered as an era of testing technologies in real situations to determine which technologies have advanced enough so that they can be the solution to some of the human's challenges. Ting et al. considered 2020 to be the beginning of an exciting decade in the development and maturation of digital technologies to overcome clinical problems and diseases (38). Ienca and Vayena reported that most countries are trying to use digital technologies to combat the ongoing COVID-19 pandemic (44).The CDC, as a disease control and prevention organization, considers the existence and use of technology in COVID-19 management to be so necessary that states "identify existing and needed technology resources by assessing and updating the availability of technology and equipment, so they would be ready for immediate use. If required resources do not exist inside your organization, create a plan for acquiring them, or identify sources from which you can access technology during a COVID-19 outbreak" (45).Therefore, modern technologies are powerful tools in controlling emerging diseases and can facilitate the passage of this crisis by increasing their appropriate capabilities.

Ting et al. state that four technologies of AI, IoT, bigdata, and blockchain are important and effective in the management of COVID-19. These technologies are highly inter-related. Collecting related data via IoT in hospitals creates an interconnected electronic ecosystem, and leads to the aggregation of a large amount of real-time data from COVID-19. Data is stored and distributed in a secure platform with the support of blockchain technology, so various applications of AI can provide the appropriate analysis of COVID-19 based on the needs (38).Thus, these four types of technology create a network that covers real data collections and complex analysis and provides timely reports of the disease situation for timely decision-making and action planning.

Wang et al. used AI technology to save critical time in diagnosing coronavirus cases. Based on radiographical changes in 453 CT scans of people with COVID-19, an image algorithm was created that could extract COVID-19's graphical features. This technology, which was formed using deep learning, was validated with an accuracy of 82.9 %, specificity of 80.5 %, and sensitivity of 84 % (17).Therefore, AIis using capabilities such as machine learningthat can play a significant role in the rapid diagnosis of COVID-19 using severalfeatures.

Wang et al. are explaining Taiwan's experience regarding big data use to prepare and deal with COVID-19. Given the New Year and Taiwanese people's physical contact with Chinese people, Taiwan has taken a new approach in identifying cases and allocating resources ahead. It integrated the national health insurance database with immigration and customs databases to create big data for analytics. This system generated real-time alerts during a clinical visit based on travel history and clinical symptoms to aid case identification (46). Thus, the high volume of data provides power which makes it possible to identify the trend of the COVID-19 and new cases of infection.

Zheng et al. emphasize the importance of individuals' isolation and their continuous monitoring so that they designed the intelligent monitoring system by combining the Internet of Things and blockchain technologies to achieve this goal.In this system, IoT tools feed a smart contract through master devices by collecting location and physical data of isolated individuals.When the data reach the threshold, an alarm is sent to an isolated person and the CDC via master devices.All these events are stored in a secure blockchain platform.This system is described as an effective and integrated system for real-time monitoring of the isolated individuals and the CDC can provide a quick response by receiving the alarm promptly (47). So, the combination of the IoT and blockchain provides an opportunity for collecting data from objects without human contact and flowing in a secure platform for data-driven applications.

Therefore, according to the experience of different countries and the positive results of

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technologies in new coronavirus management; different communities can use these technologies by considering their conditions and facilities. In this situation, for more synergy, a combination of technologies can be used seamlessly to reduce physical interactions among individuals and combat the global crisis by cutting off the virus transmission chain.One of the limitations of this study was the lack of access to real examples of applying some technologies due to their immaturity which has limited their practical explanation.

Conclusion

It can be concluded that the threat of nCOV-19 has become an opportunity for a variety of technologies to test themselves in real conditions. In the meantime, technologies with the ability to reduce human contacts through teleservices as well as those that quickly enable decision-making via in-depth analysis received more attention among the health authorities and organizations.

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Conflict of interests

The authors declared that there was no conflict of interests.

Authors' contributions

Mastaneh Z and Mouseli Adesigned research; Mastaneh Z reviewed the literature, extracted and summarized the results; and Mastaneh Z and Mouseli A wrote manuscript. All authors read and approved the final manuscript.

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