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Informatics in Medicine Unlocked 21 (2020) 100475

Contents lists available at ScienceDirect

Informatics in Medicine Unlocked

journal homepage: http://www.elsevier.com/locate/imu

Information technology in emergency management of COVID-19 outbreak

Afsoon Asadzadeh, Saba Pakkhoo, Mahsa Mirzaei Saeidabad, Hero Khezri, Reza Ferdousi *

Department of Health Information Technology, School of Management and Medical Informatics, Tabriz University of Medical Sciences, Tabriz, Iran

ARTICLE INFO

Keywords:
Outbreak
COVID-19
Emergency management
Information technology
Disaster
Epidemic

ABSTRACT

Emergency management of the emerging infectious disease outbreak is critical for public health threats. Currently, control of the COVID-19 outbreak is an international concern and has become a crucial challenge in many countries. This article reviews significant information technologyIT) applications in emergency management of COVID-19 by considering the prevention/mitigation, preparedness, response, and recovery phases of the crisis. This review was conducted using MEDLINE PubMed), Embase, IEEE, and Google Scholar. Expert opinions were collected to show existence gaps, useful technologies for each phase of emergency management, and future direction. Results indicated that various IT-based systems such as surveillance systems, artificial intelligence, computational methods, Internet of things, remote sensing sensor, online service, and GIS geographic information system) could have different outbreak management applications, especially in response phases. Information technology was applied in several aspects, such as increasing the accuracy of diagnosis, early detection, ensuring healthcare providers' safety, decreasing workload, saving time and cost, and drug discovery. We categorized these applications into four core topics, including diagnosis and prediction, treatment, protection, and management goals, which were confirmed by five experts. Without applying IT, the control and management of the crisis could be difficult on a large scale. For reducing and improving the hazard effect of disaster situations, the role of IT is inevitable. In addition to the response phase, communities should be considered to use IT capabilities in prevention, preparedness, and recovery phases. It is expected that IT will have an influential role in the recovery phase of COVID-19. Providing IT infrastructure and financial support by the governments should be more considered in facilitating IT capabilities.

1. Introduction

Many disasters can be categorized into natural and human-made groups, and for dealing with them, collaboration, leadership, and management have a foundational role [1,2]. According to the literature, a crisis could be divided into four phases: prevention/mitigation, preparedness, response, and recovery, which refer to diminishing or eliminating the probability of disaster, preparing to handle, immediate reaction to safety, and return to normal situations. Therefore emergency management requires more consideration to control and manage the disaster [1,3–5]. Emergency management of health-related events can be achieved by considering the different aspects of knowledge, behavior, health care system, and public health system. Moreover, the operation and configuration of the emergency management systems should be considered [6].

When the community encounters infection outbreaks, it means the growth rate of illness becomes excess rather than of average expectancy [7]. In the 21st century emerging and re-emerging infectious disease outbreaks are rapidly increasing significantly in developing countries with devastating health, economic, and social consequences [8]. In recent years, viral outbreaks such as Pandemic Influenza A H1N1), Avian influenza A H7N9), Middle East respiratory syndrome MERS), and severe acute respiratory syndrome SARS), were epidemic [9–12]. Emergency management of infectious disease outbreaks is essential because they can negatively impact public health, travel, and economics [13]. Hence, numerous factors, such as the number of cases, risk factors, intensity, outcomes, and transmission speed, are required to manage infectious disease epidemics [14].

Recently, **COVID-19** as an emerging virus has become a major international public health disaster because, in a short period, the number of cases increased significantly at first in China and then in several countries around the world [15]. COVID-19 occurs at a severity level of slight to imminent. The COVID-19 can transmit indirectly by contamination of objects, asymptomatic cases, and aerosolization. However, it

* Corresponding author.
E-mail address: ferdousi.r@gmail.com (R. Ferdousi).

https://doi.org/10.1016/j.imu.2020.100475
Received 24 August 2020; Received in revised form 5 November 2020; Accepted 6 November 2020
Available online 13 November 2020
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can also transmit directly through symptomatic patients [16,17]. Fever, cough, myalgia or fatigue, chest tightness, shortness of breath, expectoration, and dyspnea were reported as significant symptoms of COVID-19. There can be severe complications, including pneumonia, severe acute respiratory distress syndrome, and death [18,19]. There is a need to conduct a quickly targeted action and risk assessment, particularly at healthcare and social institutions with a high risk of transmission [20]. Using educational tools, health recommendations, infection control approaches, and infection prevention strategies could enhance healthcare providers' safety protection [21–23]. Regarding the negative impact of COVID-19 on society, economy, and global value chains, the control of the virus in the early-stage has a critical role in preventing and managing the further outbreak [24,25].

The control of each phase of the crisis can be reached or facilitated using information technology IT). IT has become popular to use in public health surveillance. Evidence indicates that IT could be a useful approach in each phase of the disaster, particularly in the response phase [4,26–29]. IT was used as a beneficial approach to increase the speed of diagnosis, improving epidemic management, save lives, and reduced the economic impact of outbreaks [30]. For example, surveillance cameras, drone-borne cameras, and portable digital recorders can monitor crowd gathering in public areas and are useful in monitoring diseases [31]. Many of these tools and techniques support emergency conditions and offer learning opportunities for providing healthcare in similar situations. For example, virtual reality-based training as a novel technology can be used to prepare and respond to different outbreaks [32]. Moreover, recent IT-based technologies e.g. digital communication technologies, data science, crisis informatics, bioinformatics, and computational modeling) provide new opportunities to reduce pandemics risk and response to international pandemics [33–35].

There are several reports and studies about the utilization of IT capabilities during the COVID-19 outbreak. The studies have used IT for different aims such as accurate diagnosis, statistical reporting, monitoring and controlling disease, forecasting, etc. [36–39]. Besides, technology startups are working with government agencies, clinicians, and academics to prevent/control the outbreak [40]. Therefore, according to IT's various advantages in the COVID-19 pandemic, presenting an overview of IT applications can help software designers, healthcare providers, researchers, policymakers, and governments obtain information and ideas in the management and control of the COVID-19 outbreak. In this regard, in this study, applications of IT in the emergency management of the COVID-19 are reviewed. However, the current study's focus is on phases of emergency management. Moreover, a taxonomy of IT capabilities for response in COVID-19 was presented. Finally, expert opinions were collected to show the gaps, beneficial technologies, and future directions for each phase of the emergency management of COVID-19.

2. Methods

This review was conducted to identify IT applications in emergency management of the COVID-19 outbreak. The search was carried out in MEDLINE PubMed), Embase, IEEE, Google Scholar, and Google search engine up to July 2020. The searching keywords were selected by consulting with experts in the related fields, including medical informatics, health information technology, and librarian science experts. The recruited keywords in this study were as follows: information system, informatic*, decision support system, decision management system, dashboard, sensor, technology, information technology, Internet of things IoT), telehealth, telehealth, telemedicine, Electronic health, eHealth, e-health, surveillance system, artificial intelligence, AI, management system, mobile, mobile application, mobile health, portal, web, social network, health information technology, telemonitoring, geographic information system, GIS, virtual reality, Google trend, covid 19, 2019 ncov, coronavirus, novel coronavirus, coronavirus 2019, sars cov 2, coronavirus disease 2019, "Severe acute respiratory syndrome coronavirus 2".

All papers were included if they used each type of information technology for emergency management of the COVID-19 outbreak. Five authors carried out study selection and data extraction. Disagreed items were discussed and resolved in the online group. After information gathering, a taxonomy was presented for checking the contents of findings. The classification and results were sent to five experts with Ph. D. degrees and related experience to validate the taxonomy. Finally, an unstructured interview was conducted through eight experts, including health information technology N = 2), medical informatics N = 3), and IT experts N = 3), to determine useful tools for each phase of emergency management and future direction.

3. Results

3.1. Taxonomy of IT application in the response phase

In this review, applications of IT for the response to the COVID-19 outbreak were classified and summarized to the following core topics: 1) detection and diagnosis, 2) treatment approach, 3) protection strategies and, 4) management aims. Fig. 1. Shows these topics and involved technologies.

3.2. IT applications for COVID-19

Based on this review's findings, there were no efforts for the pre-crisis phases of emergency management, including mitigation/prevention and preparedness. In contrast, many advantages of IT were studied and reported in the response phase. However, after the COVID-19 outbreak, studies for the recovery phase should be completed. Table 1 shows the IT applications in the response phase of the COVID-19 epidemic.

3.2.1. Bioinformatics systems

Bioinformatics systems using various methods such as deep learning, machine learning [120], virtual screening, etc. have been applied to quick drug discovery [121]. In other words, the immediate discovery of COVID-19 antiviral plays a critical role in overcoming outbreaks [40,41,43–54]. Virtual drug screening is a useful and affordable approach to rapidly identify effective antiviral agents and potential protein targets. Traditional drug investigation has high cost and needs time to develop [40,46–51,122]. Some of the protocols or methods used for computational drug discovery include ligand/target-based virtual screening, molecular docking, homology modeling, molecular dynamics simulations, small molecule docking, and machine intelligence-based GNC, homologous targets screening, and structure-based ab initio drug design [54,123].

3.2.2. Artificial intelligence AI)

Concerning the rapid spread of COVID-19, the use of AI with various capabilities is a useful technology in the faster diagnosis of positive cases, managing the outbreak, and reducing the further outbreak of COVID-19 [39,57–68,95]. AI-based analysis and diagnosis help physicians diagnose, judge, and improve patient safety by increasing accuracy, speed of diagnosis, and screening. AI could protect health care workers by giving information and by providing critical medical recommendations [62,63]. AI uses deep learning algorithms for solving complex problems to improve the accuracy of results. For example, Covid-19 symptoms are nonspecific. Hence, AI uses deep learning methods as a useful technique for accurate, timely, and sensitive extraction of unique medical images' features that facilitate the diagnosis [61]. Many studies have used deep learning for various aims such as lung infection quantification, improving diagnosis, detection, patient monitoring, quick screening, and drug discovery [65,124–126].

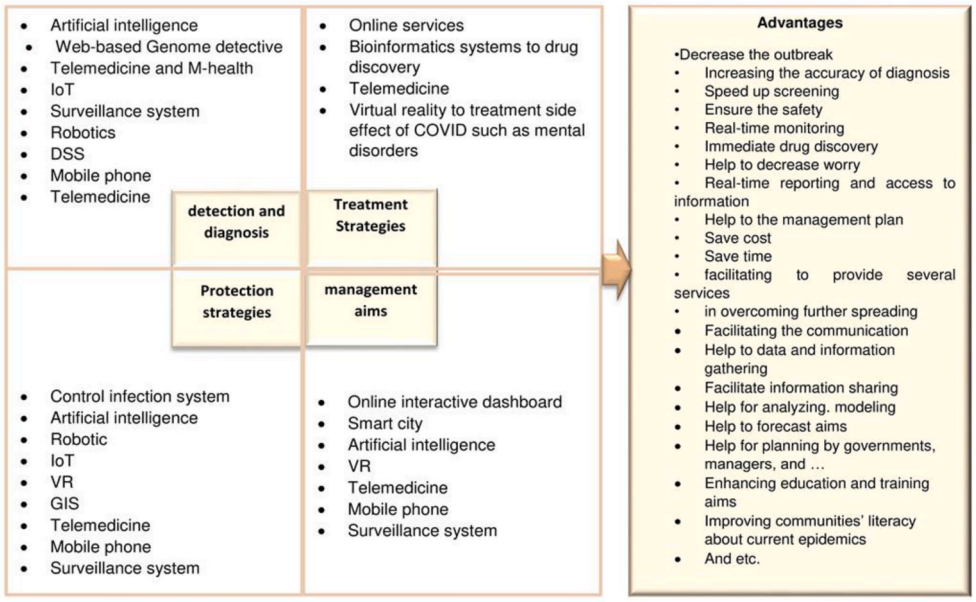

Fig. 1. Overview of IT application for COVID-19 outbreak.

3.2.3. Telemedicine

Face-to-face communication between people and healthcare providers is a serious challenge during the fast prevalence of COVID-19 [23]. However, limited access to specialists, particularly in rural hospitals, is another problem. Telemedicine services were used to remotely share the healthcare services by using a doctor-to-doctor approach to diagnosis and consulting aims [71]. Telecommunication and online education can be an unprecedented solution to reduce the destructive impact on this epidemic's cultural and educational consequences, such as environmental risks, physical health, mental health, and social life [70]. Hence, the control and treatment of individuals' psychological problems were facilitated by developing online mental health services [72].

3.2.4. Mobile phone

Mobile technology has been widely used in this period due to its accessibility [60,72,74–76,110]. For example, a phone-based online survey was used to assist in the early screening, diagnosis, and identification of COVID-19 infected individuals [60]. Moreover, mobile phones are the most popular tools for informing public health, performing telemedicine, educating, and training [60,72,74–76,110].

3.2.5. Decision support system

For administrational and clinical aims, DSSs could be developed to help decision-makers managers or healthcare providers) make the appropriate decisions. For example, determining the severity score of COVID-19 patients and supply chain management are two applications of DSS that were established to respond to the COVID-19 outbreak [78–80].

3.2.6. Infection control system

Health providers in hospitals particularly negative pressure isolated units) have the most exposure during patient care. The infection control systems by real-time monitoring are used as an influential tool for decreasing the infection, leading to immediate protection and corrective response [38].

3.2.7. Robotics

The primary purpose of designing robots is to perform the most hazardous actions, instead of medical staff, on COVID-19 patients. Robots could protect health care staff during medical procedures. However, robots also facilitated other tasks that could reduce transmission of infections e.g., disinfection, real-time monitoring, and early screening and diagnosis) [80,82–86].

3.2.8. Online interactive dashboard/GIS

Various information types, including location, number of new cases, number of death, number of recovered cases, and controlling trends of the outbreak, are reported using the online Dashboards e.g., WHO, Johns Hopkins CSSE, and Early Alert Inc dashboard). As an essential data source, Dashboards are supervised by regional and local health departments [87–90]. Moreover, GISs are useful tools by providing various information could result in better management of the outbreak. Identifying the spreading sources, location-based data for analysis/modeling, informing public events, site selection, supply chain management, and resource locator are advantages of using GISs [91–93].

3.2.9. Internet of things IoT)

For screening and monitoring COVID-19 patients, health-related data such as body temperature are captured using smart sensors at different places such as airports, bus terminals, and health organizations in smart cities. Additionally, IoT applications such as collecting data and information, monitoring or tracking COVID-19 patients, monitoring infected regions, and information sharing could be beneficial in preventing further spreading [98–102].

3.2.10. Virtual reality VR)

Virtual reality technology is defined as a computerized simulation of the real world using various software and hardware [127]. According to human demands, VR has multiple applications by providing a virtual world for relaxation, traveling, video calls, improving mental disorders by reducing stress, and training healthcare providers [99,104,105].

3.2.11. Surveillance system

The safe city can be determined by adopting a terminal tracking system. Surveillance systems are useful to identify individuals with COVID-19 symptoms and quarantine them. In other words, by applying this technology, COVID-19 cases are screened and diagnosed quickly. Surveillance systems are capable tools for the safety protection of public

Table 1
Information technology based approaches employed in the response phase of the COVID-19 management.

IT types	Applications according to literature	Example	References
Bioinformatics systems	✓Help to Drug discovery by various methods such as: •To identify existence therapeutic agents •Rapid detection of COVID-19 •classifying and tracing the genomic sequence of COVID-19 •the discovery of COVID-19 antiviral and potential protein targets ✓Help to diagnosis	*In Italy, virtual screening of FDA approved databases indicated some of the HIV protease inhibitors might be useful in COVID-19 treatment * chemical-informatics approach by integrating different ligand-based drug design strategies of some *in-house* chemicals was developed to help in the process of drug discovery in India * Modeller's version 9.11 was used to probe the molecular architecture of SARS-CoV-2 3CL and comparative homology modeling in China, as well, by using version 0.6 of MEGA software and the ProtParam tool, similar sequences and instability indices identified * In China, Isothermal LAMP-based method-iLACO adopted for rapid colorimetric detection of 2019-Novel Coronavirus RNA viruses) * web-based Genome Detective software used to help in immediate and accurate diagnosis of COVID-19. Moreover, the use of the mentioned system has the potential to characterize new mutations of viral	[40–57]
Artificial intelligence/ deep learning and Machin learning	✓Diagnosis ✓practical surveillance in quick detection and diagnosis of infection prediction ✓improving the CT diagnosis speed for each case even in some cases better than RT-PCR screening ✓early infection detection ✓to help physicians in quick diagnosis and judgment by the accurate screening of COVID-19 ✓AI tracking platform is interfaced hospitals for	* a free online screening toolkit defined as "COVID-19 Quick Test" was designed to help that citizens quickly recognize their health status and infection risks in China, as well, it offers recommendations according to the screening results * AI with deep learning method was used as a useful technique for accurate, timely, and	[39, 57–69]
	sharing information ✓Therapeutic monitoring ✓projection of infected individuals and mortality ✓drug discovery ✓traffic management ✓logistics supply chain ✓provides self-registration and crowd management modules for high-risk populations ✓to protect health care workers by giving information and alarming about COVID-19, critical medical recommendation ✓improved patient safety by increasing accuracy and speed of diagnosis and screening ✓Reducing healthcare providers' workloads ✓Help to prevention ✓Forecasting of disease ✓Lung Infection Quantification through CT images	sensitive extraction of unique features of images and facilitate the diagnosis in China. * In China, AI has improved the CT diagnosis speed for COVID-19 cases in some cases, it was better than RT-PCR screening) *AI platform provides self-registration and crowd management modules for high-risk populations, as well, the AI tracking platform is interfaced with more than 400 hospitals for sharing information	
Telemedicine	✓Telecommunication by online education ✓to reduce the impact on the cultural and educational consequences of this epidemic, especially for children who are vulnerable to environmental risks and their physical health, mental health, and productivity in adult life ✓overcome to limited access to specialists, particularly in rural hospitals ✓remotely sharing health care services by using of doctor- doctor approach to diagnosis and consulting aims ✓Alternative for face-to-face communication between people and health care providers ✓control and treatment of psychological problems such as depression, stress by developing online mental health services	*In China, Emergency Telemedicine Consultation System ETCS) has developed telemedicine services across connected hospitals to share health care services by using a doctor-to-doctor approach to diagnosis, treatment, and consulting aims * NoviGuide as a guideline based software was used for point-of-care decision support in health systems for COVID-19 diagnosis *Consult Station Medical Booths was developed for telemonitoring and screening of Covid-19 cases	[23, 69–72]
Mobile phone	✓Collecting the basic travel history along with the more common indexes ✓to assist in the early screening and identification of possible COVID-19 infected individuals ✓Informing health-related news ✓Remote teleconsultation such as	*mHero Health as a mobile phone-based system was used for health worker communications by using text messaging or SMS, *Community Health Toolkit was used for providing health communication between health workers and	[60, 72–76]

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Table 1 (*continued*)

IT types	Applications according to literature	Example	References
	Mental health advise ✓telemedicine outpatient services ✓Group consulting ✓Education and training ✓monitor chronic orthopedic ✓Radiodiagnosis ✓Monitoring of COVID-19 individuals ✓Triage for avoiding face to face or unnecessary visits	supervisors, *HealthBeats Remote was used for vitals monitoring at home, *CommCare Case Management software as open-source mobile case management was developed for COVID-19 diagnosis	
Decision support system	✓Risk assessment for suspected individuals ✓to assist GPs ✓can use in healthcare supply chain ✓can help to demand management in the health care context ✓for characterizing severity of COVID-19 ✓Triage of COVD19 Patients	*a mobile-based DSS was developed to assist GPs in gathering data, triaging, and risk assessment in China * a clinical DSS was developed for prediction of severity risk and triage of COVID-19 Patients at hospital admission at Wuhan China	[77–81]
The infection Control system in hospital	✓decrease of infection by real-time monitoring leading immediate protection and corrective response ✓protecting the safety of staff	* the initial infection control system was used as an influential tool for decreasing infection by real-time monitoring, providing immediate protection and corrective response in China.	[38]
Robotics	✓to perform most of the hazard actions instead of health providers on COVID-19 patients ✓protects the safety of health care providers ✓to assist in patrolling and monitoring the COVID-19 by public safety authorities, health authorities, and businesses ✓use robot-controlled noncontact ultraviolet UV) surface in prevention aims ✓to sterilize all high-touch surfaces ✓for autonomous or remote-controlled disinfection ✓mobile robots are useful for diagnosis and screening trough temperature ✓used to repetitively monitor temperatures of individuals in the hospitals with data sharing to hospital information systems ✓to use instead of experts in remote areas, especially in quarantine conditions ✓to assist surgery during the pandemic ✓protecting by using robotic potentials such as Receptionist Robots, Nurse Robots, Ambulance Robots, Telemedicine Robots, Serving Robots in Hospital, etc.	* a robot designed to perform most of the hazard actions such as ultrasounds, take mouth swabs and listen to sounds made by a patient's organs instead of health providers on COVID-19 patients at a Chinese university. * In China, autonomic robots developed to assist public safety authorities, health authorities, and businesses in the COIVD-19 hit regions by following tasks: 1) Police use Robots for patrolling and monitoring 2) Driverless sweeping vehicles help to keep the city clean 3) Disinfectant Robots aid in bringing in a new level of epidemic resistance	[80, 82–86]
online interactive dashboard/ GIS	✓easy capture, identify, and statistical report the location and number of new cases, death, recovered cases ✓Help control the outbreak and improve the fight against the infectious disease epidemic ✓providing various information such as outbreak source, public events, site selection, supply chain, and resource locator ✓critical source for delivering and collecting information ✓to use in analyzing, modeling/spatial modeling of disease, and forecasting aims ✓To provide web-based mapping ✓to provide health geography ✓Risk assessment through GIS	In the following, dashboards that used during COVID-19 pandemics was indicated: WHO, Johns Hopkins_CSSE, and Early Alert Inc dashboards	[87–97]
Internet of things IoT)	✓Screening and monitoring health data by using smart sensors at different places such as airports, terminal buses, health organizations in smart cities ✓Forecasting COVID-19 patients ✓Informing healthcare providers and providing quick response between healthcare providers and patients ✓To help remote consultation among patients and healthcare providers ✓To assist quickly identify COVID19 cases ✓To facilitate information sharing ✓Real-time monitoring and tracking ✓To support diagnosis e.g., Smart Helmet) ✓use in prevention and control of COVID-19 disease ✓Reduce the workload in health care organization	* a smart helmet with a combination of Mounted Thermal Imaging System, thermal camera technology, and IoT technology was designed to diagnose the COVID-19 from the thermal image automatically. IoT helps to detect infected cases by providing real-time data and monitoring the screening process * In China, the COVID-19 intelligent diagnosis and treatment assistant program nCapp)" based on the IoT was developed to diagnose infected cases early. * Internet of Medical Things IoMT) was developed for providing treatment aided to orthopedic patients, especially in remote areas during the COVID-19 pandemic through data gathering, report monitoring, testing,	[98–103]

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Table 1 (*continued*)

IT types	Applications according to literature	Example	References
		and analyzing of images	
Virtual reality VR)	✓rehabilitation Physical therapy, Cognitive Rehabilitation) ✓using by patients in the hospital for controlling stress ✓Mental health and psychological Disorders ✓Pain management ✓training purpose ✓Palliative Care ✓Virtual traveling ✓Virtual communication and collaboration	* a 360 -Degree VR Rendering of COVID-19 was used to visualize the better extent of COVID-19 inflicted damage to the lungs scan at Washington university hospital *During the COVID-19 outbreak, PwC has increased its use of VR training for managers especially while managers are working remotely) to soft skills related to leadership, diversity, equity and inclusion, and harassment prevention. * For the first time, NHS staff tackling Covid-19 on the front line are using virtual reality to support their mental health and wellbeing.	[99, 104–108]
surveillance systems	✓surveillance systems are useful to identify quarantine individuals with COVID-19 symptoms ✓increase in response to COVID-19 cases ✓enhancing staff protection in a healthcare setting ✓improving health surveillance policies ✓to estimate COVID-19 growth rate through surveillance systems ✓early detection ✓timely updates of references and population's data ✓to help governments to create time for preparedness	*the COVID-19 Laboratory-Based Surveillance System was used in Islamabad-Pakistan, which could provide the initial aims of the surveillance such as risk factor information of all suspected cases, providing timely and accurate reports * one health surveillance OHS) system was developed for early identification of COVID-19 to break the chain of transmission in India	[98, 109–115]
internet search queries	✓Google Search Volume Index for: •Showing information flow of the COVID-19 pandemic •raising public awareness •an epidemiologic surveillance tool •online tracking system for COVID-19 pandemic ✓internet search data shows information-seeking responses to news of local COVID-19 cases and showing web-search behavior	*Google trend was used to study correlation about loss-of-smell–related searches during the COVID-19 outbreak. According to the results, there is a strong correlation between them *Internet search data indicate societies respond to early report of COVID-19 pandemic in their state by closely seeking information about COVID-19. It was measured by searches for coronavirus,	[116–119]

Table 1 (*continued*)

IT types	Applications according to literature	Example	References
		coronavirus symptoms, and hand sanitizer. * in Italy, web search behavior during the COVID-19 outbreak was more related to "face masks," "amuchina" disinfectant), "symptoms of the novel coronavirus," "health bulletin," and "vaccines for coronavirus."	

health [98,109–113].

3.2.12. Internet search queries

Internet search queries e.g., the Google search volume index) were used to capture the penetration of information related to the COVID-19 pandemic. For example, Sousa-Pinto et al. showed that COVID-19–related Google trend data are more related to media coverage than to epidemic trends. Furthermore, people's web search behavior during the pandemic could be identified by analyzing internet search queries [116–119].

3.3. Experts opinion for IT applications in emergency management of COVID-19 outbreak

Table 2 shows existing gaps, future directions, and experts' opinions regarding what technologies were suitable for each phase of emergency management in the COVID-19 outbreak.

According to experts' opinions, all IT utilization in each phase of emergency management of pandemics depends on aims, IT infrastructure, IT literacy, economy, IT acceptance, and government support in each country.

4. Discussion

This review has presented IT applications in four-phases of emergency management, including mitigation/prevention, preparedness, response, and recovery for the COVID-19 epidemic. It seems that before the COVID-19 outbreak, there were not performed pre-crisis efforts mitigation/prevention, preparedness phases) for facilitating a pandemic, while IT advantages were already proven for other viral outbreaks such as SARS, MERS, and H1N1 [119,128–136]. In the mitigation/prevention phase of emergency management, IT was used for different aims. Optimal evaluation and selecting the best influenza mitigation strategies by Bayesian algorithm, providing the framework for modeling epidemic spreading and mitigation, comprehensive interactive model for predicting geographically epidemic progression, the control system for early detection of disease, the mathematical decision support tool for modeling mitigating infectious disease pandemics, deep learning short-term memory LSTM) methods for influenza epidemic prediction, flood risk management information system to support natural disaster mitigation measures are some IT-based strategies for the mitigation/prevention phase [137–150].

In the preparedness phase of previous infectious disease pandemics, the AI prediction platform AiRBO) and Canadian automatic infectious disease surveillance BlueDot) were used for correctly predicting the location and the outbreak occurrence [60,128]. The mobile phone was used to report and reach local healthcare agencies. The global epidemic and mobility model GLEaM) is a computational epidemic model used to

Table 2
IT roles in each phase of emergency management according to experts opinions.

Emergency management phase	Identified gaps	*what tools are more powerful/useful*	*Future direction*
Prevention/ mitigation	*inadequate education for societies against infection outbreak before occurrence it *inadequate monitoring and controlling system in many countries * Lack of accurate predictive and forecasting models before the infection pandemic *inadequate management of resources equipment, human, etc.)	*virtual reality for training aims *mobile health capabilities for education aims *Internet of Things IoT) and surveillance system for health monitoring aims *Robotics for monitoring purposes and using them as an alternative for human resources * developing infection control system in hospital for alerting general symptoms of patients *AI and deep learning methods for developing forecasting models	*Communities should learn how to respond to infection outbreaks in stressful conditions so the use of a designed VR environment can immerse users in simulated situations to experience the adverse condition and learn how they should answer to infection epidemics before the occurrence of them *countries should be equipped with IoT and surveillance systems to screen and monitor the people and environmental factors to provide safe and healthy communities. *development of robots can play an essential alternative for limited human resources and hazard tasks. *Hospitals should be equipped with control systems to control the environment and patient condition automatically *forecasting and predictive model should be used for predicting emergency conditions for conducting prevention efforts. *improvement of IT literacy in communities
Preparedness	*inadequate management of resources such as healthcare centers, human resource *Inadequate education and informing about adverse effects of an infectious outbreak and efforts against the pandemic * inefficient smart technologies to help early screening and diagnosis before the pandemic occurs *inadequate information system for help manages, governments, and healthcare providers in decision making	*mobile technologies for education aims *information systems for management and control of resources *VR for preparing people to respond against infection disease *develop robots for doing hazardous tasks and alternative for human resources * development of smart cities by using intelligent technologies for screening people across cities *development of decision support system for clinical and administrative aims *improvement of IT infrastructure in countries	*mobile technologies can improve people skills for preparing people to respond to infection outbreaks when a pandemic occurs *VR should be used for preparing people before pandemics to education response, prevention, and preparedness requirements *cities should equip with smart technologies for early screening and diagnosis of patients e.g., IoT could be used for measuring body temperature, or surveillance system for monitoring detecting disease symptoms.) *improvement of IT infrastructure *improvement of electronic-governments in each industry such as healthcare, business, education, and so on *clinical and administrative DSS could help to achieve an optimal decision, especially in stressful conditions.
Response	*Lack in immediate response to pandemic *Inadequate in the use of all IT capabilities in some countries	In the response phase, all types of technologies must be used to achieve an effective response see Table 1)	*Effective response to a pandemic is related to good planning in the prevention and preparedness phases, which should be considered in communities. * developing IT-based services delivery in healthcare and business are essential issues in immediate response o pandemics
Recovery	Need to planning at present for post-crisis	*Mobile technologies, telehealth, social media, and VR can be used for mental health recovery. *Use or continue the use of technology-based business and health services for saving time and cost e.g., telehealth, telemonitoring, online services, and so on) *management of resources by using information systems *Administrative DSS for helping managers to achieve optimal recovery *providing educational contents for transmitting experiences in the future	*mental disorders such as depression, stress, and phobia are common after infection outbreaks, and IT-based technologies such as telemedicine, mobile health, and VR can play a critical role in the recovery phase *Negative effects of outbreaks in economy and business could be improved by using IT-based solutions such as online services delivery and decision support systems for administrative and clinical aims. *Using databases and big data for

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Table 2 (*continued*)

Emergency management phase	Identified gaps	*what tools are more powerful/useful*	*Future direction*
			providing strategic planning in the future *Using decision systems can help managers make decisions by considering different dimensions such as time, place, cost, resources, etc. *Improvement of IT infrastructure and literacy

simulate the worldwide spread of influenza-like illnesses [151,152]. Web-based systems as an immediate surveillance tool are useful in predicting epidemics and creating preparedness plans against outbreaks [153]. Accordingly, investigation of the previous experiences of epidemics is an essential issue; in other words, lack of appropriate planning to answer serious concerns such as COVID-19 has led to such disagreeable conditions in many countries.

Concerning the COVID-19 outbreak, most of the efforts were conducted after the crisis occurred. Currently, IT has a critical role in the response phase of emergency management because there is a need for immediate reaction to disaster to reduce the hazard effect of the COVID-19 epidemic. Our review indicated that IT has a beneficial role in responding to emergency management by providing safety, immediate response, and easing the actions. Real-time control, monitoring and exchange information, response coordination, optimal use of time and cost, optimal screening, optimal diagnosis, and treatment are some benefits of IT during COVID-19 outbreak [38,40,45–52,61–63,71,72,74,82,83,87–93,98,105,109,110,131,132,140,154]. Furthermore, AI, computer-aided drug discovery, online service, robots, image processing, mobile health, and virtual reality are some other technologies that are used during the COVD-19 epidemic [44–47,60,61,83]. Portable analytical devices for point of care and easily screen of coronavirus infection [155], facilitating the detection of the adult respiratory virus by fully automated multiplex Polymerase chain reaction PCR) system [156], support vector machines SVM) for prediction of the severe acute respiratory syndrome [129], applying various computer-aided methods to drug discovery of epidemic infection [130,133,157–159], using IoT for Smart monitoring and management of MERS or SARS [131,136], cloud computing and social networks analysis with good accuracy as a useful tool for analyzing and monitoring H1N1outbreak [134] are other experiences of IT in infectious disease management. Many smartphone apps for several aims, such as education, alerting, facilitating the data exchange, communication, and coordinated reaction to respond in an emergency disaster, were developed [160,161]. Therefore, many forms of IT applications could be used in disaster situations to achieve safety and reduce the viral outbreak's hazard effect.

Finally, for the recovery phase of COVID-19, we have to wait for the disaster's ends. However, IT's role in the recovery phase of the previous disasters using social networks, mobile health, etc. in recovering mental health, economy, and organizations function is proven [162–169]. Indeed, mental disorders and economic problems will arise as important implications of COVID-19. Social networks for meditation, sport, healing, and sharing experiences with psychologists and social workers could play a useful role in the recovery of negative psychological effects of pandemics such as depression, anxiety, and phobia. Besides, mobile health tools such as cell phones, tablets, computers, personal digital assistants PDAs), and monitoring devices could be used to enhance health by providing self-care, self-management, and health-monitoring apps for managing stress, physical activity, and healthy eating behaviors. Economic problems due to decreased incomes is expected in this period. Therefore, information technologies could provide exciting tools for economic recovery during and after the COVID-19 pandemics. In other words, public organizations and agencies could consider social networks and online web-based solutions in their marketing program. Communities should use the experiences of the current condition for prevention aims in the future. Also, organizations could use databases with the content of COVID-19 data to change and improve their management strategies. Besides, Social network analysis of disaster conditions has a significant role in enhancing knowledge management, especially in the sharing, capturing, and using of knowledge. Data mining techniques can be used to predict and develop appropriate disaster management strategies from the collected information about epidemic diseases.

IT has proven its various capabilities for all phases of emergency management in previous infectious disease outbreaks. We should consider that facilitating and overcoming the crisis will be difficult without the use of IT. Unfortunately, more efforts to overcome infectious disease outbreaks such as COVID-19 usually are conducted after a crisis occurs. In other words, most IT applications were highlighted in the response phase, while the use of IT capabilities before the crisis has a critical role in reducing the destructive effect of infectious disease. For example, predicting, modeling, educating, training, informing, and automated alarming can be conducted before the crisis using various IT-based approaches. Many of the problems with COVID-19 are related to emergency management before it occurs. In addition to IT advantages in emergency management, some barriers i.e., lack of financial resources, poor organizational coordination, and collaboration of government, security problems, and privacy in e-government) should be addressed as much as possible.

There are different examples for each IT application during the COVID-19 outbreak. However, neglected tools for emergency management of COVID-19 should be extracted for each country according to their IT infrastructure, income level, etc. For example, smart city features could help in early screening and diagnosis of infected cases. However, it has not been provided in many cities. In this study, we tried to present an overview of the IT application and the existing gaps in the emergency management of the COVID-19 outbreak.

5. Conclusion

Applications of Information technology are an inevitable issue in any disaster situation, such as the COVID-19 outbreak. The crucial role of IT in the response phase of emergency management was highlighted during this period. Using IT could help manage the risk and hazardous effects of the outbreak and minimize the crisis damages. Successful experiences of various IT applications in countries during epidemics could enlighten the societies about infectious disease and outbreak management. There was no proper planning for emergency management of COVID-19 before the virus appeared, which could be a reason for the further spreading of this epidemic around the world. Improving technologies for predicting infectious disease outbreaks should be considered because they have an essential role in enhancing the country's and government's capabilities to cope with epidemics before they are involved in hazardous epidemics. Appropriate strategic planning will improve public health response to outbreaks, mitigate economic losses, and save lives. To sum up, the communities should utilize the maximum advantage of IT to support emergency management.

Sources of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Consent

Studies on patients or volunteers require ethics committee approval and fully informed written consent which should be documented in the paper.

CRediT authorship contribution statement

Afsoon Asadzadeh: Conceptualization, Verification, Investigation, Data collection, Resources, Writing - original draft, Writing - review & editing, Review & Editing, Visualization. **Saba Pakkhoo:** Investigation, Data collection, Resources. **Mahsa Mirzaei Saeidabad:** Investigation, Data collection, Resources. **Hero Khezri:** Investigation, Data collection, Resources. **Reza Ferdousi:** Conceptualization, Verification, Writing - review & editing, Visualization, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Not applicable.

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