Chapter 12
Mobile Technologies in Disaster Healthcare:
Technology and Operational Aspects

Samaneh Madanian
https://orcid.org/0000-0001-6430-9611
Auckland University of Technology, New Zealand

Reem Abubakr Abbas
Auckland University of Technology, New Zealand

Tony Norris
Auckland University of Technology, New Zealand

Dave Parry
Auckland University of Technology, New Zealand

ABSTRACT

The increasing penetration of smartphones and their ability to host mobile technologies have shown valuable outcomes in disaster management; albeit, their application in disaster medicine remains limited. In this chapter, the authors explore the role of mobile technologies for clinical applications and communication and information exchange during disasters. The chapter synthesizes the literature on disaster healthcare and mobile technologies before, during, and after disasters discusses technological and operational aspects. They conclude by discussing limitations in the field and prospects for the future.

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1. INTRODUCTION

Disasters are an inseparable part of human life disrupting the functioning of a community or a society by causing widespread human, material, economic, or environmental losses. According to the data from EM-DAT (Centre for Research on the Epidemiology of Disasters, n.d.), the numbers, severity and complexity (damage to life and property) of disasters have grown exponentially over recent decades. In 2019, 440 natural disasters were identified: these caused 24,117 deaths and affected a further 96.5 million people.

This chapter deals primarily with the human aspects of disasters and with the issues associated with the recent development and the role of mobile technologies in improving the delivery of disaster healthcare.

The chapter first describes the nature and types of disasters and introduces the concept of the disaster management cycle which provides a useful framework to illustrate the role of mobile and other e-health technologies. It proceeds by outlining the key aspects of healthcare needs in disasters and then describes in detail the current roles of mobile technologies in improving clinical care and information sharing in such events. The chapter ends with a look at the current limitations and future possibilities.

2. DISASTERS: NATURE, TYPES, AND LIFECYCLE

A disaster is a catastrophic disruption of the functioning of a community or a society overwhelming its capacity to respond.

Disasters can be natural or man-made. Environmental disasters, typified by earthquakes, volcanic eruptions, floods etc., are often short term in duration but they can cause massive destruction and loss of life leading to long-term human, material, economic and/or environmental consequences. Other catastrophes such as wars, terrorism, and pandemics are human centred in origin and frequently extend over a longer time scale than a point event but they parallel environmental disasters in their extended impact on individuals and societies. Climate change can be seen as an example of a potential disaster which has both natural and human sources.

The effects of all disaster types, especially those with a human origin, are readily magnified by globalisation, particularly by trade and travel, as is regrettably clear from epidemics such as Ebola, Zika, and the on-going and devastating COVID-19 pandemic.

Whether natural or man-made, a disaster is conveniently characterised by four phases that compromise its lifecycle: mitigation, preparedness, response and recovery (Baldini, Braun, Hess, Oliveri, & Seuschek, 2009). The first phase, mitigation, is concerned with preventing or minimising the negative impacts of disasters. The preparedness phase focuses on planning and preparing for possible disaster occurrence. The response phase, which often receives more attention than other phases, refers to the activities conducted immediately after the occurrence of the disaster to save lives and deal with damages. The fourth stage is the recovery stage which aims at restoring pre-disaster situations or improving them (Center for Disaster Philanthropy, n.d.).

These four phases are often referred to as the Disaster Management Cycle (DMC).

3. DISASTER MANAGEMENT, DISASTER MEDICINE, AND DISASTER HEALTHCARE

3.1 Disaster Management

Disaster management refers to the processes applied before, during, and after the occurrence of a disaster event (i.e. throughout the DMC) to prevent or mitigate its impacts (Nikbakhsh & Farahani, 2011).

Catastrophes such as 2004 Indian Ocean earthquake and tsunami (Telford & Cosgrave, 2007), 2005 Hurricane Katrina (Brunkard, Namulanda, & Ratard, 2008), and 2010 Haiti earthquake (Bilham, 2010) have led to a renewed interest in disaster management and its recognition as a distinct discipline. Many countries have given priority to the policy agenda in this field (Khan, Vasilescu, & Khan, 2008), and several international organisations also have taken the lead in this regard. The United Nations has introduced 'Hyogo' (United Nations, 2007) and 'Sendai' (United Nations, 2015) frameworks for a more proactive approach to disaster management and reducing disaster risks, losses and damages to communities, respectively. The World Health Organization (WHO) has also asked all countries in the world to set up hospitals with facilities for disaster relief (WHO, 2010).

In practice, the primary purposes of disaster management are logistical, e.g. dealing with damaged infrastructure, restoring services, setting up supply chains, moving victims to safety and seeing to their basic needs. Dispensing clinical treatment to those who need it is not the main role of disaster managers as has been noted after major disasters and terrorist attacks such as 9/11 (Kirsch & Hsu, 2008; Trzeciak & Rivers, 2003).

3.2 Disaster Medicine

The delivery of clinical services in a disaster is the responsibility of disaster medicine specialists trained to deliver emergency medicine under dynamic disaster conditions, which differ dramatically from normal medicine. For example, in disasters, medical resources are limited, stress levels are high, decisions have to be made rapidly with imperfect situational awareness, and training may be inadequate to maintain normal quality standards (James et al., 2010; Su et al., 2013) whilst firm guidance in international law and health policy can be lacking (Civaner, Vatansever, & Pala, 2017).

The necessary specialisms of disaster medicine span a wide spectrum that includes public health, paramedicine, and surgery; a range that demands efficient information sharing and effective communication across multiple agencies not only to clarify roles and responsibilities, but to avoid fragmentation and duplication in services (Abbas & Norris, 2018).

3.3 Challenges in Disaster Management and Disaster Medicine

Although disaster management and healthcare would seem to be natural allies in responding to disasters, these disciplines have not been able to jointly use their tools and personnel to prepare for and respond to serious events (Bissell, 2005). Post-event investigation shows frequent miscommunication and mismanagement (Russo, 2011), that lead to poor disaster responses and delayed evacuations. These deficiencies can be attributed to the different origins and priorities of the two sectors that inhibit a common understanding, and the consequent difficulties of obtaining and sharing vital information in a timely manner. Waeckerle, Lillibridge, Burkle, and Noji (1994) pointed out that disaster physicians, who have limited focus on issues beyond medical care, often need to interact with different organisations and agencies that operate under specific organisational hierarchy and operational modes. Similarly, disaster managers lack knowledge about the way the healthcare system responds to disasters (Bissell, 2005).

The above observations have led Ciottone (2006) to suggest that managers and disaster medicine specialists should join ranks to form teams of multidisciplinary responders having increased awareness of each other's roles, responsibilities, and priorities. Whatever the practicalities of this suggestion, the advances in communication and coordinated activities designed to reduce the health consequences of catastrophic events are at the heart of the integrated approach of disaster healthcare.

3.4 Disaster Healthcare

Disaster healthcare can be defined as the systematic process of using different skills and capacities – clinical, administrative, organisation, operational – to address the challenge of planning for, responding to, and recovering from the health consequences of disasters (Ardalan et al., 2009). The central goal is to provide urgent health interventions and ongoing healthcare during and after disasters (Zhong, Clark, Hou, Zang, & FitzGerald, 2014). Thus, disaster healthcare extends over all phases of the disaster cycle coordinating activities that range from preventive and resilience-building health services, through rapid response to victims' needs, to post-disaster rehabilitation programs (de Boer, 1995; Waeckerle et al., 1994).

Although early studies have acknowledged the role of information and communication technologies in transforming disaster management (Underwood, 2010; Waeckerle et al., 1994), their application in disaster medicine are still disparate and ad hoc. Using ICT to improve both disaster management and disaster medicine has the potential to bring about dramatic improvements in the efficiency, quality, access to, and cost-effectiveness of disaster healthcare (Sieben, Scott, & Palacios, 2012). Until recently, realising this potential has been a slow process but the advent of ubiquitous mobile technologies is now accelerating the acceptance of ICT and creating the conditions for massive improvements.

3.5 Challenges in Disaster Healthcare

Loss of infrastructure, lack of planning, inadequate resources, and insufficient coordination in the provision of health services during disasters (Callaway et al., 2012; Khankeh et al., 2011) are some of the factors that transfer a disaster into the healthcare environment (Hamilton, 2003).

Health response to disaster is often challenging in the first few hours of disasters due to the sheer numbers of traumatised and injured individuals. The number of injuries may overload medical facilities due to limited medical resources (Hirshberg, Holcomb, & Mattox, 2001). This stressful nature of events may consume medical staff and local responders forcing them to concentrate on medical care and delaying their awareness about the disaster situation until reports arrive at later stages. Moreover, medical personnel may be forced to deal with arriving victims without having a clue about their medical history. During such chaotic scenarios, an increase in morbidity and mortality rates can be expected.

Lack of medical history is another challenge to the provision of safe care in disasters. Disaster victims with chronic diseases may have little information about their health conditions or the dosage of medications they take (James & Walsh, 2011). Lack of crucial information adds pressure on already stressed medical staff as they try to access and collect accurate personal health information in order to prescribe the necessary treatment and medication. Inability to get hold of medical information, as is the case with evacuees, may result in increasing the risk of medical errors and threatening patient safety

(Bala, Venkatesh, Venkatraman, Bates, & Brown, 2009). Moreover, a disaster may impact the healthcare infrastructure itself adversely impacting hospitalised patients and disrupting their treatment.

Several studies have investigated the challenges associated with the delivery of healthcare in disasters (Bala et al., 2009; Chen, Gonzalez, Leung, Zhang, & Li, 2010; Lahtela, 2009; Turcu & Popa, 2009). These challenges encouraged studying disaster management and disaster medicine with a specific focus on cooperation, communication, and awareness of situations (Javed & Norris, 2012) and exploring decision-making and abilities of disaster managers (Cioca & Cioca, 2010).

A major challenge to a coordinated response to disasters is the existence of multiple often independent and territorial agencies. These agencies come from different backgrounds and have varying responsibilities that cover a wide range of aspects including infrastructure, supply chain, transport, and the well-being of the affected communities. National, international, and non-governmental organisations such as police, health, ambulance, fire and civil defence services are usually involved in the response process. Activities concerned with the delivery of healthcare are the responsibility of health professionals specialising in various medical fields including paramedicine, public health, and disaster medicine. These factors make communication and especially cross-agency communication extremely challenging particularly at times when there are high stress levels, incomplete data, and minimum time to make critical decisions.

Fortunately, developments in information and mobile technologies can greatly assist with the communication issues whilst similar advances in e-health can have major benefits in improving healthcare provision in disaster situations. The rest of the chapter focuses on the role of mobile technologies in facilitating disaster healthcare via their general role in communication and information exchange, and their more specific clinical applications.

4. APPLICATIONS OF MOBILE TECHNOLOGIES IN DISASTER HEALTHCARE

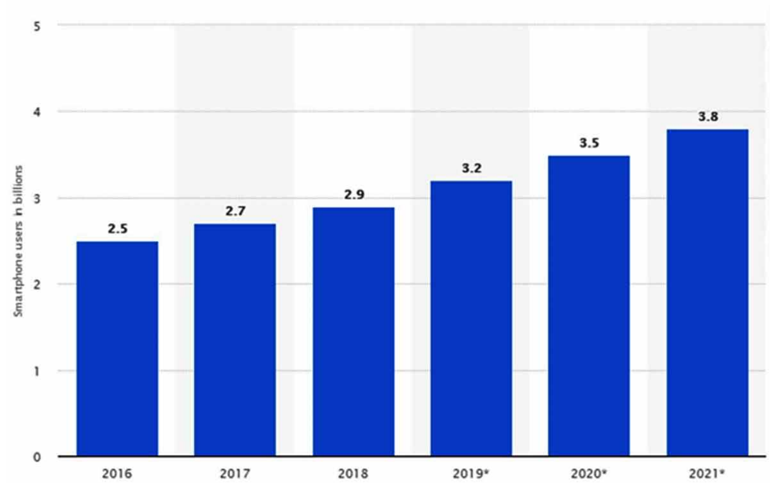
According to the International Telecommunication Union (ITU), more than 5 billion individuals are now connected to wireless networks with a majority located in low and middle-income countries (International Telecommunication Union, 2019). The driving force behind the application of mobile technologies in disaster events is the massive penetration rate of smartphones worldwide (Figure 1). According to Statista, the number of smartphone users globally has exceeded three billion with an expected increase of several hundred million in the coming years (Statista, 2020).

The widespread use of mobile phones provides an affordable platform for supporting efficient and cost-effective solutions that provide timely information. For example, in the field of humanitarian relief, the World Food Program saves about five million dollars of its annual expenses on food surveys through utilising mobile technologies including text messages, telephone interviews and online surveys (World Food Programme, 2016; Yoo, 2018).

In the context of disasters, mobile computing and social media have a huge potential for revolutionising healthcare provision (Wilson, Wang, & Sheetz, 2014). Social media platforms supported by mobile technologies have been exceptionally useful in a broad range of activities from coordinating relief activities, mapping damaged areas, identifying people in need, disseminating information and guidance, and attracting donations (Harrison, 2015).

Social media refers to a group of applications that facilitate content sharing. In disasters, gathering and interpreting information situation awareness can be enhanced through leveraging social media platforms to provide timely information and collect vast amounts of data through connecting response

Figure 1. Number of smartphone users worldwide from 2016 to 2021 (in billions)
(Statista, 2020)



agencies and various societal sectors (Luna & Pennock, 2018). A 2016 study on the Louisiana flood revealed that connecting communities affected by disasters with external organisations through social media platforms have played a significant role in improving the accuracy of disaster-related information (Kim & Hastak, 2018a).

Data exchanged on social media can be utilised in building real-time maps and developing early warning systems (Middleton, Middleton, & Modafferi, 2014). Posts on social media platforms can be systematically studied by the authorities to identify the needs of disaster-affected communities (Yin et al., 2015). Similarly, government agencies can utilise these platforms for disseminating emergency and disaster information to the public (Kim & Hastak, 2018b). Hence, the adoption of social media technologies into disaster strategies has the potential to improve the quality of disaster response. Despite these benefits which are made possible via mobile technologies, there exists a need to verify the information exchanged over these communication channels as misinformation has the potential to increase the impacts of disasters (Luna & Pennock, 2018).

Mobile applications are being increasingly utilised in disasters; a recent example is the use of contact tracing apps in combating COVID-19. To avoid communication with high-risk contacts, these applications have been explored and in some countries utilised (Bengio et al., 2020). Built upon the idea of co-locating individuals in space and time via Bluetooth, GPS, or other technologies, contact tracing apps can identify at-risk individuals. Furthermore, mobile apps help authorities understand the spread of the virus and the degree to which communities are abiding by social distance rules (Findlay, Palma, & Milne, 2020). However, due to the fact that geospatial data can be used to identify specific individuals, contact tracing apps have come under huge scrutiny especially in democratic counties (Cho, Ippolito, & Yu, 2020). Successful use of mobile technologies depends on their uptake by their targeted audience. For example, in the case of COVID-19 contact tracing apps, download is not always mandatory (Figure 2). The Indian government argues that knowing the location and health status of individuals is a public interest (Findlay et al., 2020). Although reasonably sensible, populations worldwide may not necessarily agree with this argument and hence may simply refrain from downloading the apps or using them. This highlights the ethical and social dimensions to the uptake of mobile applications.

4.1 Communication and Information Exchange Applications

Figure 2. The uptake of contact tracing apps
(Findlay et al., 2020)

Country	App name	Mandatory?	Adoption
India	Aarogya Setu	Yes	100m downloads out of a population of 1.3bn
Norway	Smittestopp	No	1/5 of the adult population
Singapore	TraceTogether	No	25 per cent of 5.7m population
Iceland	Rakning C-19	No	40 per cent of population of 340,000

No single agency is capable of responding to the needs of disaster-affected communities without collaborating with other sectors. Accordingly, cross-agency communication is paramount for exploring possible ways of collaboration between intervening agencies. The goal of collaboration is to orchestrate the activities of different disaster stakeholders (Yang, Lee, Rao, & Touqan, 2009). It includes joint needs assessment, coordinating the provision of adequate health services, identifying affected populations and mobilising resources (IFRC, 2000). Cross-agency collaboration requires extensive investment in terms of time, resources, and funds. The different authority structures across intervening agencies guide their way of responding to emergencies and disasters and make the process of cross-agency collaboration extremely complex (Abbas, Norris, Madanian, & Parry, 2016).

Poor communication across disaster response agencies necessitates the need for education to enable these agencies to understand each other's capabilities and capacities. This, in turn, leads to the establishment of trust which is central to the flow of information across response agencies. Trust is established when agencies believe in each other's abilities, resources and skills and that they have the will to collaborate and complement each other. Agencies that trust each other share information and engage in joint problem-solving and possibly joint action. This is evident in the harmony manifested between the health sector and the rest of the government in the management of COVID-19 pandemic in New Zealand. Evidence-based decision making which was based on cross-agency trust and reliable information sharing led the New Zealand response to be praised by the World Health Organisation as 'being very systematic with a very comprehensive strategy' (TVNZ, 2020).

The main challenge in a multi-stakeholder disaster scenario is to ensure that each agency has adequate situation awareness. Endsley (1988) defines situation awareness as 'the perception of the elements in the environment within a volume of time and space, and the comprehension and the projection of their status in the near future'. Situation awareness includes having a full understanding of the situation at hand, pressing needs and required actions. However, building up such a holistic picture is a complex process (Karami, Shah, Vaezi, & Bansal, 2019). Despite credibility, a top-down approach to information exchange via official channels was found to be insufficient for achieving adequate situation awareness. Horizontal information exchange via mobile technologies proved to be exceptionally useful throughout the different phases of the disaster lifecycle.

In the mitigation stage, monitoring information can be collected and processed effectively through mobile platforms. In the preparedness stage, mobile apps can be used in disaster risk education, broadcasting early warning systems, and communicating with potential volunteers. During the response, these apps can be lifesaving as they provide a wide range of services including rapid broadcasting of critical information, indications of mass gatherings, and facilitating search and rescue operations to name a few. In the recovery stage, mobile apps can readily provide damage assessment and recovery-related information (Tan et al., 2017). The innovation of entirely mobile systems that allow rapid acquisition of data from disaster sites is made possible through mobile technologies. Technologies such as cloud computing, big data analytics, Internet of Things (IoT), and social media bring huge potential when used in conjunction with mobile technologies.

Big data, which refers to data collections that are not only very large but also highly complex and diverse (Kayyali, Knott, & Van Kuiken, 2013), enables data mining to reveal inherent patterns and associations. This technology has huge benefits like in the case of epidemiology where chronological data helps predict the onset and spread of infectious diseases such as influenza and SARS. Cloud computing enables access to information 'anywhere and anytime' and increases accessibility by using various devices such as smartphones. IoT is another technology with huge potential for improving disasters response as it enables objects to be sensed and/or controlled remotely across the existing network infrastructure. This means that objects can communicate without human intervention by embedding sensors within them; an ideal means for intervention in war and conflict zones as well as in health situations where human interaction needs to be avoided.

Social media networking via Facebook and Twitter, for example, can contribute to effective response efforts. These applications, available through smartphones and tablet, can make it possible for planners to connect with ordinary citizens and involve them in the development of strategies for disaster management (Norris et al., 2015). Social media are useful in different disaster stages. Emergency workers and volunteers use social media to find people in need, map damaged areas, organize relief efforts, disseminate news and guidance, attract donations, and help prepare for future disasters. For example, when Hurricane Sandy caused flooding in New York, the Red Cross directed some trucks and relief supplies specifically in response to tweets by victims. During the Sandy response, some 88 social media posts resulted in similar changes on the ground (Harrison, 2015). Social media can provide instant news faster than traditional news outlets or sources and can be a great wealth of information, but there is also an increasing need to verify and determine the accuracy of this information.

4.2 Clinical Applications

In disaster circumstances, mobile technologies linked to centralised information systems can provide seamless care (Brown et al., 2007; Maturana, Scott, & Palacios, 2012; Singh & Kaur, 2010). "These technologies have applications in terms of enhancing mass-casualty field care, provider safety, field incident command, resource management, informatics support, and regional Emergency Department (ED) and hospital care of disaster victims" (Chan et al., 2004, p. 1229). Recent technological advances also raise the prospect of delivering health information systems that are both portable and personalised (James & Walsh, 2011). Revolutionary mobile technologies such as telemedicine, mobile health, Electronic Health Record (EHR), social media, IoT, and big data have the potential to make a radical change in disaster healthcare.

The following sub-sections review mobile applications in the pre-, response, and post-disaster phases.

4.2.1 Pre-Disaster Applications

Well-designed disaster mitigation and preparedness plans are keys to the effectiveness of health response in disasters. Healthcare organisations should regularly assess their response plans and their readiness level. These requirements are usually provided by information systems and can now be extended and be available on mobile phones and tablets via mobile technologies. This facilitates access to information by both disaster planners and citizens.

Pre-disaster activities are designed to identify the nature and likelihood of disasters, avoid or diminish their possibility or destructive consequences, or to enable communities and response agencies to take proper actions when a disaster occurs. The objective is to ensure that proper systems, plans, procedures, and resources are in place and updated. These plans assist disaster managers, clinicians, and victims in coping with rapidly changing events. Long-term but easily adapted plans and risk reduction measures decrease the vulnerability of communities (Ahmed & Sugianto, 2009; Lettieri, Masella, & Radaelli, 2009).

Pre-disaster activities include assessing risks and taking administrative measures to prevent or reduce their impacts, zoning and building codes, vulnerability analysis, public education, development of new services and response plans, preparing resources, and training, to name a few. Mobile technologies with their ability to update information and gather feedback can assist with these activities.

Education is vital for disaster preparedness for both physicians and the public. Mobile technologies such as telemedicine and social networks are appropriate tools for this purpose. Social networks offer a way to engage with communities and bring resilience by raising public awareness about how to cope with and recover from disasters. For example, text messaging is a good method to alert target groups of health campaigns (Iwaya et al., 2013) and disseminate pre-disaster warnings. These and other mobile health technologies are particularly valuable for reaching rural communities (Eisenman et al., 2009; White, Plotnick, Kushma, & Hiltz, 2009).

To enhance community or national readiness, cloud computing and big data techniques can be utilised. These technologies can be used to assess and integrate national and local medical information and resources into a single information system. Such a system can then provide a single repository of data and information to determine disaster response capacities in a range of national and local medical environments. The system can also identify critical resources and report the whereabouts and availability of emergency medical supplies, their types and volume (Zhong et al., 2014). RFID and IoT sensors can track these resources automatically with minimal human intervention, can enhance task efficiency and accuracy, and can then share the information among all involved agencies.

To optimise future response missions, the created cloud repository can be integrated with Decision Support Systems (DSS) and EHRs. This integration offers a unified repository of patient data across all operators (AbuKhousa, Mohamed, & Al-Jaroodi, 2012) allowing customised regional services such as forecasting and tracking the progress of epidemic and pandemic diseases. Such a unified repository also would be a good platform to run different Artificial Intelligence (AI) algorithms and Machine Learning (ML) to detect any possible hidden trends.

EHRs are considered core healthcare systems. These systems improve daily healthcare delivery, as well as assist healthcare organisations to prepare better for disasters by making peoples' health backgrounds easily accessible by approved carers (Brown et al., 2007). More sophisticated mobile EHR systems linked to centralised big data repositories and supported by cloud computing and DSS are set to overcome the challenges of matching patient loads and needs with available hospital resources.

4.2.2 Disaster Response Applications

Disaster response includes actions taken during or immediately after the occurrence of a disaster to control and manage its impacts. The focus of response is on the deployment of resources and provision of emergency services to affected populations. Response services include saving lives, providing relative welfare, giving aid and assistance, and preventing or reducing the spread of the crisis impacts. These activities are conducted according to plans that aim at minimising the disaster's impacts on people, properties and environment (Ahmed & Sugianto, 2007; Altay & Green, 2006; Baldini et al., 2009).

Evacuation, sheltering, search and rescue, emergency relief, and damage control are crucial activities following the occurrence of a disaster. Often, the circumstances under which these activities are carried out change rapidly causing more pressure on response teams. Disaster response is a time-critical phase that demands access to reliable information in order to deliver life-saving services. In such scenarios, mobile technologies can facilitate the allocation of resources, assist with triage, and provide critical data on patients' medications, allergies, and pre-existing conditions.

Despite the imperative of disaster education and disaster medicine training for medical personnel (Ducharme, 2013; James et al., 2010), a great number of health practitioners do not receive this training (Walsh et al., 2012). To tackle these knowledge gaps, mobile health systems and telemedicine can be used to overcome this deficiency by supporting clinicians in the field (Blaya, Fraser, & Holt, 2010). In addition to alleviating time and space barriers, telehealth provides convenient access to expert advice (Sutjiredjeki et al., 2009).

To support disaster response teams and help affected communities, central authorities and decision makers need to communicate different types of information such as the number of casualties and the required and available medical resources. For example, IoT, RFID and sensor networks facilitate these tasks by automatically collecting and transmitting precise and real-time data to responders and other decision makers thereby helping them to make informed decisions (Petersen, Baccelli, Wählisch, Schmidt, & Schiller, 2015). As these technologies have embedded memory, they have the ability to collect and store data without relying on the network infrastructure. Collected data can be later uploaded when the broken connection is re-established.

RFID and IoT technologies can be utilised in identifying, mobilising, and dispatching disaster victims, rescue personnel, and medical resources (Chan, Killeen, Griswold, & Lenert, 2004; Shamdani & Nicolai, 2012), thus addressing issues of misidentification of patients and medications (Lahtela, 2009). This has a significant impact on patient safety in the context of disaster response. Paper triage which has several proven limitations (Fry & Lenert, 2005; Lenert, Palmer, Chan, & Rao, 2005) including inefficient information retrieval and poor saving mechanisms can be replaced by IoT and RFID technologies. When integrated with mobile health, these technologies can benefit providers' handoffs during triage (Callaway et al., 2012; Kyriacou, Pattichis, & Pattichis, 2009).

To overcome the issue of data silos, because of IoT and RFID, cloud services can be used to integrate and exchange fragmented data from disparate sources. The data then can rapidly be shared across multiple organisations in different geographical areas (AbuKhousa et al., 2012).

During disasters, medical staff deal with casualties who may include unconscious individuals, infant and children, or victims who cannot effectively communicate to give information about their medical status or their previous medical history (James & Walsh, 2011). In these situations, the ability to access patients' medical history and personal information can improve the quality of provided care as well as support the continuity of care.

Disaster response activities are prone to human errors. However, DSS(s) can assist with rapid and accurate decisions under conditions of uncertainty. These systems are efficient tools for coordinating operations and assisting the making of crucial decisions regarding task assignments (Thompson, Altay, Green III, & Lapetina, 2006). Moreover, DSS can facilitate the tasks of hospital-based providers by helping to make decisions regarding rapid transport of victims to the appropriate facility (Rüter, 2006), matching the number of inbound patients with availability i.e. number and type of hospital beds (Bradt, Abraham, & Franks, 2003), as well as prioritising victims for treatment (Fajardo & Oppus, 2010).

4.2.3 Post-Disaster Applications

Recovery refers to long-term activities performed after disasters to support systems, bring order to the disaster-stricken areas, restore the situation to normal, and stabilise or even improve the levels of normal condition (Ahmed & Sugianto, 2007; Lettieri et al., 2009). This stabilisation phase may last for quite a long time. Recovery includes reconstruction, rehabilitation, and performance assessment.

Monitoring the health condition of disaster-affected populations during recovery is of great importance albeit extremely challenging given the need to restore capacities and capabilities to pre-disaster levels. The ability of mobile systems to expedite information exchange eases pressure on healthcare systems and allows the monitoring process to proceed alongside the provision of normal health services.

Continuous monitoring of disaster casualties and people with long-term chronic diseases and mental patients can be supported by IoT technologies in the post-disaster phase (Tun, Madanian, & Mirza, 2020). Equipping patients with IoT devices or sensors reduces the necessity of hospitalisation since patients' vital signs can be monitored continuously in real-time and with minimum human intervention regardless of the geographical location of physicians and patients. This provides care for the patient while reducing the strain on the healthcare system. EHRs can be integrated with IoT sensors to incorporate monitored data into the patient's medical record thus facilitating future delivery of care if any emergency arises. EHRs can utilise mobile technologies to educate patients on public health (Brown et al., 2007) and promote health self-management (Archer, Fevrier-Thomas, Lokker, McKibbon, & Straus, 2011). Instead of physical consultation, patients can receive tele-consultation, tele-diagnosis, or tele-education in a preferred location and at a convenient time (Sutjiredjeki et al., 2009). These services have the potential to provide better healthcare when there is a lack of specialists or experts in disaster-stricken areas. Telehealth services are increasingly being used to reduce disruption in care (Vo, Brooks, Bourdeau, Farr, & Raimer, 2010) and to alleviate time and space barriers between healthcare providers and their patients (Sutjiredjeki et al., 2009).

5. DISCUSSION

In disasters, healthcare routine procedures are disrupted, and healthcare needs to shift quickly from routine activities and procedures and adjust to a status of great uncertainty. In such chaotic situations, decisions need to be taken in a short time and under stressful conditions that often include a shortage of medical resources including health personnel.

Information and communication technologies can significantly enhance the provision of disaster healthcare. Among these technologies, mobile applications play a central role in information gathering and exchange and communication due to ubiquity and ease of use. Interestingly, several mobile technologies such as EHRs and telemedicine can be applied in various DMC phases for both clinical and non-clinical purposes. In different phases of DMC, mobile devices (such as tablets) are becoming so powerful that they can support and link to different databases, enabling medical personnel and governments to get informed decisions. Furthermore, ubiquity and communication features of these devices support greater involvement and care for communities in rural areas or disadvantaged communities such as refugees, people with disabilities and mental health patients. Tablets and mobile phones facilitate the acquisition of up-to-date information from the authorities or seek mental health support. Non-clinical uses of mobile applications through social media, for instance, can facilitate communication and data sharing with outside-disaster sites for support purposes.

Integrating different technologies, where possible, often augment their impact. EHR and telemedicine integration provides a robust system that enables continuity of care in disaster recovery, regardless of patients' and physicians' geographical locations. Madanian and Parry (2019) propose a framework that integrates IoT, cloud computing, and big data to assist authorities in managing disasters. The framework suggests the use of IoT sensors in collecting disaster data which is then integrated and shared in a cloud repository that uses big data algorithms to detect and identify hidden trends. The output of such integration may provide healthcare risk analysis and forecasts that assist with disaster preparedness, response, and recovery. The outcome of integrating technologies may extend over all stages of the DMC. This can be seen in countries were information and communication technologies, including mobile technologies, were recently utilised to alleviate the COVID-19 crisis. Remote patient monitoring, providing test-results electronically, case management, contact tracing are some of the outcomes of integrating technologies.

During the lockdown period of COVID-19, mobile apps proved indispensable. While the golden rule during lockdown was to be socially distant, the recommendation was to make sure communities were still socially connected. This was made possible using mobile applications. People used mobile apps to communicate with the elderly to ensure that their mental health does not get negatively impacted by being kept distant from family members and friends. Families were allowed to communicate with their loved ones who were critically ill as nurses and critical care providers used iPads and mobile phones to avoid mental stress of their patients and their families.

A technological approach to information that assumes technology can solve all problems is known as *technocratic utopianism*. According to Davenport, Eccles, and Prusak (2009), '*no technology has yet convinced an unwilling manager to share information*'. Hence, information exchange as well as successful uptake of mobile applications should consider human factors especially in disaster situations where stress levels are high and the time to make critical decisions is scarce. Disaster responders often miss the opportunity to seek information from a reliable source due to lack of understanding about the nature of information owned by various agencies. To facilitate cross-agency information sharing in disasters, response agencies need to have trust in each other's abilities, resources and skills (IFRC, 2000). Such confidence requires the establishment of successful working relationships during peace time. Relationship building can be established formally or informally. Formally, disaster response agencies need to systematically encourage cross-agency information sharing. Education and training are essential means for the successful implementation of mobile technologies which rely primarily on efficient information sharing (Kotabe, Sakano, Sebayashi, & Komukai, 2014). An approach that aims at fostering understanding and information requirements of various disaster response agencies is crucial for ensuring appropriate development of mobile technologies.

6. CONCLUSION AND FUTURE WORK

Mobile technologies and their applications have the potential to bring several opportunities to disaster healthcare. In this chapter, the application of these technologies in the different phases of the disaster lifecycle are presented. To fully utilise these technologies human and operational aspects need to be considered.

A survey of clinical and communication applications identifies key factors that need to be recognised to exploit opportunities offered by information and communication technologies including the systematic and integrated approach to disaster healthcare across all stages of the disaster cycle. Integrated healthcare demands an interdisciplinary approach to information sharing in disasters. A golden opportunity lies in the establishment of the new discipline of disaster eHealth (DEH).

DEH can be seen as a discipline that lies at the intersection between disaster management, disaster medicine, and e-health. It refers to 'the application of information and e-health technologies in a disaster situation to restore and maintain the health of individuals to their pre-disaster levels' (Norris et al., 2015). The aims of DEH is to establish effective communication between disaster managers and disaster healthcare professionals through effective utilisation of e-health technologies. This integration of human capacities, medicine and technology has the potential to identify relevant information requirements of both sectors thus improving the quality of healthcare delivery in disasters. To appropriately and adequately identify information requirements, disaster stakeholders including emergency managers, disaster medicine specialists, the general public, victims, indigenous peoples, people with disabilities and refugees should be consulted.

Software development of mobile applications requires a needs-based approach rather than a technology approach. This refers to having a good understanding of what the audience users require in a given application. This is significantly important for usability aspects with regards to the needs of people with specific needs including the elderly and people with disabilities. For these applications proper requirement analysis and extra attention to interface and usability design are extremely important for the uptake of these technologies. These criteria are also important for disaster response applications as users may be working in austere environments that require them to wear gloves, for example. These considerations could be determinant to the acceptance and adoption of mobile applications by the public in general and disaster medicine specialists in specific.

Dependency on the network infrastructure or energy sources to power mobile devices is one of the barriers that may hinder their use in DMC. Although some technologies such as IoT and RFID have embedded power sources, the majority of mobile technologies are infrastructure-dependant. Solutions include using satellite communications or solar power as alternative energy sources. However, there exists a need to explore ways of providing access to mobile technologies when the infrastructure is damaged. Moreover, factors that impact successful implementation and uptake of mobile technologies require further research.

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