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# Role of Telemedicine in Disaster Management

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## Abstract

This paper reviews the role of telemedicine in disaster management, in the context of the October, 2005 earthquake in Pakistan.
Disaster is a catastrophe, either natural or man-made. Typically, it causes loss of life, property, and paralyses daily life for the time being, and it may leave behind permanent socio-economic and ecological changes.
Disaster Management encompasses the preparedness to minimize loss to life and destruction of property; to aid relief operations, and rehabilitation of the effected population and daily activities. The core issue in disaster management is human safety where telemedicine is significant, due to expected damages in the local healthcare infrastructure on one hand, and the capabilities of electronic information and communications technologies to provide health care when distance separates the participants.
In this context, telemedicine has two basic functions. In the preparedness phase, telemedicine applications can be used in continuing medical education, knowledge based expert systems and resource databases. During relief operations, it includes tele-monitored procedures/surgery, telediagnostics and second opinion; and in the rehabilitation phase, teleconsultation, complex problem interpretation, and epidemiological surveillance.
In a developing country like Pakistan, promotion of telemedicine services to play role in disaster management requires planning and development at every social organizational level. The constraints in affordable technological access should be minimized and public/private partnerships should be promoted.

## Introduction

The word “disaster” is derived from Latin; *dis* means against and *astrum* means stars. This clearly reflects the calamity’s associations with nature. Yet, disaster can be simply defined as an unexpected natural or man made catastrophe of substantial extent causing significant loss of life, destruction of property and sometimes permanent change to the environment. The daily routine activities almost cease and sustenance of human life is greatly jeopardized. Typically, conventional systems of healthcare delivery in disaster areas are compromised, if not destroyed, and reinforcement in this context is consumed with scarcity of skilled human resources when the need for care is acute.

Developments in information and communication technologies (ICTs) during the last quarter of the 20th century heralded an information age in which economic and social activity has been widened, deepened and transformed.[1] Telemedicine/telehealth uses IC to improve access to quality healthcare. Appropriate use of telemedicine based consultation and referral systems reduce travel and other hardships by bringing the services at the doorsteps of patients. In total this brings down the overall cost.[2] Improved accessibility and cost effectiveness have highlighted the significance of telemedicine in health care delivery.

Pioneering projects have illustrated the potential benefits of telemedicine systems in

**Table-1**

| Causes of the death | Number |
|---|---|
| Suffocation or crushing | 4224 |
| Burn | 504 |
| Cranial or cervical injury | 282 |
| Major Organ Injury | 98 |
| Traumatic Shock | 68 |
| Traumatism | 45 |
| Crush Syndrome | 15 |
| Others | 128 |
| Not classifiable | 124 |
| Total | 5488 |

disaster response, and emphasized the need to institutionalize such capabilities nationally and internationally so that they could be activated on demand. These efforts fostered a global telemedicine disaster assistance mentality.[3]

When disasters occur, telemedicine can play an important role in saving lives. Telemedicine was first applied in disasters during the mid-1980s.[2] The use of telecommunication technology to provide disaster aid was started by the National Aeronautics and Space Administration (NASA) following the devastating 1985 earthquake in Mexico City. It provided critical voice communication support within 24 hours of the disaster.[4] During the last decade, the military, space programs, and various governmental agencies have progressively developed telemedicine applications, and tested them in real and simulated civilian disaster emergencies.[3]

After years of technological developments, telemedicine is emerging as an organized field in health care delivery where access is restricted by geography or environment. It encompasses diagnosis, treatment, monitoring, and education, and provides convenient, site-independent access to expert advice and patient information.

Transmission modalities include direct hard-wired connections over standard phone lines and specialized data lines (single/twisted pairs of metallic wires, coaxial lines, fiber optic cable) and ''wireless'' communications using infrared, radio, television, microwave, and satellite-based linkages. Improved space- and ground-based technologies form a communications infrastructure well suited for addressing disaster management.[3]

In the 1995 Great Hanshin-Awaji Earthquake in Japan, 5488 victims perished. According to available data, about 81% of the victims died during the first seven hours, the morning of the quake.[4] **Table 1** shows the causes of death in this disaster.

Worldwide, disasters of various size occur almost daily, having claimed nearly three million lives and having adversely affected about 800 million more in the past 20 years.[5]

**Background**

On October 8, 2005, an earthquake of magnitude 7.6 at Richter scale devastated human life and property in the northern areas of Pakistan, including the capital city of Islamabad, and many areas across Kashmir. According to the United Nations, more than 3 million people were rendered homeless and 75,000 or more injured. Subsequent tremors of lower magnitude still demonstrate the instability in the earth crust.

The affected area was in two countries, India and Pakistan. India has a well developed telemedicine system. Soon after the earthquake, it established nine telemedicine hospitals facilities in the affected part of its territory. This resulted in saving more lives and addressed a rather larger number of health issues. On the other hand, Pakistan has no such telemedicine systems which may have contributed to greater loss of life and continues to pose difficulties in helping the injured and managing other illnesses.

One of the major functions of telemedicine is to compensate for such scarcity in human medical resources, especially medical experts.

**Discussion**

Disaster Management can be broadly divided into three main stages: pre disaster preparedness, disaster relief operations, and post disaster rehabilitation. In this context, telemedicine in disaster management can be categorized from preparedness to rehabilitation.

**I) Pre-Disaster Preparadness**

**Planning and Development and Technological Needs**

Preparedness begins with the planning process and risk analysis. The disaster management plan has to be formulated and the need assessment of required telemedicine technologies as integrated component of the plan. Identified high-risk zones require priority consideration, yet no area should be considered totally safe from disaster. Planning should envisage well-defined objectives at all levels and in every domain of stakeholders.

Planning and development for telemedicine requires an understanding of the working of a telemedicine system. As the telemedicine operations are carried out between two ends, each end requires the requisite infrastructure. These applications are built and operated by trained and skilled human resources. It is wise to plan and implement a pilot project to study and establish the role of telemedicine in disaster management. This would entail generating a wide variety of data and information, which must be collected, processed, distributed and utilized. This information may be categorized into six groups:[6]

**1) Management information** includes the day-to-day management needs and for planning, programming, budgeting, and monitoring.
**2) Clinical information** includes data and information to support clinical functions such as diagnosis, treatment; and imaging.
**3) Surveillance and epidemiological information** includes patterns and trends of disease and related health care measures.
**4) Literature** is documentation, reports, formal publications and "grey" literature published in printed or electronic format (CD-ROM or over the Internet).
**5) Knowledge** is the information readily usable to support technical tasks, such as the diagnosis of a medical problem, the conduct of a laboratory test and proposed treatment.
**6) Personal and community information** is directed to the provision of health-related information directly to the public.

The sources of these data and information are within and outside the telemedicine infrastructure. Thus, the collection, flow, processing and distribution of such information constitute key factors in the efficacy, efficiency and economy of the operations and the development of the telemedicine.

The planning process, therefore, visualizes the telemedicine infrastructure which is the means by which medical data and any subsequent remote medical analysis are exchanged between the two participants. It consists of the communications software and the communications medium between the various locations. The telecommunications links depend on the nature of the services to be supported, which may require narrow or broadband, standard or high-speed telecommunications.[6] Disaster management makes it vital to plan for alternative strategies to maintain communication even when the local infrastructure is damaged. Hence, contingency wireless and mobile communication network back-ups should be incorporated in the telecommunication infrastructure plan for disaster management.

Telemedicine technology may involve the use of computers, sound, video and image processing. The choice of telemedicine technology should be based on meeting the need at the lowest cost while complying with standards.

**The Human Factor**

Human resources can be categorized in three functional, closely inter-related classes:

**1) The management and administration of the telemedicine system:** These resources should be fully aware and briefed on the background, rationale, expected result, their input and contribution to its success. They have to be fully involved in terms of integrating telemedicine into disaster management and in making them actors in the new environment through mock exercises.
**2) Medical expertise and other health and medical activities:** All medical personnel related to telemedicine should understand the basic concept of telemedicine, not as a new specialty of medicine, but a new means of medical and health care delivery. It is essential to have committed and motivated medical and support personnel in telemedicine operations.
**3) Patients and telemedicine users:** Educational and informative meetings with the patients and the community are essential.

Acceptance of telemedicine by patients has been reported as higher as compared to physicians. Cooperation from patients would be helpful in the implementation of telemedicine projects.[6]

**4) e-Training:** The existing Internet/Web-based medical training and/or consultation programs cover a wide range of topics; satisfy almost every need for specialized knowledge; and may involve a large variety of approaches spanning from e-mail exchange to videoconferencing and multimedia offerings.[8]

**Databases**

In preparedness for disaster management, databases make up the information base for relief and rehabilitation operations. Databases that describe the disaster-affected areas and the vulnerable communities can be generated, designed, and developed with the use of computer hardware, information software, and telecommunications.[7] Databases, with on site and offsite back-ups for infrastructure inventory management, human resource management, organizations with capacity to handle disasters, logistics and training material provide sound bases for disaster management. Similarly, epidemiological techniques, such as public health surveillance, simulation models that are used as planning tools, decision-making tools, and training tools for disasters, depend on good databases.[7]

**Artificial Intelligence, Expert Systems and Decision Support Systems**

Expert systems and decision support systems provide expert advice on medico-scientific issues. For example, given a patient's co-ordinates and symptoms, it could provide diagnostic support, suggest additional tests or propose specific treatment.

Dynamic learning capabilities of computers through path finding algorithms can be useful in disease management. In such a scenario, the machine would know how to respond with fast response time[18], through artificial intelligence.

The Internet would provide access to knowledge bases, decision-support systems, and expert systems in areas related to disasters and health. Expert systems and decision-support systems can be useful in evaluating and analyzing options and help in arriving rapidly at appropriate decisions for disaster management.[7]

**Geographical Information System (GIS)**

When a natural disaster occurs, ground investigation of damage may be difficult without indirect means, such as remote sensing and comparison of high-resolution imageries taken before and after the disaster.[10] The use of remote sensing and geographic information systems (GIS) have become essential tools in disaster management. GIS allows the combination of different kinds of data using models, including the combination of spatial data, non-spatial data, and attribute data and their use in the various stages of disaster management.[11]

In the disaster prevention phase, GIS is used to manage large volumes of data needed for hazard and risk assessment. In the disaster preparedness phase, it serves as a tool for planning evacuation routes, the design of centers for emergency operations, and the integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster relief phase, GIS is extremely useful in combination with global positioning systems in search and rescue operations in devastated areas. In the disaster rehabilitation phase, GIS is used to organize the damage information and the post-disaster census information, and in the evaluation of sites for reconstruction. Hence, GIS is an all-purpose tool in disaster management.[11] They help in situational analysis, risk assessment, spatial modeling, disaster mapping, and simulation.[7]

**Research Projects**

Research projects play a very important role in the development of successful systems.[10 and 12] They provide a launching pad for successful implementation of telemedicine in disaster management. Such projects should have well defined goals and objectives, and should consider cost benefit analysis. They should envisage systematic integration of telemedicine in overall health services infrastructure.

**II) Disaster Relief Operations**

Response begins as soon as a disaster is detected or anticipated. It involves mobilizing and positioning emergency equipment; getting people out of danger; providing needed food, water, shelter and medical services; and bringing damaged services and systems back on line.[13]

**Robot assisted Medical Reachback**

Typically disasters hamper medical missions in reaching victims. Medical missions consist of three steps: finding the victim (victim localization), assessing whether the victim is dead or alive and general condition (life algorithms), and maintaining life until the victims are extricated (victim management). Rescue robots permit medical personnel access to the victims during the initial 4-10 hours of the disaster. Robots can carry out all the functions already being performed by medical personnel but at deeper depths of 10 to 30 meters in the rubble.[20]

**Patient Tracking Systems**

Traditionally, tags are used for identifying victims of disaster. But these tags can be torn, removed or changed accidentally.

Recent advances in triage tagging technology have focused on the use of bar codes and mobile wireless data acquisition to identify and track victims of disasters. Bar coding systems have been piloted and tested for mass-casualty disaster drills in Europe. For example, the Patient Barcode Registration system developed in Utrecht, The Netherlands, has linked patient identification and registration data with out-of-hospital and in-hospital medical data. By scanning patient wristbands at various locations (disaster site, emergency department upon arrival, hospital location), the system can track and provide the approximate location of patients[17] as needed.

**Critical State Patient's Telemonitoring Through Sensor Devices**

Immediately after a disaster, the major challenge is the management of critically injured patients. Devices with sensors can collect the vital signs of such patients and transmit them through wireless networks to remote specialists or expert systems for diagnosis and management.

Recent advances in micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that are small in size and communicate un-tethered in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes. Sensor networks represent a significant improvement over traditional sensors.[14]

**Pre-Hospital Management Through Mobile Technology**

Mobile technology can be deployed in ambulances and primary health care units. It allows telediagnosis, long distance support and teleconsultation by specialized physicians. It can be fixed or portable, transmits crucial biosignals of the patient (ECG up to 2 continuous leads, heart rate, SpO2 trends or waveform, CO2 trends or waveform, non invasive blood pressure, invasive blood pressure, respiration, temperature). The type of transmitted signals depends on the medical monitor used in each case. Several communication links, wireless (GPRS, GSM, and Satellite) and wired (ISDN or standard phone lines) can be used. The transmission may be based on the TCP/IP protocol.[15]

Recent computer miniaturization has produced pocket-sized personal digital assistants (PDAs) with personalized interfaces. These small computers can support keyboard, pen, touch, and voice inputs, and provide information management, portability, connectivity (via phone modem, wired or radio-frequency local area network, and diffuse infrared transmission) and, to varying degrees, e-mail, fax, graphics, digital photography, and voice recording capabilities. The ability to use a single small communicator to transmit different types of information anywhere in the world would be ideal for the disaster field worker. A small ''pocket telemedicine'' unit equipped with Web browsing capability, a digital camera, telephone, and computer could be used to conduct on-site, real-time consultations whenever necessary.[3]

The U.S. military is developing innovative applications for advanced sensors and smart materials. The Personnel Status Monitor (PSM), a miniaturized device resembling a wrist watch, can be worn by all soldiers as part of the combat uniform. It combines advanced environmental sensors and non intrusive physiologic sensors with a CPU, geopositioning receiver (interacting with global positioning satellites), and low-power wireless radio. The PSM will monitor the soldier's vital signs (pulse rate, temperature, respiration, and blood pressure) continuously. The PSM remains passive until queried, when it replies with the soldier's geographic location and vital signs. However, if the soldier's vital signs depart significantly from established norms, the PSM would transmit location and vital signs until shut down by a medic.[3]

**Telediagnostics**

**Teleradiology:** Traumatic injuries in most disasters require immediate attention for timely diagnosis and management. Teleradiology refers to the electronic transmission of radiological images from one location to another for the purpose of interpretation or consultation. However, the term has grown to include other related types of image transfer. It includes x-rays, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound as well as nuclear medicine, thermography, fluoroscopy, and digital subtraction. Each of these applications can produce an image of the patient's anatomy and/or pathology.[16]

**Telepathology:** Telepathology involves rendering diagnostic opinion on specimens at remote locations using computer and telecommunications technologies. Microscopic and chemical analysis of different specimen is a very important supporting tool in the diagnosis and management of patients. Special studies on a pathology specimen are frequently performed after the initial evaluation of the microscopical preparations. Sometimes these studies cannot be performed at the referring site. Otherwise, the pathology material would have to be sent to the consultative site for processing. This process takes time (which the patient might not have), and it costs money. Also, pathological specimens must be kept under special conditions, otherwise the specimen may be compromised or destroyed.

Telepathology can minimize these problems. This can be done isn two ways: remote dynamic screening by robotic video microscopy or remote diagnosis from selected still video microscopical images.[16]

**Clinical Decision Support Systems**

The sustained management of ambulatory patients can be carried out through clinical decision support systems, where shortage of medical personnel poses management difficulties of patients in large numbers.

These systems can transact various types of important clinical and related data including demographics, encounter, laboratory and vital signs, merge, unmerge, and pharmacy.[19 and 21] Wireless and evidence based decision support systems (WEDS) can provide an efficient way to use evidence-based approach for decision making in the crush of injury patients. The performance WEDS may be improved for clinical decision making if data are limited.[22] Artificial intelligence applications can also help to diagnose and give guidelines for management of diseases, especially in this context.[18]

**Telesurgery and Teleconsultation**

The surgeon is located at a distant site, yet plays a role in surgical procedures in a disaster area. Telesurgical interventions can be implemented through various ways. One way is medical robot applications of remote telesurgery in which the specialist is hundreds or thousands of miles away, and is totally dependent on communication links.[20]

The other way is teleeducation and telementoring through videoconferencing during the surgical procedure in the disaster area, and during examination of patients requiring surgery.[23]

**III) Post-Disaster Rehabilitation**

During this phase, many of the victims tend to live in relief camps with great physical and psychological stress. There are numerous threats to health that can be encountered by corrective measures with on-site limited resources, including post disaster psychological trauma, public health threats, burden of disease and rehabilitation to normal life.

**Telepsychiatric Interventions**

Telepsychiatry plays an important role in assessment and differential diagnosis, identification and surveillance of high-risk groups, consultation, education about normal responses to trauma and loss, psychopharmacologic interventions and psychotherapy to assist in the resolution of persistent symptoms.

The most recent version of the Diagnostic and Statistical Manual of Mental Disorders includes acute stress disorder, a condition characterized by the presence of dissociative and other trauma-related symptoms in the days to weeks following a disaster.[24]

Also needing clinical attention in a disaster's wake are psychiatric impairments because of head injury or burns, symptoms of depression, sleep-disruption, anxiety, and maladaptive behaviors such as substance abuse and violence. Early assessment, coordination of resources, and appropriate treatment play an important role in preventing chronicity and debilitating sequelae.[24]

Children are especially vulnerable during times of disaster. They can manifest a wide array of symptoms: depression, sleep disturbance, anxiety, trauma-specific fears, behavioral problems, and somatic concerns. The level of distress tends to increase with the child's age and with pre-existing health problems of parent or child. The child's exposures to a disaster as well as the parents' reactions are prominent predictors of morbidity. Interventions with parents and families are directed at (a) assisting children to regain a sense of safety; (b) validating children's emotional reactions, rather than discouraging or minimizing them; (c) anticipating and providing additional support during times of heightened distress, such as anniversaries of the event; (d) and minimizing secondary stresses.[24]

**Public Health Threats**

The public health objectives of disaster management are two-fold: **(1)** to prevent unnecessary morbidity, mortality, and economic loss resulting directly from a disaster; and **(2)** to mitigate morbidity, mortality, and economic loss directly attributable to the mismanagement of disaster relief efforts.[7]

- **Early Warning Systems** in relief camps should be employed to prevent outbreaks of infectious diseases. Daily computerized data plotted on weekly graphs would help to detect outbreak at the onset when median line is crossed analysis and intervention guidelines are provided through remote expertise.
- **Disaster Medicine** is "the study and collaborative application of various health disciplines to the prevention, preparedness, response, and recovery (PPRR), from the health problems arising from disaster.[11] Prevention strategies, research and epidemiological studies, education programs, rapid mobilization and deployment of resources and services, community preparation, remote area planning, medical incident management, disaster site arrangements, communication network from the disaster site to the casualty treatment post, training, disposal of dead, vector control, hygiene and sanitation, and psychological interventions, are components of disaster medicine. All can be made more effective with the use of ICT. The telecommunication infrastructure allows community health providers to access innovative and interactive continuing education opportunities at minimal time expenditures and no trave.[l7]
- **Epidemiology:** Epidemiological methods aided by ICT would provide rapid assessment of health and medical needs, continuous monitoring and surveillance of the health problems faced by the victims of disasters, and disease control strategies, as well as the assessment of the use and distribution of health services during a disaster. Moreover, epidemiological methods, such as evaluation of the natural history of disasters and acute health effects, and analytical studies of risk factors for adverse health effects depend on good databases that can be analyzed using computer hardware and software. Such technology will make it possible to model or simulate disasters. Epidemiological methods used for community hazard and vulnerability analysis can be made more effective with the application of GIS. Surveillance data on health events are analyzed, transformed, and disseminated to decision-makers for policy development and action. The application of MIS helps management make appropriate decisions. It helps in the public health surveillance that entails systematic collection, analyses, and interpretation of data on specific health events. This can be used by emergency managers, healthcare providers, emergency workers, and the community at large. Electronic data systems would rapidly collect data under highly adverse conditions, which can provide timely information on morbidity and mortality to decision-makers.[7]

**Telerehabilitation**

Telerehabilitation covers telesupport for independent living.[25] In this context, community centers for telerehabilitation can be established with videoconferencing facilities for psychological counseling.

The Remote Console (ReCon) is a product of several iterations of development tools. The focus of the ReCon, the monitoring window, has evolved from a web-portal, which displayed finger angles of a single hand exercise to a real-time web-based monitoring system for telerehabilitation, in which a 3D simulation is coupled with performance gauges from the rehabilitation site.[25]

## Conclusion

Telemedicine has a great potential in minimizing the loss of human life when a disaster occurs. Much has been done in this regard in countries with advanced ICT infrastructure and developed telemedicine services including India. Yet, in the backdrop of the October 2005 earthquake devastation in Pakistan and India, it was apparent that countries that do not have telemedicine facilities should go for it without unnecessary delay.

Planning and development for telemedicine should envisage all levels, including telemedicine training and service centers at the community level, operational district level plans, and strategic three and five years plans, at provincial and central levels respectively. Governmental policies should aim at eliminating constraints in the growth of a telemedicine culture. They should facilitate local language content, indigenous ICT research and development, and they should provide subsidies for telemedicine equipment and bandwidth provision. Official plans should envision environment for human resource development and necessary resources through funding, sponsorships and budgetary allocations in partnership with the private sector. Incentives for investment in urban networks and rural integration and development of online applications should be offered. The role of telemedicine in disaster management should also be explored through close contacts and coordination with the World Health Organization, which is already working on an “e-Health disaster manager strategy”.

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