Internship Training

at

International institute of Health Management Research, New Delhi

Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios.

by

Col. K. Ranjit

PG/18/057

Under the guidance of

Dr. Anandhi Ramachandran

Post Graduate Diploma in Hospital and Health Management

2018-20

International Institute of Health Management Research

New Delhi

The certificate is awarded to

Col. K. Ranjit

in recognition of having successfully completed his Internship in the department of

International Institute of Health management and Research, New Delhi

and has successfully completed his/her Project on

Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios.

3-Feb-2020 to 2- Jun-2020

at

International Institute of Health management and Research, New Delhi

He comes across as a committed, sincere & diligent person who has a strong drive & zeal for learning.

We wish him/her all the best for future endeavors.

Dr. Anandhi Ramachandran

Associate Professor,

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FEEDBACK FORM

Name of the Student: Col. K. Ranjit

Dissertation Organization: International Institute of Health management and Research, New Delhi

Area of Dissertation:

Descriptive Secondary data review on Digitization and technology to counter Pandemics with its historical perspective and relevance in current and future scenarios.

Attendance: 98%

Objectives achieved:

1) Understanding the past and current use of technology in countering pandemics
2) Exploring the opportunities and challenges in leveraging digital technology in the country.

Deliverables:

1) Detailed information about use of technology been used to counter Pandemics in past

2) Landscaping various technologies that are being used in countering pandemics

3) Exploring the role of digitization in countering future pandemics

Strengths: A very committed, sincere, diligent, cooperative and positive natured individual with strong drive and zeal for mutual learning. He is willing to continue to work on an assignment until its near perfect. He puts in sustained hard work towards his work

Suggestions for Improvement: Col Ranjit needs to learn to assert himself a little more than he does currently. He needs to put a bit more attention to details while finalizing the deliverables.

Dr. Anandhi Ramachandran

Associate Professor

IIHMR, New Delhi

Date: 26-june-2020

Place: New Delhi

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Col. K. Ranjit** student of Post Graduate Diploma in Hospital and Health Management (PGDHM) from International Institute of Health Management Research, New Delhi has undergone internship training at**, International Institute of Health Management Research, New Delhi** from **3- Feb-2020 to 2-June-2020.**

The Candidate has successfully carried out the study designated to him during internship training and his approach to the study has been sincere, scientific and analytical.

The Internship is in fulfillment of the course requirements.

I wish him all success in all his future endeavors.

Dr Pradeep K Panda

Dean, Academics and Student Affairs

IIHMR, New Delhi

Dr. Anandhi Ramachandran

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Certificate of Approval

The following dissertation titled **"Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios."** at **"International institute of Health Management Research, New Delhi"** is hereby approved as a certified study in management carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite for the award of **Post Graduate Diploma in Health and Hospital Management** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

Dissertation Examination Committee for evaluation of dissertation.

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Dr. Ajay Sood

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Certificate from Dissertation Advisory Committee

This is to certify that **Col. K. Ranjit,** a graduate student of the **Post- Graduate Diploma in Health and Hospital Management** has worked under my guidance and supervision. He is submitting this dissertation titled **"Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios."** At International Institute of Health management and Research, New Delhi in partial fulfillment of the requirements for the award of the **Post- Graduate Diploma in Health and Hospital Management.**

This dissertation has the requisite standard and to the best of our knowledge no part of it has been reproduced from any other dissertation, monograph, report or book.

Dr. Anandhi Ramachandran

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INTERNATIONAL INSTITUTE OF HEALTH MANAGEMENT RESEARCH, NEW DELHI

CERTIFICATE BY SCHOLAR

This is to certify that the dissertation titled **"Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios"** and submitted by **Col. K. Ranjit** Enrollment No. **PG/18/057** under the supervision of **Dr. Anandhi Ramachandran** for award of Postgraduate Diploma in Hospital and Health Management of the Institute carried out during the period from 3-Feb-2020 to 2-June-2020 embodies my original work and has not formed the basis for the award of any degree, diploma associate ship, fellowship, titles in this or any other Institute or other similar institution of higher learning.

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At the onset, I wish to thank the almighty and my mother, a perpetual source of inspiration, my elder brother for being my guiding light, my wife Smitha for being the pillar of my life and my kids and family for their love and support

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Covid-19 has made life difficult amidst all the lockdowns, but my classmates who were with me in these times to support me and my family need a special mention. I wish to specially thank Rimjhim Mishra for her constant push and competitive environment she creates for us. Surabhi and Saijosree were with us and together we handled the lockdown period in an enjoyable and constructive manner. My family joins me in thanking these bright young ladies. Thank you all for being with me.

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Table of Contents

Abbreviations

COVID-19	Coronavirus Disease
CDC	Center for Disease Control
EpiSPIDER	Semantic Processing and Integration of Distributed Electronic Resources for Epidemics
GCBR	Global catastrophic Biological Risk
GPHIN	Global Public Health Information Network
GPS	Global Positioning System
IoT	Internet of Things
IoMT	Internet of Medical Things
ICMR	Indian Council of Medical Research
MERS	Middle Eastern Respiratory Syndrome
MoHFW	Ministry of Health and Family Welfare
MoH	Ministry of Health
NCDC	National Centre for Disease Control
PHEIC	Public Health Emergency of International Concern
SARS	Severe Acute Respiratory Syndrome
SARS-CoV-2	Severe Acute Respiratory Syndrome- Coronavirus 2
WHO	World Health Organization

Chapter-1

Abstract

Digitization and technology to counter Pandemics: Historical perspective and its relevance in current and future scenarios.

Col K Ranjit (PG/18/057)

Health Batch (2018-20)

Covid-19 has affected over 200 countries and the world is looking for ways to address this challenge. In this baffling battle, science and technology is playing a vital role in countering the pandemic. **Objective** of the study is to understand the past and current use of technology in countering pandemics and to explore the opportunities and challenges in leveraging digital technology in the country. **The study** aims to answer questions like: How has technology been used to counter Pandemics in past? What are the various technologies that are being used in countering pandemics? How can digitization help in countering future pandemics? The **Methodology** adopted is a narrative review using keywords for searching the internet databases like PubMed, Google Scholar, Lancet and BMJ. The Inclusion criteria for the search are English only articles/ papers, full text articles. A total of 41 journals/ papers were reviewed. Additionally, number of websites and blogs were also reviewed. The results of the study highlight that technologies that are democratized, distributed, field ready, user friendly, and globally attainable are essential. Pro-active approach to combine the use of surveillance technologies like using Big Data, AI and IoT (used by China) with traditional measures like the quarantine/ lockdowns (used by Indian and western democracies) will assist in gaining an upper hand in the fight against these catastrophes. Novel approaches to disease detection, surveillance and situational awareness (using tech like ubiquitous genome sequencing, drone networks, microfluidic devices). Innovations in medical care that enable care at home (like self-spreading vaccines, micro array patches for vaccine administration) will help people survive even if healthcare systems are overwhelmed and healthcare providers are unavailable. The main challenges in use of technology are the regulatory provisions of a particular country, access to healthcare, changing nature of the virus and deployment of technology during a pandemic.

Keywords: Digital technology, digitization in health, AI for health, Machine learning, smart-technologies, human driven, COVID-19, Techno-driven

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Chapter-2

Introduction

The world has been witness to some dreaded pandemics in the past like the Black Death (1346-1350), the Sixth Cholera Pandemic (1899-1923), Spanish Flu (1918-20), the Asian Flu (1957-58), and Swine Flu (2009-10). Today the world is experiencing the COVID-19 Pandemic, a corona virus infection, third of its kind, preceded by the severe acute respiratory syndrome(SARS) and middle east respiratory syndrome (MERS).

With rapid advances in transportation, trade, tourism etc. the world has become a smaller place (by way of access). The frequency of the pandemics is also increasing as they are occurring and spreading faster than ever. It is imperative that we learn to live with this fact and devise measures to counter and if possible avoid these deadly diseases. The way ahead is by the use of digitization, big data analytics and by use of various technologies which exists currently and those which are being developed like AI and Machine learning.

The twenty-first century began with unusual optimism. The halting of the Severe Acute Respiratory Syndrome (SARS) epidemic in 2003 was hailed as the result of rigorous quarantine and isolation measures, with the "de-emergence" of the disease (Peckham 2016a) fostering the legitimacy of these sixteenth-century technologies of epidemic control. Ten years later, the 2014–2016 Ebola epidemic in West Africa came to brutally deflate this quarantine euphoria, proving the implementation and efficiency of the particular anti-epidemic measure to be far a more debatable and contentious matter than advocated by the proponents of the "lesson of SARS." Soon after, the Zika crisis in South America saw another turn, this time toward an epidemic control method that had been largely discredited within the growing Health paradigm: vector eradication. Historical literature has been dominated by the examination of three measures: quarantine, vaccination, and vector control.

Preparing for what is forecasted as an unpreventable event of disease emergence leading to a pandemic, and its existential risk to humankind, involves the development and mobilization of surveillance, modelling, simulation, and sentinel technologies. While some scholars aim at the detection of spillovers, in other words, the proverbial jump of a novel virus from domestic or wild animals to humans, others focus on preparing human societies for pandemic impact. Preparedness thus relies on early detection or early warning technologies (Caduff 2014), and on technologies fostering resilience in spheres that Collier and Lakoff (2015) have identified as "vital systems" of our technoscientific societies.

Novel Coronavirus (Covid-19) is the most recent pandemic that has resulted in unprecedented social and economic impact on society. Covid-19 is one of a large group of viruses that was transmitted to humans from bats in a local live animal market in Wuhan in late 2019 ([Ji, Wang, Zhao, Zai, & Li, 2020]). It infects the upper respiratory tract and can result in pneumonia and other associated illnesses, which can eventually affect the central nervous system, ultimately leading to death for those with underlying health conditions. Given the potential for human-to-human transmission and that inventing a vaccine would ideally take about one or two years, the World Health Organization (WHO) recommended that governments worldwide should quickly intensify active surveillance to identify infected individuals to allow rapid isolation and quarantine. There have been two major strategies to counter this current epidemic. Use of technology & digitization and the traditional quarantine/ lockdown approach. One of the recent advance in countering infectious diseases is Health Information Technology. This is an important tool to address the onset, propagation and mitigation of infectious diseases which otherwise have a potential to become an epidemic/ Pandemic. Prevention, early detection, infection control, treatment and mitigation by use of latest and upcoming technologies including digitization, big data analytics, robotics, IoT, IoMT etc. is the way ahead to be prepared and counter epidemics/ pandemics.

Chapter-3

Rationale and Research Questions

Rationale

Major infectious disease emergencies can arise with little notice and cause severe detrimental and lasting effects on health and society as a whole. In order to counter a pandemic, surveillance is critical for the health system for early detection of the, changes in morbidity & mortality, measuring of disease burden and for timely implementation of control and preventive measures. It is well established that the viruses causing the pandemics like Flu etc. mutate and hence we have to be a step ahead to counter them. Therefore, better understanding of how pandemics have been dealt with in the past, with special emphasis on technologies used, needs to be studied. Framing the technology requirements to counter pandemics is critical as what is needed is qualitatively and quantitatively different than those used routinely in health care and routine medical practice. What should be considered is better sensitivity to facilitate prevention, improved capacity to make response decisions in a faster time frame, distributive strategies and reduced time lags in implementation of those technologies. This study therefore aims to analyze the use of digitization and technologies used to counter pandemics historically. The study would also attempt to study how they can be used to counter the current and future pandemics

Research Questions

- How has technology been used to counter Pandemics in past?
- What are the various technologies that are being used in countering pandemics
- How can digitization help in countering future pandemics?

Chapter-4

Review of Literature

Brief History of Pandemics

A pandemic is an outbreak of disease of global proportions which happens when a infection due to a bacterium or virus becomes capable of spreading widely and rapidly beyond national borders. Some pandemics that have occurred throughout history include:

- **541–542:** Plague of Justinian
- **1346–1350:** The Black Death
- **1899–1923:** Sixth cholera pandemic
- Some of the more recent ones includes:

Disease	Causative Agent	Year(s)	Death Toll	Classificiation
Spanish Flu	H1N1	1918-1919	~50 million	Pandemic
Asian Flu	H2N2	1957-1958	~1.1 million	Pandemic
Hong Kong Flu	H3N2	1968-1969	~1 million	Pandemic
SARS	SARS-CoV	2002-2004	774	Outbreak
Swine Flu	H1N1 (new strain)	2009-2010	~151,700 to 575,400	Pandemic
MERS	MERS-CoV	2012-present	871*	Outbreak
Asian Lineage Avian Influenza	H7N9	2013-2017	~605	Epidemic
Ebola Virus Disease (EVD)	Zaire ebolavirus	2014-2016	11,325	Epidemic
COVID-19	SARS-CoV-2	2019-present	217,769*	Pandemic

*as of 30 April 2020 Data Source: WHO, CDC

In recent years, there has also been concern about viruses that experts have linked to camels (Middle East Respiratory Syndrome, or MERS-CoV) and monkeys (Ebola). Modern surveillance systems, lessons from the most recent Ebola outbreak in West Africa, and an experimental vaccine offer hope that authorities can handle future outbreaks swiftly, increasing the chances of disease containment. Some of the technologies used to counter pandemics are as under: -

GIS to Map Epidemics

The U.S. CDC is using geographic information systems, which integrate data from several sources to create a picture around a specific issue, to track and better combat the Zika virus. Precise geo-location of the breeding grounds of the disease-causing mosquito, in this case, can create a surveillance system to forewarn about the spread of Zika.

Wearables in Africa to Monitor Ebola. Monitoring physiological symptoms, such as heart rate, blood pressure, blood oxygen levels and more, leads to better diagnosis and analysis of diseases via portable biosensors. U.S. Agency for International Development in partnership with the White House and CDC, created and distributed a Modular Wireless Patient Monitoring System, essentially a "band-aid" sensor, for monitoring Ebola infected area. The sensor looked to develop "personalized predictive analytics to support automated alerting of early changes in patient status and allow for the better-informed triaging of scarce resources,"

Latest Technologies to counter epidemics/ Pandemics. Global catastrophic biological risk (GCBR) is a special category of risk involving biological agents—whether naturally emerging or reemerging, deliberately created and released, or laboratory- engineered and escaped—that could lead to sudden, extraordinary, widespread disaster beyond the collective capability of national and international organizations and the private sector to control. Technology, when applied thoughtfully can improve our ability to anticipate, recognize and address these epidemics/ pandemics. Transformative technologies in countering epidemics and pandemics should possess these attributes: -

- Better sensitivity to facilitate prevention
- Improved capacity to make response decisions
- Distributed approaches to improve scale and access
- Rugged and easy to use in variety of settings
- Reduced time lags in development, availability and fielding.

For this literature review, these technologies have been classified into five categories. Under each of the categories, technologies which have been developed and are under development are discussed below:

1. **Disease detection, surveillance and situational awareness**. A number of emerging technologies often referred to as digital disease detection and digital epidemiology, rely on novel sources of surveillance data, including genomic sequencing and sensing, social media and internet search logs, satellite imagery, or over the counter drug store transaction data. Traditional surveillance strategies rely on either passive reporting from the healthcare delivery system or active reporting from healthcare providers. Though reliable, they depend on individuals seeking care. Further there are delays in reporting mechanisms because of the gap between symptom onset and care seeking. Non-traditional surveillance strategies seek to overcome these shortfalls by monitoring changes in patterns in the community or the environment.

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a. **Ubiquitous Genomic Sequencing and Sensing.** Ubiquitous sequencing would allow for near real time characterization of pathogen biology, including determinations of virulence, transmissibility, and sensitivity or resistance to medicines or vaccines**.** The ability to rapidly and accurately, and affordably determine the nucleotide sequence of genes or gene fragments in a given sample is one of the most important advances in the history of biological sciences. The ability to detect and describe microbial life has improved substantially. Ubiquitous sequencing is using computational and analytic tools to arrive at an advanced genomic sensing capability that would provide unprecedented awareness and knowledge of the biome. One application of these new sensing tools would be the monitoring of a variety of substrates and settings for the presence of non-or novel pathogens, strains, phenotypes. Genomics sensing systems could be established that would continually monitor the air, water, soil, transportation hubs, mass gatherings, forms and other micro environment is relevant to pathogen transmission. Nanopore sequencers is one such advancement towards this technology. Nanopore sequencing is the process by which strands of DNA or transported across a membrane through an electrified carbon Nanopore. Physical passage of the nucleotide through the Nanopore generates a change in electrical resistance based on the nucleotides distinct shape, which then provides the specimens genetic sequence. They have been used to generate genomic information in West African Ebola and Zika.

b. **Drone Networks for environmental detection**. Drones or unmanned vehicles typically associated with air travel which are remotely controlled. Based on purpose, different payloads can be attached to the drone. Networks of land, sea and air base drones autonomously conducting environmental surveillance would be one way to help fill gaps in monitoring of the environment for biological disruption to important ecosystems and bioterrorism events. Drones can traverse different ecosystems to collect data using a variety of sensors and tools, ranging from optical cameras to complex biotechnology. Drones are already being used to monitor air and water quality and they can be fitted with autonomous sample collection and analysis technologies like real-time PCR and sequencing platforms. This capability enables on-board analysis rather than requiring a laboratory to process samples. When multiple drones are used network together, they can conduct ongoing environmental surveillance.

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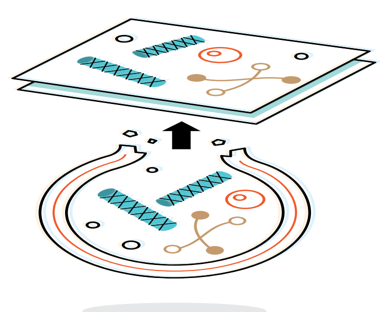
c. **Infectious Disease Diagnostics.** In addition to surveillance and detection of potential global catastrophic biological events, rapid and accurate diagnostic capabilities are critical to identifying cases of infectious disease and ensuring that appropriate interventions, both medical and non-medical are implemented. One of the biggest challenges in outbreak response is the availability of reliable diagnostic assays that could quickly and accurately determine infection status. This capability is especially important early in an outbreak, as responders attempt to characterise the pathogen and disease and contain the outbreak while it is still a manageable size.

d. **Microfluidic devices.** Microfluidic devices are "Labs on a Chip" devices that have the potential to augment or replace traditional lab testing equipment, making diagnostics more accessible, usable, and useful in resource constrained environments. These devices are available in plastic or paper versions. The plastic version of a microfluidic device is a small – often credit card sized or smaller – object embedded with embedded channels throughout. The channels are lined with cells, agents, antibodies, or other diagnostic components, and the diagnostic samples, taken from a sick individual, are forced through the channels, usually propelled by a pump. The fluids interact with the reagents in the channels to yield the test result. Several processing steps can be combined in a single chip, which increases efficiency and decreases the amount of training a user requires. Paper microfluidic devices are cheaper but are limited to less complex reactions than the plastic versions. These could be revolutionary for diagnosing infectious diseases in the field. Rather than relying on access to centralised care providers and laboratories, healthcare workers could potentially distribute microfluidic devices to clinics or even to households. Decentralising laboratory functions would increase testing capacity and decrease delays in diagnosis and treatment. This alternative testing strategy could also be combined with telemedicine to extend clinical care to remote or poorly resourced settings.

e. **Hand-Held Mass Spectrometry. A** Mass spectrometer precisely determines the mass of chemical and biological material in a specimen in order to reveal the composition of the sample, a technology which has been in use since long. In recent times, it has been used to analyse biological specimens also. Advances in mass spectrometry have enabled devices to detect proteins and peptides that serve as biomarkers for specific pathogens, without requiring specimen to be cultured. The current mass spectrometry units are the size of a desktop printer but with advances, by use of carbon nanopores, they could be hand-held in times to come, which will make it usable in field and at point of care. Some mass spectrometry technologies- in particular PCR electrospray ionization mass spectrometry(PCR-ESI/MS)- may provide pathogen-agnostic or pan-domain diagnostic capability (Rollins G, 2014).

f. **Cell-Free Diagnostics.** Cell-free diagnostics do away with the cell membrane to use the machinery within bacterial cells in combination with engineered genetics circuits to make proteins for diagnostic purposes. These cells-free diagnostics can generate rapid colorimetric outputs visible to the naked eye for easy interpretation. The cell extracts can also be freeze-dried onto paper for use in austere environments. For diagnostics, a new approach to genetic control of translation using highly Program Riboregulators known as “toehold switches” (Ausländer S et al, 2014) allows for tight translational control of a gene. A riboregulator consists of a particularly complimentary pair of RNA sequences: a sensor strand that normally forms a hairpin loop whose structure prevents the ribosome from initiating translation of a protein product, and trigger RNA that relieves the translational depression. The trigger RNA – in terms of diagnostics this would be the viral or bacterial RNA one is trying to detect – would then bind to the toehold sequence, which will linearize the hairpin structure. This can be used to initiate the production of enzymes that generate a colorimetric output visible to the naked eye for rapid detection of the presence of a pathogen. Proof of concept study has already been completed



Molecular diagnostics for field use during pandemic situations must be developed quickly – they should be highly sensitive and specific, inexpensive, and rapidly deployable and they should provide timely diagnostic capabilities in low resource areas. They need to be easy to use and interpret without technical expertise, and production should be highly scalable for implementation on global scale. Cell-free based diagnostic platforms address many of these important practical limitations.

2. **Distributed Medical Counter-measure Manufacturing.** For the world to counter epidemics and Pandemics medical countermeasures(MCM), i.e. Vaccines and drugs, will need to be manufactured rapidly and in mass quantities. The current capacities to manufacture essential drugs needed for such pandemics are limited and a new approach to MCM manufacturing is the need of the hour.
    a. **Synthetic Biology for manufacturing Medical Countermeasures.** Genetically engineered strains of bacterial organisms, such as yeast and salmonella, can be used to manufacture many drugs and vaccines (Lawrence J, 2015). Synthetic biology takes advantage of the fact that bacterial bio-synthetic pathways have the natural built-in modularity, meaning they can be edited and re-modelled to customise the products being produced by bacterial cells. These pathways, which were used naturally by bacteria to make chemical compounds and biological products such as proteins, can be reprogrammed to make different products and in large quantities. This approach to MCM development and manufacturing is relatively new. One of the first successful test cases for pharmaceutical production using synthetic biology is the drug artemisinin, an antimalarial chemical compound. Synthetic biology provides the opportunity for novel approaches to both finding and producing therapeutics, as well as the capability to produce these are not tailored and distributed way.
    b. **3D printing of chemicals and biologics.** Three-dimensional (3D) printing is the process of building an object in successive layers by fusing or depositing materials. Digital inputs, a 3D printer can produce an object out of existing material or agents in almost any shape. This technology could be applied to devices and parts, biological components, and pharmaceuticals, among other users. This technology could facilitate personalised medicine through printing of active pharmaceutical ingredients. If applied to health emergencies, 3-D pharmaceutical printing could be used for distributed manufacturing of MCM's as well as personalised drug dosing formulations. The main advantage of this technology is its potential to address distribution and access problems in current MCM manufacturing. In addition, 3D printing may facilitate the creation of drug delivery systems that overcome barriers related to drug stability or intermittent dosing. 3-D printing also helps accelerate the process of MCM discovery and testing through use of 3D printed tissues that can be printed in the field and used as drug evaluation platforms. (Vaidya M, 2015)

3. **Medical Countermeasure Distribution, Dispensing and Administration.** Once drugs and vaccines make it through discovery, R&D, testing and manufacturing, they still need to be delivered and administered directly to people who need them. This last bit is sometimes difficult to do quickly and effectively. Catastrophic conditions would require rapid mass administration of MCM in order to reduce morbidity or mortality. Despite adequate stocks sometimes, the delivery is an issue. For example, during the 2009 H1N1 influenza pandemic, even as the new vaccine became publicly available in United States, only 34% of people in initial priority groups and 29% of adults at high-risk were vaccinated (CDC website, 2009 data). Given below are some technologies that would greatly facilitate the last mile of MCM distribution, dispensing, and administration, making a pandemic response more effective.

    a. **Microarray patches for vaccine administration.** The micro array patch (MAP) is an emerging vaccine administration technology that will modernise the conduct of mass vaccination campaigns. Adopting the MAP technology would enable completion of vaccinations during epidemics and pandemics. Currently, MAPs are being evaluated by the CDC and PATH for global health applications but they could be highly effective and emergency response settings as well. Favourite types of Aps have been developed, the most promising of which is comprised of an array of small, water soluble, thermostable cones that are embedded with the antigen of choice and held against the skin with an adhesive bandage. Once applied and pressed into skin, the cones dissolve within minutes, delivering the antigenic payload into the dermal tissue. Or a reliable, pain-free method of delivering an intradermal injection that could minimise the amount of vaccine needed to confer immunity. Additionally, in the context of a severe pandemic could enable self-administration of vaccines, which would not require advanced medical training or expertise. Immunologically, antigen is delivered via intradermal administration or taken up by specialised antigen – presenting cells (APC) that reside in the skin. These cells take in and process antigen from the vaccine, transfer it to the lymphatic system and present the antigen to T and B cells. T-cells are able to recognise and kill virus-infected cells, and B-cells can make antibodies against an invading virus, thereby generating a protective immune response. severe epidemic and pandemic like the influenza, Ebola, and Zika have catalysed initiatives to expedite vaccine research, development and manufacturing (Rottingen JA et al, 2017) however, little attention has been paid to addressing the logistical and technological aspects of administering vaccines in an emergency.

b. **Self-Spreading Vaccines.** They are also known as transmissible or self-propagating vaccines. These are genetically engineered to move through populations in the same way as communicable diseases, but rather than causing the disease, they confer protection. In this case a small group of people are vaccinated and the vaccine strain would then circulate in the population much like a pathogenic virus. These vaccines could dramatically increase vaccine coverage in human or animal population without each one vaccinated individually. There are two main types of self-spreading vaccines; recombinant vector vaccines and live viral vaccines. Company director vaccines combine the elements of a pathogenic virus that induce immunity (removing the portion that causes disease) a transmissible viral vector. Cytomegalovirus is one candidate vector for recombinant vaccine, because it is highly species specific and moderately transmissible. Tell us predict vaccines have been effectively used in animals. There are challenges in genetically engineering viruses however synthetic biology tools such as CRISPR/Cas9 are likely to aid researchers.

c. **Ingestible Bacteria for Vaccination.** Bacteria can be genetically engineered to produce antigens in a human host, acting as a vaccine, which triggers immunity to pathogens of concern. One such example of a vaccine platform (Vaxonella, created by Prokarium) turns a genetically engineered attenuated strain of *Salemonella enterica* bacterium into an in vivo bioreactor to create recombinant vaccines. These bacteria are placed inside capsules that, once swallowed, dissolve in the small intestine and release the bacteria. Once inside the human immune cells, the engineered bacterium begins to express antigens that trigger the APCs to stimulate all arms of immune system. The bacterium is self then quickly destroyed by the body's immune cells. Typhella, a vaccine for typhoid has already been made using this platform. Simplified and low-cost administration makes oral vaccines an attractive option. Through the use of synthetic biology, the Vaxonella platform overcome several of the limitations that have prevented widespread use of oral vaccines. because, in this case, and antigen is being made within own cells, and hence there is no need for costly protein purification topics used to develop antigens in a laboratory.

d. **Synthetic Vaccinology: Self-Amplifying mRNA Vaccines.** Recent research in synthetic vaccinology has highlighted self-amplifying mRNA (SAM) vaccines for their safety and excellent immunogenic response profiles. Although the idea of RNA vaccines is not a new concept, recent advances in potential delivery systems in combination with RNA vaccine have renewed interest in these products. SAM vaccines use the genome of a modified virus with positive sense RNA. Positive sense RNA is recognizable to our human translational machinery, whereas negative sense RNA is not. Normally, once a positive sense RNA virus enters a human cell, it is translated by the human cell into various structural proteins and a viral replicase (which creates copies of the viral genome). The SAM vaccine works by enzymatically synthesising a positive sense RNA strand from a complimentary DNA Template. Once inside a cell, the SAM is immediately translated and creates two proteins: the antigen of interest and the viral replicase. The use of a positive, single- strand RNA viral backbone for vaccine ensures self-amplification in a human host, while the removal of viral structural proteins eliminates the production of viral particles, effectively preventing a potentially harmful infectious cycle.

e. **Drone delivery to remote locations.** Drones can support a variety of capabilities which can become critical during the epidemic/ pandemic. One of the most popular applications of existing drone systems is the airborne transportation of clinical specimens, MCMs or other supplies within or to a remote area. Further these systems of drone transportation networks can be used to facilitate distributed manufacturing capabilities to support local outbreak response. Rather than relying on centralized, large-scale production platforms, on-demand delivery of specific active pharmaceutical ingredients, drug precursors, or genetic material could enable local production of MCMs, vaccines, or other products on a smaller scale, tailored to a particular pathogen. Drones prevent human interface and hence reduce or eliminate exposure to deadly pathogens and hence be effective in curbing disease transmission.

4. **Medical Care and Surge Capacity.** Surge capacity in medical care is a limiting factor in responding to severe infectious disease events. Epidemics/ Pandemics of highly infectious nature can overwhelm a complete health care system. A very high percentage of casualties would not get access to healthcare and that would result in very high number of deaths.

a. **Robotics and Telehealth.** Robotics and Telehealth are two potential broad categories of healthcare technologies that would be most relevant during a epidemic/ pandemic. Like most technological advances they extend both the human sensorium and our ability to act over large distances. Diffusion of robotic technology to healthcare is a recent phenomenon. From transportation of lab samples in hospitals, to conduct of operations in a more direct application of healthcare. With the application of AI and machine learning, the robots are able to undertake more complex clinical tasks. The second category, is the ability to remotely connect healthcare providers to patients through advanced information and communication technologies- a modality nowadays referred to as “telehealth”. Telehealth can facilitate the remote diagnosis, treatment, education, care, and follow up of a patient, and it is now used routinely for general infectious disease consults in the United States. A strong foundation of telehealth in India is also coming up. The recent ongoing COVID-19 pandemic has further strengthened the use of this technology.

b. **Portable, Easy-to-use Ventilators.** In a severe outbreak of respiratory disease, ventilators will be needed for the sickest patients to support breathing during the worst of their illness and while they recover. An inexpensive, portable mechanical ventilator that is intuitive and largely automated—particularly if it did not require significant resources (eg, highly trained supervision, electricity, compressed gas) to operate- could allow for the care and survival of many more patients than would be possible if a pandemic emerged today. patients who are recovering from their illness, or who are less severely ill but who still require ventilation to support breathing, may require less- intensive care and could be ventilated outside of a hospital in an alternative care facility. Two types of ventilation exist with the potential to be modified for applications outside of a hospital setting. The first is positive pressure ventilation, in which pressurized air is forced into the lungs, and the second is negative pressure ventilation, in which the chest cavity is mechanically expanded to lower the pressure inside the lungs and draw air in. Simplified versions of positive pressure ventilators, are made applicable to pandemic settings through a simple user interface that allows for easier control of breathing rate and volume. The air supply is provided using either an internal oxygen compressor or external compressed air (depending on available resources), and they operate using long-lasting rechargeable batteries that make them adequately suited for austere environments without reliable power. They can also be less expensive, costing just a fraction of the price of a typical hospital ventilator. In a major pandemic involving a respiratory illness, the healthcare system will quickly be overwhelmed by the large number of critically ill patients who need supportive care, including mechanical ventilation. A ventilator that can be used in alternative care facilities with less professional supervision, and fewer resource requirements like compressed air, may enable lifesaving supportive care for patients who are less severely ill or are recovering when hospital-level treatment is unavailable due to patient surge or other lack of access to care.

5. **Artificial Intelligence (AI), Data Science and technology**. China exhibited a strong tech savvy response to the current pandemic. Its use of AI and other data analytics paves way for applications of these technologies to counter pandemic and epidemics. Given below are 10 ways to use these in countering and managing pandemics and epidemics:
    a. **AI to identify, track and forecast outbreaks**. The better we can track the virus, the better we can fight it. By analyzing news reports, social media platforms, and government documents, AI can learn to detect an outbreak. An example of Tracking infectious disease risks by using AI is what the service Canadian startup Bluedot provides. In fact, the BlueDot's AI warned of the threat several days before the Centers for Disease Control and Prevention or the World Health Organization issued their public warnings. Artificial intelligence in the form of automated disease surveillance platforms, is helping process data that is already available online from public health organizations, population databases and transport records to track its spread and the number of cases worldwide. The technology uses a blend of machine learning and natural language processing to report the spread of COVID-19 in real-time.
    b. **AI to help diagnose the virus.** Artificial intelligence company Infervision launched a coronavirus AI solution that helps front-line healthcare workers detect and monitor the disease efficiently. Imaging departments in healthcare facilities are being taxed with the increased workload created by the virus. This solution improves CT diagnosis speed. Chinese e-commerce giant Alibaba also built an AI-powered diagnosis system they claim is 96% accurate at diagnosing the virus in seconds.
    c. **Processing healthcare claims.** It's not only the clinical operations of healthcare systems that are being taxed but also the business and administrative divisions as they deal with the surge of patients. A blockchain platform offered for example, by Ant Financial helps speed up claims processing and reduces the amount of face-to-face interaction between patients and hospital staff.
    d. **Drones deliver medical supplies.** One of the safest and fastest ways to get medical supplies where they need to go during a disease outbreak is with drone delivery. Terra Drone (Japanese) is using its unmanned aerial vehicles to transport medical samples and quarantine material with minimal risk between Xinchang County's disease control centre and the

People's Hospital in china. Drones also are used to patrol public spaces, track non-compliance to quarantine mandates, and for thermal imaging.

e. **Robots sterilize, deliver food and supplies and perform other tasks**. Robots aren't susceptible to the virus, so they are being deployed to complete many tasks such as cleaning and sterilizing and delivering food and medicine to reduce the amount of human-to-human contact. UVD robots from Blue Ocean Robotics use ultraviolet light to autonomously kill bacteria and viruses. In China, Pudu Technology deployed its robots that are typically used in the catering industry to more than 40 hospitals around the country.

f. **Drug Development.** Google's DeepMind division used its latest AI algorithms and its computing power to understand the proteins that might make up the virus, and published the findings to help others develop treatments. BenevolentAI uses AI systems to build drugs that can fight the world's toughest diseases and is now helping support the efforts to treat coronavirus, the first time the company focused its product on infectious diseases. Within weeks of the outbreak, it used its predictive capabilities to propose existing drugs that might be useful. The Australian Academy of technology and engineering report highlights the use of AI to develop a vaccine. Excerpts from the report are as given:

- "Genomic sequencing technologies and data are playing an important role in building an understanding of the virus. A task force of Chinese researchers were the first to sequence the virus in January 2020, which revealed the pathogen causing the disease."
- "Numerous teams have since sequenced the genome, which has informed the development of diagnostic tests and the identification of treatment options for the virus. A number of biotechnology companies are working on producing new, portable and faster electronic devices for DNA sequencing and diagnostics."
- "A team of scientists from the Peter Doherty Institute for Infection and Immunity in Australia were the first laboratory outside China to grow COVID-19 from a patient sample. This sample has helped to accelerate virus diagnosis and vaccine development."
- "Multiple labs around the world are working on producing a vaccine. Some are using machine learning techniques to create new drug candidates or to predict if existing drugs might work as a vaccine for COVID-19."
- "The University of Queensland (UQ) has created a candidate vaccine for COVID-19 and is working quickly towards pre-clinical testing. The lab's 'molecular clamp' technology can engineer a vaccine that could be more readily recognised by the immune system, triggering a protective immune response."

IIHMR DELHI

g. **Advanced fabrics offer protection.** Companies such as Israeli startup Sonovia hope to arm healthcare systems and others with face masks made from their anti-pathogen, anti-bacterial fabric that relies on metal-oxide nanoparticles.

h. **AI to identify non-compliance or infected individuals.** While certainly a controversial use of technology and AI, China's sophisticated surveillance system used facial recognition technology and temperature detection software from SenseTime (patented tech) to identify people who might have a fever and be more likely to have the virus. Similar technology powers "smart helmets" used by officials in Sichuan province to identify people with fevers. The Chinese government has also developed a monitoring system called Health Code that uses big data to identify and assesses the risk of each individual based on their travel history, how much time they have spent in virus hotspots, and potential exposure to people carrying the virus. Citizens are assigned a color code (red, yellow, or green), which they can access via the popular apps WeChat or Alipay to indicate if they should be quarantined or allowed in public.

i. **Chatbots to share information.** Tencent operates WeChat, and people can access free online health consultation services through it. Chatbots have also been essential communication tools for service providers in the travel and tourism industry to keep travelers updated on the latest travel procedures and disruptions.

j. **Supercomputers working on a coronavirus vaccine**. The cloud computing resources and supercomputers of several major tech companies such as Tencent, DiDi, and Huawei are being used by researchers to fast-track the development of a cure or vaccine for the virus. The speed these systems can run calculations and model solutions is much faster than standard computer processing.

Smart technologies and COVID-19: A Chinese perspective. China's interest in using smart technologies for governance dates back to the overall shift in its innovation policy that began in the early 2000s (Ling & Naughton, 2016; Liu, Simon, Sun, & Cao, 2011). Wuhan, the most affected city during the current COVID-19 outbreak itself is a smart city. At the micro level, the IoT is so far penetrated into Chinese daily life that passenger bus rides are often charged based on facial recognition technology. Furthermore, smart devices are connected to utilities such as rubbish bins, which are electronically connected to a system that alerts authorities when they are full (Andrelini, 2019). Thus, both the built environment and citizens in the major cities have been oriented towards the adoption of the enhanced use of the IoT for the past 10 years. As a result, China has the most sophisticated IoT industry, thanks to its aspirations for building smart cities (Kshetri, 2017). In addition, it has the best technological manufacturing industry in the world (Li, 2018). With the help of the IoT, big data, and AI, cities can perform continuous monitoring, offer catastrophe warnings, and make quick decisions (Zhu et al., 2019). Among the other sectors, health care has benefited significantly due to the heightened adoption of new-age technologies (Sun & Medaglia, 2019). Given the centralised power structure, the IoT ecosystems were set into motions by bringing key stakeholders and devices to track and trace ine individuals who were infected with the virus. They primarily used three pronged approach to contain and counter the epidemic viz:-

Active surveillance and identifying the infected. One advantage china has is its surveillance system. Top five surveilled cities of the world are in china. Most of the Chinese investment in smart cities is built around improving surveillance of their citizens in addition to focusing on built environment (Andrelini, 2019). Karpal (2020) emphasises that during the quarantine, the government even installed CCTV camera on apartment doors to ensure that residents would not leave their quarantined houses. Some of these cameras include AI technology and facial recognition to identify people (Keegan, 2019). Chinese cities were coordinated under central leadership to make use of the sensors for data collection throughout the cities, conduct decentralised testings, and flag those who were infected by Covid-19. The AI technology developed for identifying individuals is so robust that while CT scans results can take upto 15 mins to diagnose, AI can complete the task in 10 seconds (McCall, 2020). Drones equipped with cameras and controlled by operators were further deployed for conducting surveillance and issuing instructions and warnings to those failing to wear masks or failing to follow the emergency protocols. In cases where citizens failed to report their travel history in the affected areas, IoT devices were used to ascertain their travel history and flag those cases (Liu & Li, 2020). In addition, corporations allowed the government to acess their systems hosting the mobile applications (Apps) that the citizens routinely use to track their own travel history. For instance, apps like Alipay and WeChat, that are routinely used across china, helped the government to track down those who were infected.

Public transportation has also adopted specific technologies like AI body temperature screening system (deployed in most metro stations in china). Further police officers in the Chengdu smart city wear smart helmets that detect people with high temperature within a 5-meter radius. AI has been used to integrate body and face identification with the help of dual sensing by visible light and infrared cameras to quickly identify patients. These data are shared with central server to supply necessary medical resources.

Isolate the infected from others. AI has been useful in assisting understaffed medical professions to navigate through the available data and understand the emerging trends. In Suizhou, a city 170 km from Wuhan, 2.2 million citizens were able to register their health condition using mobile Apps. A digital prevention system developed by Alibaba in collaboration with Suizhou enabled DingTalk and Alipay Apps allow citizens to register for healthcare systems. This technology enabled the self-registration of patients meaning there was a reduced need for them to visit hospitals and spread the infection to medical professionals (Jie and Qiao, 2020).

Lockdown and quarantine. In addition, a new health code was implemented in over 100 cities via an online prevention system allowing people to share their travel history and health status. Every citizen was allotted with a QR (Quick Response) code. Based on information, the individuals were allotted a particular colour code. Those who were affected by the virus or had recently travelled to Hubei province were given red code. Yellow code had to self-isolate for two weeks and green colored coded people could freely access the city. (Lauer et al., 2020)

Highly affected zones were completely locked down, drones were used to ensure lockdown implementation. The technology china had built over the years to conduct surveillance on its citizens became a source of advantage. As a result, China has one of the strongest technological potentials for handling pandemics compared to other countries.

Smart technologies and COVID-19: A Western perspective: Extreme surveillance measures followed in china may not work in other countries, as they impose severe restrictions on the human rights of the citizens (Cohen & Kupfesrchmidt, 2020). Western democracies have therefore focused on human-driven approach, comprising of collecting anonymous data, ensuring lockdowns and quarantine.

Active surveillance and identifying the infected. Unlike Chinese smart cities, smart cities of western democracies have heavily invested in the human capital of citizens. Individual privacy and freedom is of paramount importance and have strict privacy laws. For example, some several states of USA have banned facial recognition technologies (Pyzyk, 2020). As a result countries have asked mobile companies to provide anonymous data on concentration and movements. The UK Covid symptom tracker app, tracks symptoms of infected individual and determines the range of virus spreading in a particular area to help understand why some people become critically unwell compared to others (Wakefield, 2020). Similarly, Germany has developed Corona Data Donation smart watch app which gathers anonymous data from volunteers to track down infections.

Isolate the infected from others. Lack of coordination between smart cities has resulted in people travelling from one city to the other, especially in Italy, Spain and USA. Despite the government of Italy having data of its citizens having unique personal identification number to access healthcare, lack of coordination between different healthcare departments has resulted to use big data effectively. Smart cities, in general require active coordination among different departments and levels of administration (Angelidou, 2014).

Lockdown and quarantine. While Western countries have not adopted technological approaches for screening and isolating infected patients, they have focused on lockdown of affected regions and/ or entire countries. UK, France, Spain and Germany are few to name.

<u>India's response to COVID-19</u>. India has responded to the COVID-19 pandemic in the most spectacular way. The initial response of quarantine and lockdowns were simultaneously followed up with innovations and use of available technology to counter the pandemic. Many available technologies were used, a flurry of innovations were initiated by both government and private firms. Given below is the gist of technologies developed and underway as compiled by VIGYAN PRASAR(An autonomous organization of Department of Science and Technology):

Chitra GeneLAMP-N. Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, an institute of national importance of the Department of Science and Technology (DST), has developed a diagnostic test kit that can confirm COVID-19 in 2 hours at low cost. The confirmatory diagnostic test, which detects the N Gene of SARS- COV-2 using reverse transcriptase loop-mediated amplification of viral nucleic acid (RT-LAMP), will be one of the world's first few, if not the first of its kinds, in the world. The test kit, funded by the DST called Chitra GeneLAMP-N, is highly specific for SARS-CoV-2 N-gene and can detect two regions of the gene, which will ensure that the test does not fail even if one region of the viral gene undergoes mutation during its current spread. "

"DBT-InStem develops germicidal protection for PPE. Dr. Praveenvemula's lab at DBT-Institute for Stem Cell Science and Regenerative Medicine (inStem) has developed a proprietary germicidal molecule, which could be used to produce anti-germ facemasks and other personal protection material (PPE). This molecule can be covalently attached to any type of cotton fabric including household cotton and the fabric can then be stitched into PPE such as a facemask. The molecule is effective against both Gram- positive and Gram-negative bacteria and even enveloped viruses. Research and testing has concluded that this compound remains attached to the fabric for up to 25 cycles of standard detergent wash (industrial grade) at least. One can use such 'germicidal' masks efficiently and repeatedly without much fear by just cleaning them with regular soap wash at home or dipping them in boiling water for five minutes and drying, thus resulting in better waste management and environmental pollution. "

"COVID GYAN. Covid Gyan serves as a hub to bring together a collection of resources in response to the COVID-19 outbreak. These resources are generated by research institutions in India and several associated programmes. The content presented on the website provides a scientific understanding of the disease and its transmission. The main objective of the website is to create public awareness and bring in a holistic approach to the understanding of COVID-19 disease and potential means to mitigate it. "

"Test Kit. Researchers at the Rajiv Gandhi Centre for Biotechnology (RGCB),Thiruvananthapuram are in the final stages of developing a kit that promises to help detect SARS CoVID-19 infection as early as four days post-infection of the virus.The kit will be able to detect two types of antibodies - Immunoglobulin M (IgM) and Immunoglobulin G (IgG)."

"Covid-19 Sample Collection Kiosk (COVSACK). A kiosk has been developed by DRDO-DRDL that can help healthcare workers take samples from suspicious patients, without the need of PPE kits. It is designed as such that the Kiosk can be disinfected automatically with the help of its inherent features without any help of human personnel. "

"Synthesis of nanoparticles and its coatings on cotton/ polyester fibres for having antiviral and antibacterial properties. Centre for Materials for Electronics Technology (CMET), Pune, under the aegis of scientific society of *Ministry of Electronics and Information Technology (MeitY)* has developed antiviral and antibacterial masks with metal/metal-semiconductor nanoparticles as a cost-effective alternative of N95 masks for the Indian market. Yshawantrao Chavan Institute of Science,(YCIS), Satara, Maharashtra".

Cost-effective portable plasmonic sensor for random testing of novel coronavirus at the community level. "Centre for Materials for Electronics Technology (CMET),Thrissur, Kerala, under the aegis of scientific society of Ministry of Electronics and Information Technology (MeitY), has developed a point-of-care plasmonic portable sensor with disposable semiconductor-based chips to detect antibody with the presence of COVID-19 virus in the blood.The sensor was tested for food-borne pathogens by Rajiv Gandhi Centre for Biotechnology (RGCB), Thiruvananthapuram. Functionalization of the sensor and the docking efficiency analysis are being carried out on the designed bio-receptors with different pathogenic strains."

Besides these other technologies have been effectively used by India to counter the current pandemic. Some of these are:

Disease surveillance using ICT. The implementation under ICT consisted of the following three sub-components:

- Supply, installation and maintenance of computer hardware and system / application software
- Development, installation of specific software including training of human resources to use the software
- Establishment of network between districts, states and central level (including handholding and support)

The ICT component of IDSP was initially envisaged to create a four-tiered network with Primary Health Centres and Community Health Centres connected using Interactive Voice Response System (IVRS); district health offices connected through computers and a low-end server; state health offices connected with computers and a mid-range server; and the Central Surveillance Unit connected through computers and larger number of mid-range servers. In Project Implementation Plan (PIP), it was conceived that five computers would be provided to each district to be installed at the District Health Office, District Public Health Laboratory, District Hospital, local Medical College and private sentinel surveillance unit. Significant hardware and software was proposed for procurement. The procurement process for the ICT items when under advanced stages of processing was forfeited in view of several other vertical health Programmes having supplied similar hardware and software to targeted health facilities. Different National Health Programmes including RCH, NVBDCP, RNTCP and NPSP have also provided computers to strengthen District Health Office. It was therefore agreed to that there is a need to reassess the hardware requirements at different levels taking into consideration the computers already supplied under these centrally sponsored programmes. Accordingly restructuring of the ICT component under IDSP was done in the year 2006. IDSP decided to establish an integrated health information centre supported by connectivity that allows distance training and video conferencing in addition to data transfer at the district level. Incorporation of ISRO to further strengthen the network was done. This would provide the following:-

- Tele-education / Distance learning
- Data entry, transfer and analysis from district unit to state/centre units
- Video conferencing at State Surveillance Units and Central Surveillance Unit

Application of Modern Technology

S No	Application	Description	References	Status in India
1	Diagnosis using radiology Images	• AI is used to extract radiological features for timely and accurate COVID-19 Diagnosis • Early detection of COVID-19 cases using different CNN modelscan be tested by increasing the number of images • COVID-Net, a dep CNN design can be used for detection of COVID-19 cases from CT images and X-rays • COVID-19 detection neural network (COVNet) detects COVID-19 and distinguish it from community acquired Pneumonia and other lung diseases • 3-dimensional deep learning model can be used for early detection of COVID-19 cases	Wang et al, Narin and Xu et al	yes
2	Disease Tracking	• Abnormal respiratory patterns classifier may contribute to large scale screening of infected people • Time dependent SIR model is used to estimate the infected persons • GRU neural networks with bi-directional and attentional mechanisms (BIT-AT-GRU) for classifying respiratory patterns • SEIR – Susceptible, Exposed, infectious and removed or recovered model is used to forecast the trajectory of the outbreak	Wang et al	yes
3	Prediction outcome of patient's health condition	• Supervised XGBoost classifier provides a simple and intuitive clinical test to	Yang Zhang, Goncalves et	No

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		precisely and quickly quantify the risk of death • Machine learning based CT radiomics models showed feasibility and accuracy for predicting hospital stay in COVID-19 patients	al, Qi No et al	
4	Computational Biology and medicines Perspective	• BenevolentAI used to seach for baricitinib, which is predicted to reduce the ability of the virus to infect the lung cells	Richardson et al	No
5	Protein structure Predictions	• Critical structure of techniques for protein structure Prediction (CASP) using deep neural networks predicts properties of the protein from its genetic sequence • Convolutional network Architectures examining for dense prediction • Residual learning framework is used to ease the training of networks that are substantially deeper, for image recognition	Jumper, Hassabis and Kholi, Yu and Kholtun, He et al	Yes
6	Drug Discovery	• Integrated AI-Based drug discovery pipeline to generate novel drug compounds • Adversarial autoencoders is used to disentangle the style and content of images, unsupervised clustering, dimensionality reduction and data visualisation	Zavoronkov et al, MAkhzani et al	yes
7	Awareness and social control through Internet	• Smart phone thermometer as an authentic and alternative apparatus for assessing temperature of infected people • Cough type detection using extensive set of acoustic features applied to recorded audiofrom a relatively large population of both healthy subjects and patients	MAddah and Beigzadeh, Nemati et al	yes

Table -1 Application of modern technology during COVID-19 Pandemic

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ICT Tools used During Ebola and Zika Outbreaks

Potential digital use in epidemics	Technology and tools application	Implications and impact
Surveillance, tracing and tracking, mapping and early warning	Social media, Digital Network Diagrams & Maps, Crowding mobile mapping, CDRs, Satellite images, Drones	Preparedness, instructions and guidelines, individual and communities guidelines, engagement and participation, contact tracing, data-driven decision making frontline action, early warning, population movement
Social mobilisation, participation and resilience	Social media, SMS & IVSS	Enables individuals and communities to understand epidemic risk and initiation action for recovery
Data and information access, reporting, sharing and dissemination	Mobile Apps, social media, SMS	Sharing information regarding the outbreak between healthcare workers
Advocacy and mitigation outreach to wider population	SMS, Mobile Apps, social media	Mobilization alert, instructions and advice, communities engagement on disease and actions, allows individuals in remote communities to shared anecdotal and positive journalism

Risk communication and rebuilding trust and confidence to the affected communities	Social media, Tele-consulting	Patients can communicate with family and friends, healthcare workers can communicate with patient
Reimbursement, incentivizing payments and financial management	SMS, mobile apps	Reimbursement, micro credit or insurance enquiries, paying healthcare workers, accepting donations from contributors
Training care providers and field health workers empowerment	SMS, mobile apps, webinars, and online tutorials	Efficiently train new healthcare staff, keep existing staff informed about updates
Monitoring and evaluation	Closed circuit social media, internet , thermal cameras	Circuit social media, internet ,TV, migration cameras, surveillance of patients, monitoring

Table -2 ICT applications and tools usefulness and impact on Zika and Ebola epidemics worldwide (Tambo et al J Health and Med Informat 2017, 8:2 DOI: 10.4172/2157-7420.1000254)

Chapter-5

Objective of Study

Objective

To understand the past and current use of technology in countering pandemics and to explore the opportunities and challenges in leveraging digital technology in the country. To understand what all technologies are available to counter current and future pandemics and their relevance in today's perspective with special emphasis in India.

Historically, technology has not been leveraged much to counter pandemics. Its only with the Ebola epidemic that some use of technology been witnessed. The current pandemics throws light on how various technologies and strategies have been adopted by different regions of the world to handle the health scenario. Studying these perspectives and projecting the future and developing technologies with an aim to counter pandemics is the underlying theme of this study.

Specific Objectives

- To gain an understanding of use of technology in the past to counter disease pandemics globally.
- To map the use of digital technology for combating covid-19 pandemics globally.
- To highlight the use of technology in India towards Covid-19 response.
- To identify the challenges and opportunities in use of digital technology for healthcare.

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Chapter-6

Methodology

Methodology

This study was a Secondary Research. A Narrative Review using keywords like digitization, technology , pandemics, artificial intelligence in health, machine learning to counter pandemics and mobile applications was done by searching the internet databases like PubMed, Google Scholar, Lancet, BMJ. Inclusion criteria for the search included the period of search. A 200 years pandemic history was included in the search however on doing the search it was revealed that technology was used very lately from the Ebola epidemic. Other inclusion criteria included words like epidemics, pandemics. English only articles/ papers shortlisted. Full test articles were selected as it was an inclusion criteria.

Study Design is Descriptive study based on literature review. 58 journal articles and 22 other Blogs/ technology sites were identified. 64 studies were shortlisted for screening. A total of 41 articles and reports were reviewed after shortlisting based on inclusion criteria as given above.

Study Data : Secondary data was used in the study for a narrative review. PRISMA diagram was generated based on the articles retrieved and shortlisted for the study

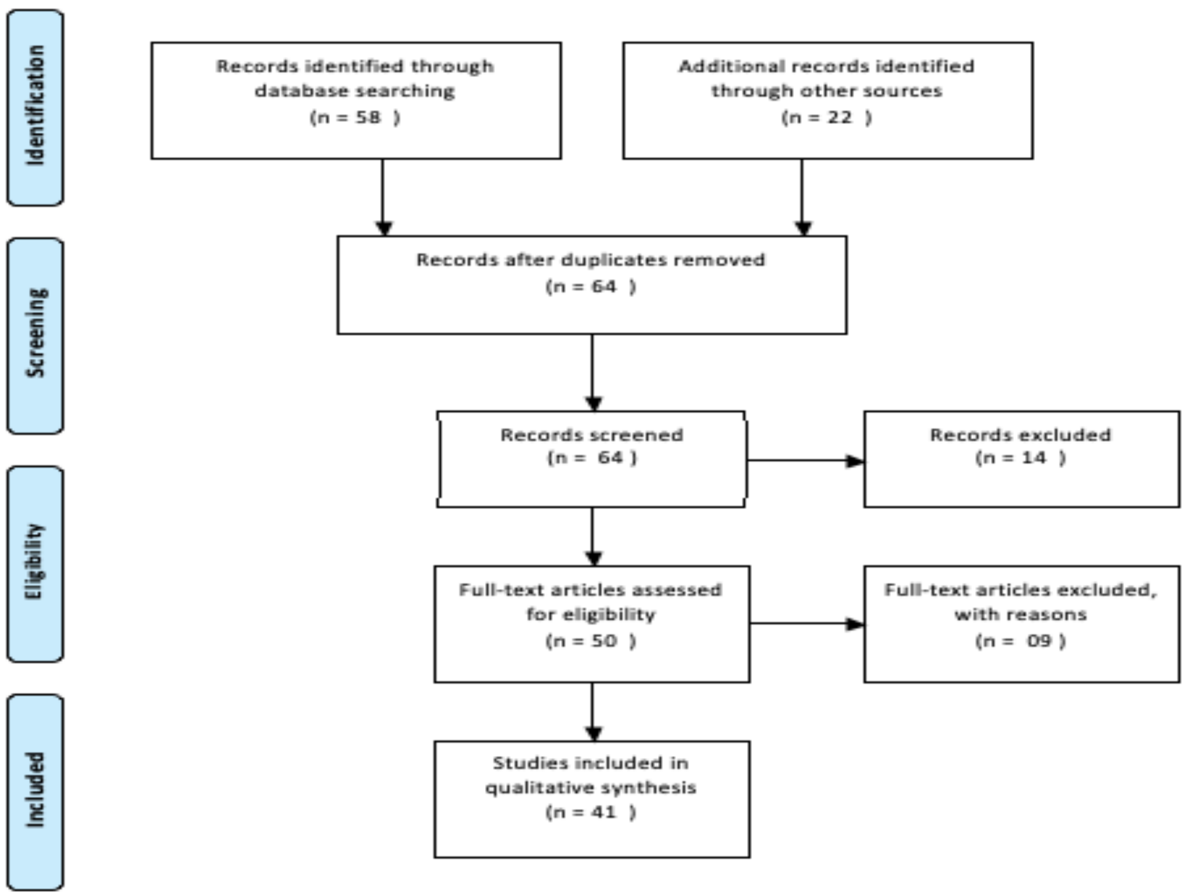
The articles were reviewed and a comprehensive literature review based on various themes like technologies, epidemics, responses of various countries, special emphasis of India's response was written. The research questions and objectives selected were addressed using the inputs of the literature reviewed.

The results were analyzed based on technologies used in various major epidemics, the use of specific technologies by other countries and specifically by India. 15 specific emerging technology were analyzed based on its availability and cost of implementation.

Chapter-7

Results and Findings

The results of the study highlight that the technologies presented, represent new possible approaches to addressing severe risks caused by epidemics. The study was conducted by reviewing journal articles and technology websites. The shortlisting of the articles is highlighted below using a PRISMA Diagram.



PRISMA Diagram

A total of 50 full text articles were assessed and 9 articles were excluded as the contents of those were already being covered in parts in the 41 articles finally selected. Finally, 41 studies were used in the qualitative synthesis in this narrative review. Technology was first effectively used during the Ebola epidemic and that too was very restricted. We are aware that the epidemics have a set pattern of progression. It is generally classified into four stages; -

- **Stage I** - Imported Cases. The first stage of an outbreak in a particular nation is characterized by its first reported incident of the disease, in the case of COVID-19, the disease does not spread locally, and the infection is usually limited to the people with travel history to an already affected region.
- **Stage II** - Sporadic Cases/Local Transmission. The second stage of the outbreak occurs when there are a few sporadic cases of the disease in the country. This happens when infected people with the disease spread it to people with whom they come into contact, generally with immediate family members, friends, and colleagues. Here it is possible to perform contact tracing and limit the spread of the disease by quarantining the infected people.
- **Stage III** - Clusters of Cases. The third stage of the outbreak in a country is marked by the presence of several clusters of the cases, i.e., when the disease-causing virus starts circulating within a geographic location and infects individuals who have neither a history of travel nor contact with someone who does. At this stage, it becomes hard to trace the source of the virus transmission, and geographical lockdown becomes highly necessary to prevent the outbreak from reaching stage IV.
- **Stage IV** - Community Transmission. The fourth stage of the disease causing and epidemic/ pandemic in a country is associated with community transmission, i.e., very large outbreaks of local transmission in a country, which would lead to an extremely high number of reported incidents and deaths. At this stage, the outbreak gets out of control, and finding a cure or vaccine is the only way to mitigate the impact of the disease. Countries like Iran, Turkey, Canada, and the USA are currently in the fourth stage of the COVID-19 pandemic**.**

At each stage, technology can be effectively used, to control the progression of the disease. How effective this intervention is, will decide how better we can contain the damage which the epidemic will cause. Use of technology globally for some of the earlier pandemics have been recorded. Given below are examples of some of the technologies used in various countries for pandemics.

Global Use of technology for Pandemics

S.No	Name of the Pandemic	Year	Use of Technology	Purpose	Country	Reference
1.	SARS CoV	2002-04	• GPHIN, EpiSPIDER • Bio Sensors for detection • Failsafe air safety systems	• Outbreak and emerging public health threat detection • Disease Detection	China, Canada USA, Hong Kong, Singapore, Vietnam	WHO, J S Mackenzie et al.
2.	HINI	2009	HealthMap system	Disease surveillance	France, UK	John S Brownstein, 2017
3.	Ebola	2014	• Mobile • mHealth, • Nanopore Sequencing	• Awareness spreading • data and info sharing • vitals monitoring • Gene sequencing	West Africa	Tambo et al, J Health Med Informat 2017 , Juliet Van Wagenen
4.	MERS- CoV	2012	Vaccine Technology Platforms	Vaccine development	Saudi Arabia, Middle East countries, Korea	Ryan Aguanno et al, 2018

It was the Ebola and Zika epidemics where modern technology was started to be used for controlling the disease. Technology can assist national and international efforts to control the spread of the disease, like it played a critical role in raising awareness about Ebola, prevent the spread of the disease, and support the role of frontline healthcare workers by providing better means to communicate simple, trustful and reliable instructions and information. In such innovative approaches that connect biomedical and social sciences, that are community-based, and that use new technology that proactively forecast/anticipate, detect, and respond to current and emerging threats, while providing primary healthcare coverage for all. In case of Ebola, communication using mobile technologies was effective and applied. Effective social mobilization empowerment via supportive messaging, short message service (SMS) and Intelligence Voice Response Systems (IVSS) on safety and preventive measures, care seeking treatment and use of protective equipment during safe burial practices and hospital or Ebola centre infection prevention in Sierra Leone and Guinea were used and foster and enhance individual and community's participation and building trust and communities recovery resilience from Ebola outbreak

Some research agencies also tried using wearables to track the vitals of the patients remotely, that way remote tracking and analysis could lead to better assessment of risk and requirements of the resources needed to tackle the disease. Nanopore sequencing was beginning to take roots, and this would later grow and be used along with AI.

During the SARS CoV pandemic of 2002-04, global public health Information Network(GPHIN) was used to assess the threat detection and outbreak monitoring. It was called event based surveillance for public health threat detection. The Global Public Health Intelligence Network (GPHIN) is one of the most important event-based surveillance systems that systematically scans a multitude of such informal sources, including web sites, electronic discussion forums, news reports, online newspapers and the email listserv of the Program for Monitoring Emerging Diseases (ProMED-mail, www.promedmail.org/) for unusual disease events and rumors for outbreaks. GPHIN processes approximately 3000 news items per day, however one fourth of those may represent duplicates or irrelevant data. In some but not all event-based systems, generated raw data is then being investigated, verified through official sources and assessed in terms of its epidemiologic significance by specialist teams to arrive at various predictions and simulations. Other widely used event based systems are Argus, HealthMap and EpiSPIDER.

Global use of Technology for countering COVID-19

Artificial Intelligence. Technology here refers to techniques, frameworks and devices where scientific information is utilized for practical purposes. Artificial intelligence can be characterized as Machine Learning (ML), Natural Language Processing (NLP), and Computer Vision applications. To counter the Corona Virus Pandemic, AI majorly focuses on diagnosis of the patients, identification of virus, medical imaging process, disease tracking and its prediction. On the other hand, it also covers alerting, creating awareness and social control through the internet. AI can assist in providing effective solutions. This study has categorised some of them. AI capacities can be valuable to analyse, predict and clarify (treat) COVID-19 patients, and help reduce financial effects. So far, most clinical utilizations of artificial intelligence to the COVID-19 reaction have concentrated on diagnosis dependent on clinical imaging. Some of these are:

1. Diagnosis using radiology images. With the assistance of Deep Learning, radiologists can diagnose COVID-19 using X-ray pictures. COVID-Net an artificial intelligence application is created to analyse COVID-19 symptoms in chest x-rays utilizing information of different lung conditions and COVID-19 patients.
2. **Disease tracking.** Artificial intelligence can be used to track illness with spread of COVID-19 with time and place. Ongoing discoveries recommended that COVID-19 has respiratory patterns which are different from seasonal influenza and regular cold, eminently that they display tachypnoea (fast breathing). Forecast of tachypnoea could be a first-order diagnostic feature that may add to enormous scope screening of potential patients. Tracking the spread of COVID-19 can be significant information for general public health authorities to design, plan, and deal with the pandemic.
3. **Prediction of a patient's health condition.** In lieu of the methodology which was proposed dependent on features contained in patients' clinical data and blood tests to assist doctors in identifying high-risk patients as early as they can under these circumstances, thus improving the forecasting of patients and lessening the mortality of those that are seriously sick, a forecast model dependent on the XGBoost calculation was made to predict mortality risk and distinguish key features by using AI. The researchers found out three key clinical pointers (lactic dehydrogenase, lymphocyte and high-affectability C-receptive protein) for assessing a patient's mortality. By analysing these the predictability will improve considerably.
4. **Computational biology and medicines perspective.** Computational Biology includes the development & use of data analytics, mathematical modeling and computational simulation procedures to study biology. Computational biologists are assisting with battling coronavirus through disease modeling and finding another medication for this pandemic. Disease dynamics modeling contributes in understanding the effect of parameters that rules the spread of the infection, and the impact that mediations can have in controlling this spread.
5. **Prediction of protein structure.** When virus RNA genome first enters a cell, it mingles with the host's protein-production, utilizing it to make proteins that can duplicate RNA molecules. These RNA-replicating proteins, called "polymerases," make a target for treatments. There are two primary ways to deal with the forecast task: template modelling, which predicts structure utilizing similar proteins as a template sequence, and template free modelling, which predicts structure for proteins that have unknown related structure. Identification of these using AI is a technology that is being researched and developed.

6. **Drug Discovery.** Using the crystal structure of the protein, the co-crystalized ligands, and the homology model of the protein decoy receptor or protein is made as medication by using AI.
7. **Spreading of social awareness and control through internet.** An example is WHO using its Information Network for Epidemics (EPI-WIN) for imparting data to key partners so that there is no wrong information spread to public causing panic.

IoT and IoMT. (Internet of Things and Internet of Medical Things). Data collected by appliances or gadgets which are connected to the internet and capable of sending any data, constitute the internet of things and amalgamation of medical devices and software applications which provide healthcare services and connected to healthcare IT networks form the Internet of Medical Things. Applications of IoMT include monitoring patients from remote locations, tracking medication orders and using wearables to send health information to experts. Leveraging IoMT will reduce burden on healthcare resources. Some of the technologies and devices used in IoMT are:

1. **Smart Thermometers.** Almost a decade ago, a US health technology company named Kinsa had launched internet-connected thermometers to screen people for high fevers. This is now very handy in monitoring COVID-19 Patients remotely. Kinsa Health has deployed more than a million smart thermometers to households in various cities of the USA. These thermometers are linked to a mobile application, which allows them to transmit their readings to the company immediately. Once received, this data is assimilated by Kinsa to generate daily maps showing which of the US regions are witnessing an increase in high fevers, thereby allowing the US authorities to identify potential hotspots.
2. **IoT Buttons.** To maintain high cleaning standards and limit the number of hospital-acquired infections (HAIs), several hospitals in Vancouver have installed battery-operated IoT buttons. These buttons, named Wanda QuickTouch, were designed for rapid deployment in any facility, irrespective of their size, in order to issue prompt alerts to the management, warning them of any sanitation or maintenance issue that may pose a risk to public safety.
3. **Tele-Medicine.** Using IoMT technologies to carry out remote patient monitoring is called telemedicine/ telehealth. In this the clinicians evaluate, diagnose, and treat patients remotely. A rapid surge in tele-medicine traffic is been seen post the COVID crisis. Benefits of telehealth techniques are twofold: Firstly, it has lessened the burden on the overworked hospital staff and secondly, it has reduced the risk of spread of the virus from the infected individuals to the healthcare personnel. Given below are some of the telemedicine platforms which are being used around the world to manage the impact of COVID-19:

4. In the USA, the George Washington University Hospital (GWUH) has adopted the use of several telemedicine strategies, including video consultations and live facebook webinars to provide remote medical expertise to several people.
5. Another university hospital in the USA, the Rush University Medical Center, has adopted the use of telemedicine platforms to facilitate on-demand video consultations and also to screen them for the COVID-19
6. In India, the state governments of Assam and Andhra Pradesh have rolled out telemedicine facilities to enable remote interaction of potential COVID-19 patients with medical experts.
7. In Israel's largest hospital, the Sheba Medical Center, several telehealth technologies were used to monitor 12 Israeli passengers that were on board the cruise ship quarantined in Japan for several weeks. They used it to ensure minimal human contact while treating them within the hospital premises.

Drone Technologies. During the times of a pandemic like COVID-19 pandemic, Unmanned Aerial Vehicles (UAVs, i.e., drones), can offer many advantages. Not only can they ensure minimized human interaction, but they can also be used to reach otherwise inaccessible areas. China has made great use of drone technology to counter the COVID-19 outbreak. Some of the uses of Drones during this pandemic are as under:

1. **Crowd Surveillance.** Drones, can offer many advantages. During such time. They ensure minimized human interaction, as also, can also be used to reach otherwise inaccessible areas. China effectively drone technology to counter the COVID-19 outbreak. An example is MicroMultiCopter, based out of Shenzhen in China, has deployed over 100 drones in several cities of China in an attempt to survey areas and observe crowds efficiently. In India too, many companies are offering solutions , for example a global technology solutions company named Cyient has provided the Telangana police with unmanned aerial spectrum monitoring technology to help manage the crowd during COVID-19 lockdown.
2. **Public Announcements.** Important announcements in hard to reach areas can be achieved. Example is The police authority in Madrid, Spain, used a drone equipped with a loudspeaker to inform people of the guidelines put in place regarding the state of emergency that was imposed.
3. **Screening Masses.** China employed the use of drones equipped with infrared cameras to carry out large-scale temperature measurements in several residential areas. In India, the authorities in New Delhi have employed the use of a multipurpose drone to contain the spread of the COVID-19. Dubbed the "corona combat" drone, it is equipped with a thermal camera for screening individuals, a night vision camera for

IIHMR DELHI

monitoring the crowd, a portable medical box for carrying essential medical supplies, a loudspeaker for making announcements, and a disinfectant tank with a capacity of 10 litres for sanitizing public. Another example is the Canada-based commercial UAV manufacturer DraganFly, who are in the process of developing a "pandemic drone" to remotely observe and identify people with infectious respiratory infirmities. These drones are to be installed with a specialized sensor and computer vision system that can monitor people's temperature and heart. They can also detect sneezing and coughing of people in public spaces. This would revolutionise the COVID-19 testing methods.

4. **Spraying disinfectants.** Spain has become the first country to use agricultural drones to spray disinfectants in public places.
5. **Delivery of Medical and other supplies.** Ireland in 2019, had first used drones beyond visual sight to deliver diabetic medicines. In the current state of crisis, this can be a very valuable proposition. China used the effectively. Marut Drones, a Hyderabad-based start-up led by a team of Indian Institute of Technology (IIT) alumni, recently launched an entire line of drones to combat the COVID-19 pandemic in India. To combat the COVID-19 pandemic, the company has drones for sanitizing, medicine delivery, thermal analysis, movement monitoring, and crowd surveillance in its arsenal. "They claim that their medical delivery drones, equipped with obstacle avoidance and advanced navigation technology, can cover a distance of 12 kilometres in merely 8 minutes, thereby ensuring medical deliveries 80 times faster than the conventional methods".

Robots and Autonomous Vehicles. Like drones, have made great strides in countering the current pandemic.

1. **Robots.** With minimal or no human contact, robots are being used for UV based decontamination procedures. They are also being used to conduct thermal scans at public places like airports, railway stations, Hospitals etc. A Kerala based startup called Asimov Robotics has developed a three-wheeled robot that is being used to assist patients in isolation wards. The robot does the job of doing tasks like serving food to the patients as well as giving them medication, thereby protecting the healthcare workers and reducing their burden. Another example is Xenex Disinfection Services, a company established by two John Hopkins educated epidemiologists, has developed an autonomous disinfection robot to help limit the number of hospital-acquired infections (HAIs). A Danish robotics company, UVD Robots, has developed multiple disinfection robots, using powerful UV rays based disinfecting tech, to be delivered in hospitals in Japan, Italy, Singapore etc.
2. **Autonomous vehicles.** China is using these to deliver medicines and supplies in hospitals and other places.

Wearables. Wearables are communication enhancing devices worn on the body that are connected to an internet source. Wearables range from smartwatches like Apple Watch, fitness trackers like Fitbit, smart headbands like Dreem, to personal sensors & patches. The ability to monitor people's physical health, along with their stress levels, has made wearables an ideal technology for adoption in the healthcare sector. In the midst of the current health crisis, various organizations have modified their existing offerings or rolled out new wearables to aid in COVID-19 impact management. Some of these are as under:

1. **Whoop strap 3.0.** A Boston-based human performance technology company, WHOOP, is working with a team of researchers at the Central Queensland University (CQUniversity) in Australia to examine a possible link between alterations in respiratory rates and the COVID-19 symptoms with an aim to detect the disease at a primary stage. The wrist mounted strap will identify abnormal respiratory behaviour and intimate the user of a potential COVID infection. Other companies like Garmin and FitBit are also working on this technology.
2. Estimote, a start-up known for its Bluetooth location beacons, has recently developed a set of wearable devices to enable contact tracing at the workplace, in an attempt to provide employees with a safer workplace environment. This wearable device allows organization leaders to monitor the health status of their employees remotely and to keep a record of any case of COVID-19 transmission amongst them. It enables early detection and prevents spread of the disease.
3. **LifeSignals Biosensor Patch.** A Silicon Valley start-up named LifeSignals plans to launch a novel biosensor patch that leverages the cardiovascular monitoring technique to assist early detection of the COVID-19 in an individual. This single-use, showerproof, and lightweight wearable named Biosensor Patch1AX, when affixed on the chest area, can record the temperature of the person along with his/her respiration rate, ECG trace, and even the heart rate in real-time.
4. **Loop Signal.** Spry Health is a company that is known for its health management and telemedicine technologies. This company has launched a wearable device called Loop Signal to limit patients from visiting hospitals unnecessarily, especially during these times of Pandemic. Loop Signal helps to remotely manage the health of people who have symptoms of COVID-19. Worn on the wrist, Loop Signal tracks the heart rate, respiratory rate, and pulse-oximetry of the patient.

Mobile Applications and other Platforms. Mobile Apps works towards management of an epidemic in many ways like education, training, monitoring, surveillance etc. Most of these modern platforms use a wide variety of technologies, like Bluetooth, Global Positioning System (GPS), and Geographic Information System (GIS). Certain Apps have used the emerging blockchain technology, which helps store data in immutable blocks. one of the main advantages of using blockchain-enabled apps is blockchain's capability of validating continuously changing data. This feature can prove to be quite valuable in managing the rapidly escalating COVID-19 situation. Two examples of this are; A Canadian start-up specializing in blockchain solutions has recently launched a safety system, in the form of an app, known as Civitas, which could assist local authorities in various countries of the world to control the impact of the COVID-19. Another example is MiPasa, which is a data streaming platform built on top of the Hyperledger Fabric. This platform uses the services provided by the IBM blockchain & the IBM cloud platforms, to facilitate the sharing of verified health and location information among individuals, authorities, and hospitals. This application works by collecting the information provided by various medical organizations, public health officials, and other individuals.

Geographic Information Systems (GIS), Bluetooth and GPS are other technologies which augment the available resources to effectively manage the pandemic situations. Bluetooth technology can be used for proximity calculation as has been done in the Indian Aarogysethu App. TraceTogether is another contact tracing app launched by the Government of Singapore, that uses Bluetooth technology to determine the history of exposure of an unaffected individual to an infected one. Tech Giants Apple and Google are working jointly on such a contact tracing tehnology. The Aarogya Setu App uses the GPS location of the cellphone user in addition to the Bluetooth technology to determine if an individual has been exposed to any potential COVID-19 patient listed in the database.

Voice Detection. This is to detect the presence of the disease based on the vocal input of a person. Two prominent examples of agencies working on this technology are Carnegie Mellon University and DY Patil Institute of Bio-Technology and Bio Informatics, Mumbai, India. To use the app, one has to speak into the microphone of his/her device, following which the app breaks the sound into multiple parameters, including frequency and noise distortion. The values of these parameters are then compared to an average person's parameter values to determine if an individual is potentially infected with the COVID-19. A summary of technologies used by the world and India (specifically) are given in the tables below.

Use of Technology to counter COVID-19 (Best Examples)

S.No	Technology	Use of Technology	Country	Reference
1	**AI**	• Disease Surveillance, • Risk Prediction • Medical Diagnosis and Screening • Curative Research • Virus Modeling and Analysis • Host Identification • Busting Fake News • Enforcing the Lockdown Measures	**China, USA, Thailand, South Korea**	**Dinh.C et al, 2020, Rama Krishna Reddy Kummitha, 2020**
2	IoT and IoMT (smart Thermometers, IoT Buttons, Telemedicine)	• Remote monitoring of patients • Tracking medication orders • using wearables to transmit health information	China, Israel, Taiwan	Tambo et al, J Health Med Informat 2017 , Aishwarya Kumar et al, 2020
3	Drones	• Crowd Surveillance • Public announcements • Mass screenings • Disinfectant spraying • Delivery of medical supplies	India, Ireland, China, Australia	Tambo et al, J Health Med Informat 2017 , Vinay Chamola et al, 2020

4	Robots and autonomous vehicles	• Disinfection • Medicine delivery	China, India, Denmark	Vinay Chamola et al, 2020
5	Wearables (bio sensor patches)	• Vitals monitoring • Disease detection • Contact tracing • TeleHealth	Australia, Singapore, China, USA	GCBR Tech report, GHBSPH,
6	Mobile Applications and other platforms (Block chain, GIS, Bluetooth, GPS, Voice detection, Geo-Fencing) and 5G tech	• Disease detection based on voice • Surveillance • Contact Tracing • 5G Medical Imaging • 5G Thermal Imaging • 5G + Robots	Italy, South Korea, Germany, Thailand, China	Vinay Chamola et al, 2020, Juliet Van Wagenen, 2017

India's Use of Technology to counter COVID-19

S.No	Technology	Purpose	Public/Private
1	Dashboards & Modelling	Telemedicine	AP, Assam
2	Surveillance Apps	Aarogya setu	National App
3	Media	Information sharing, Training, awareness generation	National and local
4	Robots	Sanitisation, delivery of medicines/ stores, surveillance	Asimov Robotics(Kerala) In hospitals, Airports
5	Touch free Bio-metric systems	Identification, surveillance, movement control	Hospitals, Airports, Railways, Offices
6	Drones	Surveillance, announcements, sanitisation	Cyient (Telengana), Corona Combat Drone(New Delhi), Marut Drone(Hyderabad)

India's Use of Technology to counter COVID-19

S.No	Technology	Purpose	Public/Private
7	Vaccines , Testing Kits, PPE	• Voice based testing,, • Vaccine development, • Testing	Maharashtra(under testing), 14 Firms currently developing vaccines. Chitra Genelamp-N (Kerala)
8	Devices for Treatment	• Portable Ventilators • Scanners • Smart Thermometer • Foot operated washing stations • Sample collection kiosks • Portable plasmonic sensor for random testing of novel coronavirus at the community level	DRDO, various state governments, CMET(Pune)
9	Thermal Scanners/ cameras etc	AI enabled scanning, surveillance, integration with Aadhaar for mapping.	Private players like Aggrex-AI, State Govts
10	Antibacterial and Anti-viral nanoparticle coatings	Masks, protective wear	Centre for materials for electronic Tech (Pune)

Chapter-8

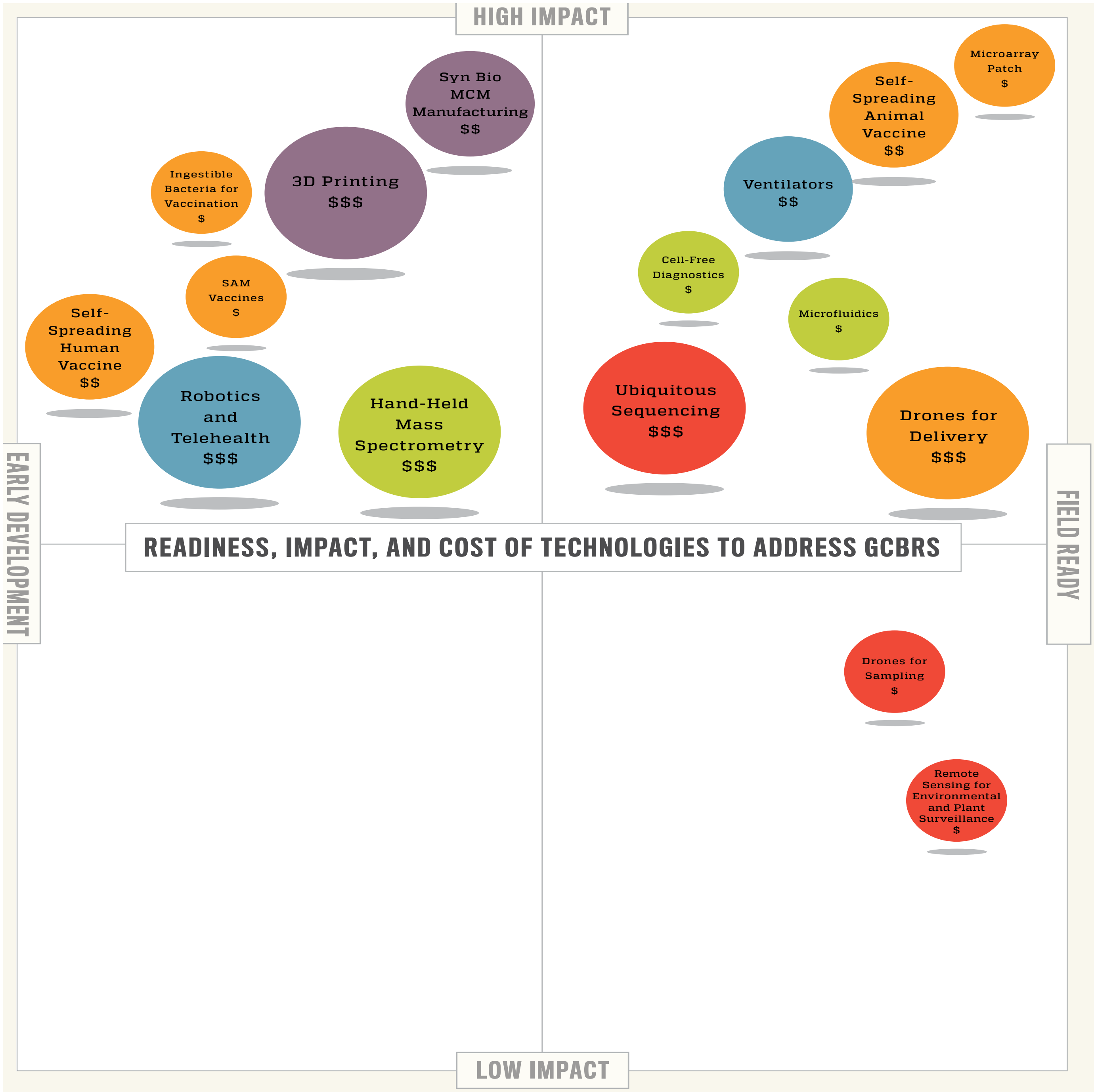
Discussion

Technology cannot stop the spread of the disease in the epidemic but it can educate, warn, empower and reduce the impact of it. There were four major aspects which emerged from the learnings of the Ebola epidemic. They are Messaging, Training, Connectivity and real time monitoring.

1. **Messaging.** During an outbreak, clear messaging to the local population is vital to ensure that they have the information and can use appropriate precautions. It was due to Africa's technological push for mobile phones, that several NGOs were able to spread the message highlighting the hazards of Ebola and how to avoid contracting the virus. Updating the local populace, especially when the hazards changes course and becomes aggressive is very important. Making people aware of the issues and treatment becomes a vital factor.
2. **Training.** Tech advances in mobile computing makes it easier to train health workers in a standardized manner. Tools such as Oppia Browser and e-buddi have been used to train people on ground. Healthcare workers have to remain fully updated and in a standardized manner. This training continues to help even after the emergency period is over. This helps in optimizing healthcare infrastructure also.
3. **Connectivity.** Effective measure to counter a pandemic to reach all locations to deliver the counter-measures. Rural areas suffer the most when it comes to delivering care during such pandemics. It is here that drones etc can substantially support the cause. Stable communication and transportation is essential to counter a pandemic/ epidemic.
4. **Real time monitoring**. Several innovative solutions such as Epi-info VHF and EVDNet have been trial evaluated to assist in the monitoring of a new virus outbreak. This is an area that has seen real innovation in using the available mobile capabilities. The viability of these approaches will only grow with the increase in mobile penetration.

Computer modelling of the spread of epidemics will create effective strategies to assess, and counter the future epidemics. Mapping of the epidemic/ Pandemic using tools like GIS helps the decision makers to strategize against the growing disease. Pattern recognition using tools like AI, Machine learning, IoT and IoMT enables us to be future ready against Pandemics.

Parameters to be considered while implementing Technology



(Source : Dr Crystal Watson et al, Technologies to address global catastrophic biological risks , 2018)

Major considerations while implementing new technologies to counter any disease of global proportions (pandemic/ epidemic) are as follows:

1. The readiness of each technology? At what stage of development it is?, is it field ready? These are the questions to be asked before considering the application of any technology in a given scenario. The technology has to be trial evaluated and implementable in an environment. It should be socially acceptable, be ethical and follow the rules of the state where it is being implemented.
2. Potential Impact. Another important factor is to assess the potential impact of the technology in countering a GCBR. Every technology can be measured on some scale as to how much of impact will it have in controlling, managing and mitigating a global risk.
3. Investment. The amount of investment has to be commensurate with the potential of the technology.

A combined assessment of all these parameters will define as to which technology will be used in what situation.

Opportunities

Advent of new technologies makes new vistas, in countering the current and future pandemics. Some of the opportunities visualized during this study in use of technology and digitization are as under:

1. Use of wearables and its development will have a wider and comprehensive surveillance cover. This will lead to efficient monitoring of the pandemic, health situation of the subjects and pave way to launch efficient counter-measures.
2. Use of AI in conjunction with other technologies like IoT,IoMT, Drones etc. will be the new normal to counter pandemics. It will serve as early warning and hence will lead to better countermeasures. we have seen the potential of AI to be effective in all stages of the epidemic, including prevention of the outbreak all together. With passage of time and new developments, AI will stand rock solid in all aspects of disease management.
3. Data sharing and security, will be a important aspect to be considered especially in the non-communist regimes and westernized democracies. Efficient and safe data management will give the healthcare professionals and the administrators a head start to manage any epidemic.
4. Novel approaches to medical counter measures distribution, dispensing and administration can save lives. Use of 3-D printing of drugs, devices etc. will give localized power to local self-governments to effectively

deal with the outbreak. Equality of availability of healthcare will be addressed, with advent of such technologies

5. Innovations for medical care at home can help save lives even when healthcare facilities are overwhelmed. Self-administration of drugs, self-assessments using wearables and technologies will reduce the burden on healthcare facilities.
6. Field deployable and hand-held diagnostic tests can help flatten curve at the earliest. Shortage of resources including trained manpower is one of the biggest short comings in a pandemic situation. Availability of gadgets, which can be used at grassroots levels will empower detection, and management of the disease at the earliest.
7. Distributive manufacturing by use of 3D printers can scale up availability of Drugs and devices

Challenges

We know that every pandemic situation is different. In case of the current COVID-19 emergency, we know that the virus mutates and every time it does so, it brings about new challenges of detection, mode of spread, how quickly it spreads, treatment protocols etc. Over and above the disease and its peculiarities, the way it is handled by each country also differs. Sometimes the economic factors play a detrimental role. Given below are some of the challenges envisaged during the study:

1. Legal and regulatory rules for autonomous vehicle. Every country has certain set of RTO rules, amendment to those would be necessary, in those countries where there is a restriction on autonomous vehicles movement.
2. Ethical and security complications for environmental surveillance.
3. Ethical and human right issues associated with information sharing. Especially in western democracies, personal information sharing has a lot of restrictions. In an advent of a pandemic, personal health data, and other sensitive health related information sharing will be a problem area. This needs to be addressed.
4. Data security. Once the data is shared, it has to be secure and free from malpractices. A sensitive health information can become a source of potential business for some. This has to be guarded against.
5. Physical security during delivery of health parameters by Robots/ Drones. The potential harm that a robot or drone can cause inadvertently, will always remain a challenge. The technologies will have to mature to avoid any mishaps.

IIHMR DELHI

6. AI models require substantial data, newer strains of viruses will generate different sets of data. Data updation at real time is a necessity for AI to continuously learn.
7. AI requires human interface currently. This means that potential biases can occur.
8. Lack of knowledge about technologies and its localisation. Though globalisation has made worls a smaller place, still the technologies are localised. This may be due to the costs involved, business strategies or government policies. Countering pandemics will require globalisation in letter and spirit.
9. Hacking and operation of Drones beyond visible range. Beyond visual range drones are susceptible to jamming and hacking. Precious cargo or potentially dangerous cargo, if any, can fall into wrong hands making it a biological risk which is unintended.

Chapter-9

Conclusion

19 specific Technologies was studied as part of this dissertation. These will help set up ground for countering current and future pandemics. Technologies have to be democratized, distributed, field ready, user friendly, and globally attainable. Pro-active approach to combine the use of surveillance technologies (as used by China) with traditional measures like the quarantine/ lockdowns (used by Indian and western democracies) will assist in gaining an upper hand in the fight against these global health hazards. Surveillance, isolation and lockdown strategies need a relook. Coupled with use of latest technology, global data sharing, early warning and coordinated response is the way ahead India has shown great resolve in handling the current pandemic, but differences in state level strategies is making the curbing difficult. Impending economic scenario, is adding to the burden. The pandemic has given rise to innovations at national and local level. Use of AI, Machine learning, Big data analytics, IoT, IoMT, and other novel technologies will go a long way in countering the current COVID-19 pandemic as also make mankind ready to tackle future pandemics. It has been noticed, especially in countries which used big data, digitization and other novel technologies, the curve has flattened much fasted and efficiently than those countries which are primarily dependent on traditional quarantine and lockdown strategies.

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