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Review Article

Telemedicine- digital revolution in healthcare through virtual interconnection: A review

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ABSTRACT

Advances in technology have created quality network services, allowing individuals to get better health care, and making it cheaper and more accessible to more and more people. Telemedicine can be described as the use of telecommunications technology to provide medical services to people who are far from the provider. The most important aspect being people and their intent to use technology, their orientation, motivation, and training. The telephone lines were being used to transfer medical data in lesser time previously. Radios have been used to order medical supplies. With the advancement of the technology and internet today telemedicine has expanded its scope and relies on phones, computers, gadgets etc. thus, resulting in a faster, and more efficient, and accessible healthcare delivery system.

1. Introduction

The digitalisation journey of healthcare had its predecessors in other industries. The huge amount of health data generated around the world attracted the attention of technologists, but the healthcare providers were only interested in better service delivery with a humane touch. This made the technology advancement a slow game in healthcare. But the pandemic was a game changer even in terms of motivation and attitudes of the people. With the advancement in technology, quality network services have enabled individuals with improved healthcare delivery and made it available to people in an economic and timely manner.[1] Telemedicine, telehealth, e-health or m-health are some of the terms used interchangeably with slightly different meanings were the very first mode of technology advancement that swept healthcare arena. The term telemedicine defined 'healing at a distance'. It can be described as the use of telecommunication technology that provides healthcare services to people who are at a distance from providers.[2] It is being used as an overarching term to describe health delivery system along with other aspects like education, research, health surveillance and public health promotions.[3]The other terms used interchangeably are eHealth for health data stored, retrieved or transmitted through electronic media; mHealth or mobile health is the use of wireless devices like mobile and tablets to improve healthcare services, research and obtain better health outcomes; telehealth on the other hand, comprises of telemedicine services along with the administrative duties and non-clinical functions of healthcare as well.[4] Telehealth differs from the telemedicine as the former refers to provide and felicitate health related services like provider, patient education, medical care, health related information services and self-care and the latter is confined to physician provided healthcare service.[5]

In ancient times, telemedicine was done through communication methods like pigeons, signals, drums, etc. and only after the discovery of electricity, communication became more common, leading to the development of

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the telegraph for medical care during the American Civil War.[4] As per WHO, the delivery of healthcare service, at a distance using information and communications technology is a critical factor, especially by all medical professionals on receiving relevant information for the prevention, diagnosis, and treatment of injuries, and diseases, research and evaluation, and for the training of health care providers, for advancing the health of individuals and communities is termed as telemedicine.[6] With telemedicine there is an improved capacity of health providers to provide care without physically being there.[1]

In medically underserved communities' telemedicine can improve the healthcare access and healthcare outcome.[7] Telemedicine can be best solution to combine health, medicine, and technology to enact in various medical situations.[8] The researchers have empirically evaluated that diverse user-centered design (UCD) of user interface of healthcare applications has better user acceptance. Many attributes of information and communication technology (ICT) exists which can be: (1) transmission (voice, sound, video and pictures) (2) communication technologies (standard telephone lines, coaxial cable, satellite, microwave, digital wireless, Integrated Services Digital Network (ISDN), and Internet (3) user interfaces (computers, various standalone systems fax machines, mobile phones, and peripheries). Many studies have proved the effectiveness and safety of telemedicine compared to the hospital treatment.[9] Telemedicine can help in many ways such as maintaining the social distance, minimizing cross-infection and avoiding prolonged waiting time.[10] The various trends of telemedicine in recent times are depicted in (Figure 1).

2. Evolution of Telemedicine

Sound and visible signals have been used as a mode of communication since ages. Many places still continue to use drums, horns and even sound patterns corresponds to certain codes. On April 1924, telemedicine was first introduced when patients could interact with the physicians and learnt to make use of heartbeat and temperature indicators.[11] We could find the published records of telemedicine practice when ECG was transmitted over telephone lines in the 20^{th} century.[3]

In 1990, there was rise of internet due to information explosion. The information included education level of patient, medical images like X-rays, real-time audio and video consultations and vital signs measurements.[11] As the technology advanced the foundation of telemedicine expanded. Today telemedicine relies on personal mobile phones, computers that are integrating into healthcare delivery.

3. Scope of Telemedicine

The use of information and communication technology can be utilized in achieving the high-class health services through the digitalization like national digital health authority and national e health authority (NeHA). Figure 2 illustrates the applications of Telemedicine. The practice of telemedicine has gone beyond the boundaries and are also in field of conventional medicines in India like National AYUSH Telemedicine Network. There are also AI integration in telemedicine like in IOT devices that is continuously monitoring the asthma attach and heart failure in real time. Early detection of stroke, cancer and many heart diseases via CT scan, Cardiac MRI images. The national health stakes aim to collect the health data digitally.[12] Data- driven decision making is now possible with the information stored in electronic health records/ electronic medical records (EHR /EMR) which helps in health analytics for making better patient diagnosis and treatment plan and generating alerts and reminders for the physician to note the high-priority events during treatment for better decision making.[5]Figure 3 illustrates the top 10 telemedicine startups in India in 2023.

4. IoT in Telemedicine

Internet of Things (IoT) is the future of the telemedicine. When it is blended with the medical devices it is called as Internet of medical Things (IoMT). These technologies have aided in patient comfort, economic and timely treatment with the personalized healthcare delivery system.[13] These technologies have resulted in making the healthcare more patient centric than hospitals centric as many clinical aspects of healthcare can be performed at home itself. With the advancement of technologies such as machine learning, IoT and big data analysis, it has helped in good accessibility and ease of transfer of the clinical data in the absence of the healthcare professionals. It connects the electronic wireless devices to internet. They are found in agriculture and automobile alongside healthcare. IoT devices have made humans more independent and has increased their ability to interact more with the technologies.[5]

4.1. Structure of IoT

The integration of IoT and cloud computing can have a very high significance in the field of healthcare. The IoT has three main components based on which it is structured. The first component is the publisher which represents the network to which all the devices and sensors are connected, they record the patient's vitals and other health data. These data may contain the information and records of patient's blood pressure, ECG, EEG and so on. The second component is the broker, it is responsible for the processing and storage of the patient's information in the cloud. The third main component is the subscriber, they are the one who are

monitoring the patient information that are through the smart phones, tablet etc. [14]

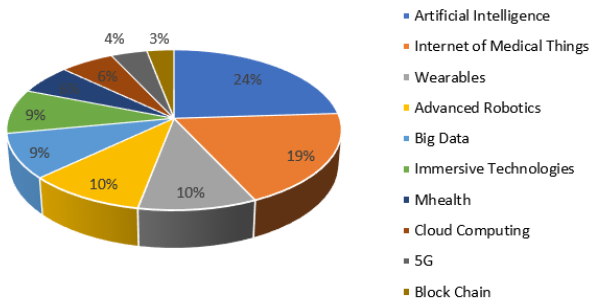

Figure 1: Trends of telehealth in 2023

Figure 2: Application of medicine

Figure 3: Top 10 telemedicine startups in 2023

Figure 4: Some popular telemedicine apps currently in use in India

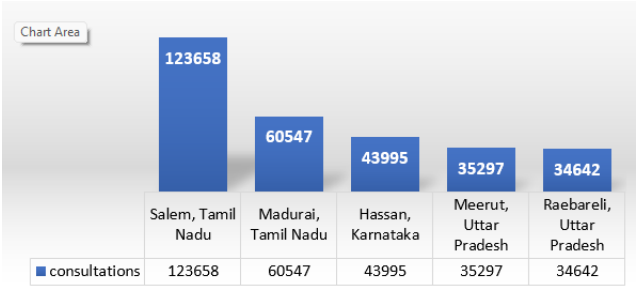

Figure 5: Consultations using eSanjeevani portal

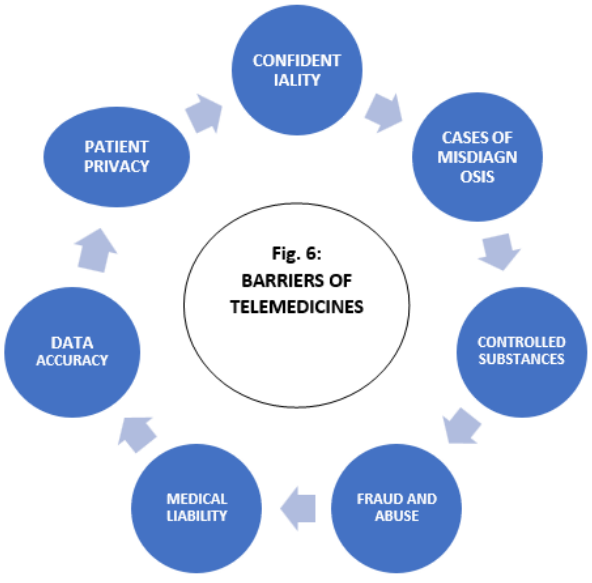

Figure 6: arriers of telemedicines

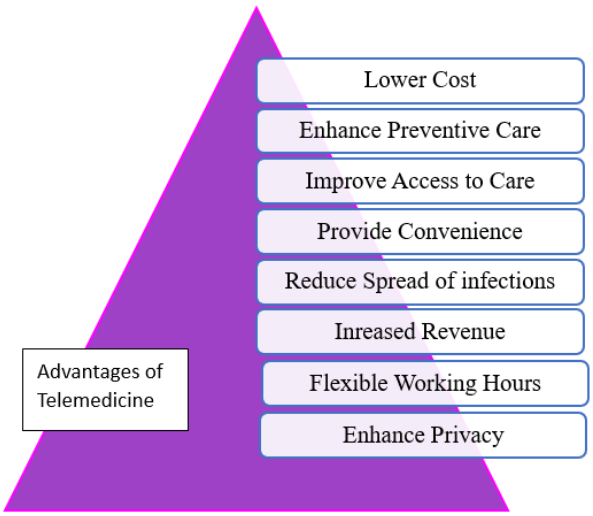

Figure 7: Advantages of telemedicine

4.2. Application of IoT

4.2.1. ECG monitoring system

IoT based ECG monitoring system can be used which will provide the high potential to record the ECG data. This system has two main components i.e., data acquisition and other is the receiving processor that will collect the data in the real time.

4.2.2. Glucose level monitoring system

With the recent advancement in the IoT, there are certain devices and wearable gadgets that are non-invasive, comfortable and can monitor the blood glucose data in real time. E.g. IoT based non-invasive glucometer.

4.3. Other applications

These includes the blood pressure monitoring system, medication management, Asthma management, mood monitoring system, oxygen saturation monitoring, detection of skin lesion, chemotherapy, radiotherapy, consultation, and research.[14]

Figure 4 illustrates some popular telemedicine apps currently in use in India.

5. Tele-Consultation

Tele consultation may be described as the main form of telemedicine in which we can achieve long distance clinical healthcare with the help of ICT. It can improve the health care system by promoting the high quality medical resources and healthcare efficiency.[15]T he method of linking the medical expert with the people at remote areas[16] or at a distance from provider.[2] Covid19 pandemic in recent years has drastically changed the way patients and clinicians interact.[17] Tele-consultation has helped in improved patient's experience through avoiding unnecessary waiting time, travel cost and multivisits.[15] Populated countries of Africa like Nigeria are conducting pilot projects on the tele-consultation with an intend to establish permanent teleconsultations platforms for their population to access the healthcare services. Health department of South Africa has introduced the tele-consultation services in areas where there is lack of specialists.[16]

5.1. eSanjeevani

This national teleconsultation platform was introduced by the Ministry of Health and Family Welfare towards the nationwide implementation of teleconsultation services operational in all 31 states and union territory in India. It has acted as a bridge between the urban and rural areas as far as health services are concerned with more than 3 million patients have been addressed while 35,000 are using this as medium for remote health consultations. It has identified the shortage of doctors and specialist thus reducing the burden of secondary and tertiary care. It has been integrated in all PHCs, HWCs, CHCs, Civil and District Hospitals. It works on Hub and Spoke model i.e. doctor to doctor based on hub and spoke model and doctor to patient (eSanjeevani OPD).[18]Figure 5 shows the top 5 districts with largest consultations through eSanjeevani portal.

5.2. Tele monitoring

The emergence of telemonitoring came up due to challenges faced by the western healthcare system, dynamic demography, and patient centered quality care. It is described as the subset of telemedicine which is an innovative way of patient care delivery.[19] In the case of chronic health conditions, telemonitoring extensively studied as an approach in which the care is provided remotely to patient at home and timely intervention are given by the providers.[20] In many conditions like inflammatory bowel disease (IBD), telemonitoring plays a role in continuous monitoring of the clinical data which are reported to their healthcare providers by the patient in their usual environment. Tele education is one of the other components of it that makes use of information and communication technology (ICT).[21] Telemonitoring technology makes the use of videoconferencing, email, remote telemonitoring equipment, social networking apps, and internet that allows the self-monitoring of health data by patients and health education and long-distance intervention by the providers. It reduces face to face consultations, clinic visits, improve the quality of health care, and improved health outcomes. This results in an improved patient empowerment, self-management, and compliance. Some studies found barriers in telemonitoring as lack of privacy, security, patient safety, internet connection, technology infrastructure, regulations, and allocation of task.[22] It

is expected that telemonitoring will enhance the remote interaction between patients and practitioners, a faster way to improve the disease management for older people with chronic diseases like chronic obstructive pulmonary disease (COPD).[23]

5.3. Tele-surgery

The term tele-surgery is an amalgamation of networking and robotic technology that connects surgeons to patients who are located at a distance. The technical accuracy and surgeons' safety can be appreciated along with the patient's benefit. This system not only reduces long distance travel but also significant financial burden, high quality surgical care, gaining geographical inaccessibility, potential complications and improving high quality surgical care.[24] Patient those who live in rural area and cannot travel long distances do not receive the medical treatment due to lack of medical personnels.

Robotic surgery: In the year 1985, the first robotic surgery was carried out which was non-laparoscopic and with the help of PUMA560 a robotic arm. In 2002, the first transatlantic tele surgery was performed using asynchronous transfer mode (ATM) with data transfer rate of 54 byte and network that spanned 14000 km from Manhattan, New York to Strasbourg, France.[25] With the entry of robots in the medical field in recent years and with technological advancement there have been wider and expanded acceptance by the medical community and general population. Even though surgical system costs start at half a million, it has turned into a profitable business.

1. Supervisory controlled system (SCS): These types of systems are common for hip and knee replacement. This involves three steps system firstly starting with mapping the area of interest on the body and then collecting details. Second step involves the aggregation of the collected image. Third step is the actual surgery that is performed by the robot as doctor directs it in first position and it follows the path.
2. Tele surgical: It is a kind of system in which the surgeon manipulates the robotic arm by a console system that he operates.
3. Shared Control System: It is seen in surgeries like neuro and orthopaedic surgery in which a group of surgeons operates the robot and act as an assistant.[25]
4. Building Blocks: These kinds of robots are equipped with arm integrated with voice-activated endoscope. On behalf of the surgeon this system gives greater control and cost effective as it does not require additional assistant with integration of camera guidance.[26]
5. Da Vinci Surgical System: it was developed in USA in 1991 by intuitive surgical (IS). It is used in cardiothoracic surgeries like CABGs as well as gynaecological surgeries like hysterectomy.

The system has following components:-

1. Surgeon's console
2. Patient side cart
3. Endo wrist instruments
4. Vision system

1. Depending upon the arms, the incisions are made, and the arm is fitted with 3D dual channel endoscopic camera which is introduced inside the incision. The surgeon sitting at a distance with console operates commands on joystick like system with which he operates and manipulates the instruments for suturing. The surgeon also receives a stereoscopic image which is 12 times modified. The da Vinci computer sends signals that mimic the surgeon.[25]
2. Raven (I and II): integrated with dual arm with freedom of seven degree with a spherical mechanism that allows rotation around remote centre. While the patient site has two surgical devices positioned over the patient. The surgeon has two control devices and a video feeder and communicating system consisting of TCP/IP network from the operator site.

Main features include: -

1. Patient site (slave)
2. The surgeon site(master)
3. And a network

1. The Socrates system: It was used for the first time in 2001, in this system, one surgeon can remotely access another surgeon worldwide. The operation is performed by remote console.
2. Miro Surge Robotic Surgery System: It was developed by German Aerospace system used in minimal invasive as well as open surgery. The two types of interfaces bimanual haptic type and partial tactile feedback. In the second type optically, handheld forceps are used by surgeons to control forceps.
3. Trauma Pod: It is designed in such a way that it's MASH unit can receive, access, and stabilize wounded soldier.[26]

5.4. Tele-psychiatry

Telepsychiatry is the oldest form of telemedicine. It makes the use of various forms of technology what provides the psychiatric care remotely. According to Drago et al., telepsychiatry is the use of electronic communication and information technologies to provide psychiatric care or support patients clinically at a distance. The integration of AI in psychiatry encompasses the use of language processing and machine learning algorithms which helps to access the patient's mental health. People with poor mental

health are not only disabled and are in great distress but also are burden to their family and society. Inadequate treatment of mental disorders is mostly due to lack of accessibility and affordability of the treatment.[27]

5.5. Evolution of telepsychiatry

1. 1956: A two-day closed-circuit television was used for education and medical purposes.
2. 1961: psychotherapy for video conferencing was used.
3. 1973: Dwyer first used the term telepsychiatry to describe the medical services that was provided at Boston from Massachusetts.
4. Mount Sinai school which connected child guidance clinic in New York city where telepsychiatry services were used..
5. 960-1970: sporadic use of the telepsychiatry.
6. 1980-1990: improved technology, reduced equipment costs and increased government fundings.

Telepsychiatry is yet to be a landmark in middle- and low-income countries despite its success in developed countries. Due to this lack, technology can be harnessed to impart psychiatric education and training across the globe to not only medical students but also to the primary care doctors, nurses, social workers, psychologist, and other paramedical staffs. Personalizing the telehealth is another way to gain potential in the field of telepsychiatry. Through the latest advancement in the telecommunication as in smartphones which can help to harvest services and care for persons with mental illness (PMI). In recent years many online groups have emerged with an intent to respond to the diminished health resources. These support groups have created increased access to health information and support thus creating a paradigm shift for PMI.

e-Manas, an initiative taken by the government of Karnataka, department of health (the term “manas” in vernacular language means “mind”) initiated an innovative way to address the issue with title “mental health management system”. It is a state-wide digital registry of mental health establishments (MHEs), mental health professionals (MHPs), PMIs and treatment records with Mental Healthcare Act (MHCA), 2017. It was done in collaboration with NIMHANS, Bengaluru and electronic health research centre, International Institute of Information Technology (EHRC-IIIT-B).[28]

5.6. Tele-dentistry

It is a form of virtual assistance for dental care guidance, education or treatment through information technologies ruling out the face-to-face interaction of patient and providers that include distance dental procedures like screenings, consultations and prescribing a treatment plan.[30] It started as a project by the US military around the world in year 1994 to serve US troops. It is found to be as comparable to real time consultation in remote areas.

6. Components

6.1. Teleconsultation

In this, the patients or the health care providers seek help from the dental specialists using the telecommunication technologies. This does not require patients to be physically present. This aid patients especially who are aged or physically disabled. This also help to reduce the referral from primary healthcare centres.

6.2. Telediagnosis

In this, we use the radiological data, images, and information for the diagnosis of any oral lesson. The use of smartphones aid in the transmission of these images and information for early detection of caries. With the tele cytology there is the early detection of pre-malignant and malignant lesson. Mobile mouth screening helps in the early detection of the cancerous lesson of oral cavity. Tele diagnosis programs like EstomatoNet has helped to reduce the referral from 96.9% to nearly 35.1%.

6.3. Tele triage

In the current scenario, the smartphones help in the timely disposition of patient symptoms by the specialist. The tele radiology can act as a tool in triaging the maxillofacial trauma successfully. It also resolves the socio-economic and demographic difficulties.

7. Telemonitoring

Telemonitoring can be used as an important tool to avoid multiple visits for follow-up of the patients. The process involves the virtual visit of the provider for the disease progression or the outcome of treatment.[29]

7.1. Barriers of tele dentistry

The barriers and challenges of tele dentistry at an individual level includes the poor literacy about the information technology, there is resistance when it comes to adopt the new technologies, there is resistance to emerging technologies, there is no direct patient contacts, lack of trust on the data and health records, lack of trust over the validity and quality of health records, there is increased work load and time and increased cost expense.

At the infrastructural level, it includes lack of internet access and poor connectivity, incompatibility of hardware and software, complex technology, sustenance of fundings, lack of training and ongoing technical support.

At an organizational level, it includes the incompatibility with the current healthcare system, reimbursement structure, malpractice, and medicolegal issues.

7.2. Tele-radiology

The significant advancement in past 25 years in the field of telecommunication has contributed to a significant change in the field of radiology as well.[30]Teleradiology is the largest medical branch that is utilizing technology for the transmission of radiological images at a distance. It includes the computed tomography (CT), magnetic resonance imaging (MRI), Ultrasound and X-ray.

Teleradiology came into demand to meet the diagnostic needs of the patients due to lack of healthcare professionals, timely diagnosis, lack of diagnostic facilities in the rural areas, unavailability of the emergency diagnostic services and lack of qualified radiologist and poor quality of reporting.

8. History of Teleradiology

1929: for the first time X-ray for dental procedures were transmitted using the telegraph.[31]

In the 1980s: the development of camera system and video system was utilized transfer of images.

8.1. Applications

1. Teleradiology can be used in cases where second opinion is required to diagnose and treatment.
2. In case of humanitarian aid and disaster relief management teleradiology can play a very vital role.
3. Teleradiology can be used in case of war hit zones and during the military operations for immediate diagnosis.
4. In case of pandemic like Covid-19 it can be utilized to reduce the doctor patient contact thus help in decreasing the spread of the disease.[32]

There are other branches of telemedicine like telepathology where like teleradiology is an image intensive branch, images of digital slides are transferred via technology for simultaneous diagnosis and discussion through teleconferencing. One of the first branches of medicine to use technology was ophthalmology, tele-electroretinography cameras, software, including Digital Imaging and Communications in Medicine (DICOM) may be required to conduct teleophthalmology diagnoses and treatment. Tele dermatology is the third largest user of telemedicine after teleradiology and telepathology. The information exchange may occur asynchronously, store-and-forward, but real-time videoconferencing (synchronous) is also conducted for treatment purposes. Telecardiology includes not only tele-video-consultations, but also transmission of tele-electrocardiograms, tele- echocardiograms, and tele-angiograms and use digital stethoscopes to hear patients' heart sounds at a distance. Tele-obstetrics involves prenatal and gestational telemonitoring and real-time tracking and transmission of biomedical parameters for early detection and diagnosis of any condition in pregnant women. Telecare in geriatrics involves videoconferencing, use of sensors and artificial intelligence (AI) to get access to the aged patients and support their independent living. Tele-oncology helps to mitigate the dearth of onco-specialists to support in genetic counselling, radiation, bone marrow transplantation, surgery, and palliative care especially in patients located small towns and villages. Tele neurology includes tele stroke evaluations along with advanced optics and neuroimaging integration. Tele diabetes has shown to improve the overall health of diabetics by improved diabetic education and continuous telemonitoring. Tele otorhinolaryngology involves not only telecare in ear, nose, throat (ENT), but also includes transoral surgery and tonsillectomy by robotic surgery, and emergency management of foreign body retrieval, peritonsillar abscess, and other ENT procedures. Tele emergency services, tele-intensive care unit (ICU), eICU, or remote ICU, tele dialysis, telerehabilitation are some of the other branches of telemedicine for diagnosis, monitoring, and management of patients in need of care.[5]

9. Discussion

Universal Health Coverage (UHC) aims to provide all individuals with access to essential quality health services without exposing them to financial distress. One such strategy for Universal Health Coverage (UHC) is digital transformation of the health system.

Almost all industries have been impacted by the wave of digitalization, and healthcare is no exception. Beginning 2020, India has launched its flagship program called Ayushman Bharat Digital Mission (ABDM) to digitize all healthcare services and build a common digital infrastructure to facilitate low cost, seamless last mile healthcare service delivery.[33]

The retrospective health policy analysis demonstrates how some of the drivers for digital transformation came from outside the healthcare sectors and the advancement of digitization in the Indian healthcare system is a product of multisectoral synergy. Rashtriya Swasthya Bima Yojana, the Aadhaar Scheme, popularization of Unified Payments Interface and other developments in FinTech, availability of cheap internet/data, Pradhan Mantri Jan Aarogya Yojana and the COVID19 pandemic are some major punctuations in the Indian digital healthcare transformation journey. A key takeaway from India's journey is the undeniable importance of interdepartmental collaboration and public private partnerships in achieving universal health care. Primary healthcare in India has historically been of great interest amongst policymakers and myriad attempts have been made to further healthcare access in the country through programmatic verticals.[34] Digital healthcare policies are still in their nascent stage with some of the earlier mentions in 2017 and the advent of Ayushman Digital Bharat Mission (ABDM) in 2020. ABDM is governed by the

Ministry of Health and Family Welfare and implemented nationally by the National Health Authority. Telemedicine is one such vertical which has been effective in providing equitable healthcare service during the pandemic around the world and India was no exception. Telemedicine has surfaced as a transformative influence in augmenting emergency medical services amid the COVID-19 pandemic, particularly showcasing a substantial enhancement in the decision-making process for patients within emergency departments anticipating transfers. Introduction of 5G network after COVID pandemic has helped the emergency physicians guide paramedics to stabilize patients before they reach the hospital in cases like stroke, road traffic accident (RTA), poisoning cases. Telehealth in emergency medicine helps in prehospital triaging of the patients. The setup of video conferencing in ambulances with the control room in the hospital helps manage emergency patients better and treat better.[35]

10. Limitations and Recommendations for Telemedicine

The lack of physical examination in is one of the major drawbacks of the telemedicine. It is important that the patient owns instruments like oximeter, blood pressure cuffs etc that will help to record vital signs. Patients must be encouraged to use good quality cameras and lighting during their consultations. The provider-patient relationship must be good for an efficient result. Countries like India with a large population that is majorly unaware of the benefits of telemedicine must conduct awareness drives to educate people about its importance. Patients must also be made aware that telemedicine is just another option for them, and they are free to visit the clinic if they want to.

There are times when patients' satisfaction is affected especially when patients are required to visit the facility. In such cases, there must be regular patient satisfaction assessment. The out-patient visit and virtual visit, both are susceptible to emergency medical situation, for such cases, patient safety protocol must be laid down and followed. There must be a continuous contact via video call or voice call between the patients and the consultant throughout the emergency.[36]Figures 6 and 7 highlights the barriers and advantages of telemedicine respectively.

11. Conclusion

Telemedicine not just provide the healthcare delivery to remote places or virtual services but also bridges the gap of scarcity of health professional in countries like India. Timely and affordable healthcare services is very important in strengthening the health system and better health outcomes. Recent advances in telemedicine includes Extended Reality (XR) which encompasses Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). The digital age has seen a rapid acceleration of innovations, particularly driven by the pandemic. XR enhances the feeling of presence by creating the illusion that the virtual environment is authentic. It elicits embodiment by instilling the perception that a virtual body represents one's genuine physical form. Additionally, XR nurtures telepresence by conveying the sense that an individual is in a different space alongside virtual entities.[37] It is used in various departments like surgery, anaesthesia, psychiatry, and radiology making the accessibility and availability of better healthcare services from doctors sitting in remote areas.[38]

12. Source of Funding

None.

13. Conflict of Interest

None.

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