Chapter

How e-Health Has Influenced Patient Care and Medical Education: Lessons Learned from the COVID-19 Pandemic

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Abstract

The concept of e-Health involves the application of information and communication technologies from off-site locations to various domains of healthcare ranging from patient care, public health, and administration to health education. It refers to health informatics, telemedicine, electronic health records, and clinical decision support systems. The e-health initiatives aim to improve health outcomes in terms of quality, access, affordability, and efficient monitoring. The application of e-health interventions has particularly expanded in recent times because of the restrictions imposed by the pandemic. It has been proven to be nearly as effective as in-person care along with high patient and provider satisfaction and at decreased costs. We present our experience from the use of various e-health interventions during the COVID-19 pandemic along with a review of related literature. This ranged from Internet-based services, interactive TV or Polycom's, kiosks, online monitoring of patient's vital signs, and remote consultations with experts. Our success and experience with various e-health interventions during the pandemic allow us to provide a more hybrid form of healthcare in the future both for patient care and medical education and training.

Keywords: COVID-19, e-Health, telemedicine, telesurgery, remote health

1. Introduction

The term "electronic health" (e-Health) was first introduced around the 1990s with a rapid expansion of Internet-based services. It was first used by marketing strategists and industry leaders rather than health professionals and academicians in line with other "e-words" such as e-business, e-commerce, and so on [1]. It was initially defined by Eysenbach as an "emerging field in the intersection of medical informatics, public health, and business, referring to health services and information delivered or enhanced through the Internet and related technologies." [2] The term encompasses a vast array of disparate entities from health, commerce, and technology. In a systematic review by Hans Oh et al. in 2005, at least 51 published definitions of e-health were identified [3]. The World Health Organization (WHO) defined e-health as the use of information and communication technology for health. It encompasses a set of diverse processes and informatics tools to improve healthcare and public health [4].

Considerable overlap exists among terms such as "e-Health," "telemedicine," and "telehealth." The American Telemedicine Association considers e-Health and telehealth as interchangeable nouns and propose a broad definition to include remote health and other components such as education, administration, and research. Telemedicine on the other hand is reserved for clinical patient care alone [5, 6]. Although "e" in e-health may mean "electronic," Eysenbach [2] had his own ideas and thus proposed variable meanings of "e" in e-health, which are as follows:

1. **Efficiency**: to decrease costs by avoiding unnecessary diagnostic and therapeutic interventions and better liaison among healthcare institutions.

2. **Evidence-based**: efficiency and effectiveness should be established by a rigorous scientific evaluation.

3. **Enhancing quality**: to improve the quality of healthcare by allowing comparisons and quality assurance programs.

4. **Education**: of both physicians and consumers through online resources.

5. **Enabling**: exchange of information among healthcare providers.

6. **Extending**: the scope of healthcare beyond the geographical and conceptual boundaries.

7. **Encouragement**: to foster a new relationship between doctor and patient to reach decisions in a shared manner.

8. **Empowerment**: of both the patients and consumers by providing the knowledge base easily available on the Internet.

9. **Equity**: to allow more equitable delivery of healthcare. However, the digital divide that exists in society might further widen the gap between the "haves" and the "have-nots."

10. **Ethics**: e-health poses new threats and challenges to the doctor–patient relationship with online practice, consent, and privacy issues.

Various interventions have been included under the umbrella of e-Health services. Using these services, patients can get information about their health condition, consult a healthcare provider, receive a diagnosis, and even arrange prescriptions [7]. Possible interventions and functions of e-Health include the following:

1. **Virtual visits**: live interactions between the patient and health care provider via telephone, live chat, or video call.

2. **Chat-based interactions**: asynchronous, online, or mobile app-based communication to review or deliver a consultation, diagnosis, or treatment plan based on the patient's vital signs, physiologic data, or diagnostic images.

3. **Remote patient monitoring**: involves the collection, transmission, and evaluation of patient-related health data to an extended care team at times outside a hospital using wireless devices, wearables, implanted health monitors, and mobile apps.

4. **Technology-enabled modalities**: provide platforms for patient education, digital diagnostics, and digital therapeutics either stand-alone or with conventional drug therapies.

e-Health has the potential to transform the healthcare system, particularly in the developing world. The digitization of the health system could play an enormous role in strengthening the continuum of care [8]. However, most e-health interventions at present are implemented based on the assumptions of benefits of e-health alone, while there exists a paucity of data to provide comprehensive guidance on assessing the e-health programs [9]. The effectiveness of an e-health intervention depends on three pillars: quality, access, and cost-effectiveness. Any e-health intervention must fulfill these criteria to attain a successful outcome [10]. The application of newer technologies, such as machine learning and artificial intelligence (AI) can allow better surveillance, early and improved diagnosis, and personalized care [11].

2. Use of e-Health during the COVID-19 pandemic

The concept of e-Health has been put forward by many as an ideal tool to face this pandemic. It is an effective means of communication between patients and healthcare providers when in-person care is either not necessary or not possible. The use of technology in medical practice is not entirely new. The use of fires and smoke signals by the Greek fleets to communicate the spread of the plague is a very elementary form of application of telemedicine. Progress in the field has remained limited to specific niches such as space and maritime medicine [12].

The uptake of e-health interventions was at best minimal before the pandemic but has since expanded significantly because of the restrictions that were imposed [13]. Various administrative regulations and a lack of robust legal guidelines have been considered strong reasons behind the slow growth of e-health. Reluctance to adopt telemedicine by patients and providers alike along with limited economic investment have also played their part. In a study from the United States, only 24% of the healthcare organization had an e-health program in place as of January 2020, before the fallout of the COVID-19 pandemic [14]. Thus, an unprepared clinical workforce, as well as the patient population, was suddenly thrust into the era of e-health and telemedicine [15].

However, as the pandemic progressed, various e-health interventions have come into routine patient care. These services have allowed better access to patients, safer working conditions for healthcare providers, reduced risk of cross-infection, and lower costs. The restrictions imposed by the pandemic on personal interactions for in-patient consultations, in-patient care, and medical education has allowed tapping of the previously unutilized potential of e-health. In a database compilation by McKinsey, the overall telehealth utilization for outpatient care was 78 times higher within just four months of the breakdown of the pandemic (February–April 2020) [16]. The overall telehealth adoption in the United States was just 8% pre-pandemic and had reached 17% since the initial spike of COVID-19 [16, 17].

The following e-health services have been used during the pandemic:

2.1 Telemedicine and the online outpatient clinic

Outpatient consultation or virtual ambulatory control is one area with the maximum presence of telemedicine even before the pandemic. As the COVID-19 restrictions imposed a barrier on the conduct of physical in-person consultations, most centers shifted to virtual consultations [18]. The search for continuity of care, while at the same time avoiding transportation to hospitals and preventing unnecessary contact in waiting areas thus reducing the exposure of both patients and doctors, has played an important role in patient care. The Centre for Disease Control (CDC) has suggested the use of telemedicine to deliver critical patient services during the pandemic [19].

Telemedicine enabled patients to talk to concerned specialists depending upon the nature of their complaint and be advised regarding the next step in their management, viz., prescription, investigations, or need for an emergency visit. It provides an excellent opportunity to "forward triage" patients to sort before they make an emergency call [14]. The use of telemedicine undermines diagnostic evaluation due to the limitations of audio-visual aids. Thus, a low threshold should be kept for advising a hospital or emergency visit in equivocal cases [20]. Studies from countries such as India, Italy, and the United States have reported virtual migration rates between 60 and 95% of their usual among various specialties. Additionally, they have confirmed a satisfactory control of various chronic ailments thus reaffirming faith in telemedicine [21–23].

Our hospital was a part of the e-Sanjeevani service, which is a first-of-its-kind online outpatient consultation service offered by the Government of India. It consists of a dedicated outpatient service called "e-Sanjeevani OPD." [24] Through this service, patients receive video consultations from the confines of their homes. It was launched during the COVID-19 pandemic in April 2020 when the country was going through the phase of complete lockdown and since then has been running successfully although face-to-face outpatient attendance is increasing after the large-scale vaccination program and rapid decline in active new cases and COVID-related deaths in the country. This service is free of cost and can be availed in the following simple steps:

i. **Patient registration** – patient registers through the portal,

ii. **Token generation** – following the registration a unique identification number is received on his mobile phone,

iii. **Login upon getting notification** – logs in following his turn (patient has to wait in queue for his/her turn),

iv. **Consultation with the doctor** – through a real-time video call,

v. **Download the e-prescription** – if the diagnosis can be made and if the physician is confident that the symptoms can be managed through the online platform, a prescription is generated as per the advice of the physician. Otherwise, the patient is registered for the face-to-face outpatient clinic visit to the hospital and called on a specific date.

e-Sanjeevani: This is a unique doctor–to–patient telemedicine system spread throughout the country by the Ministry of Health and Family Welfare of the Government of India under the Ayushman Bharat scheme [25]. It needs a centralized telemedicine facility at the hospital, a dedicated portal through an online link, and a smartphone with the patient. It helps to provide basic and primary healthcare services to the masses at large in both rural areas and isolated communities without patients attending the hospital and thereby increasing hospital attendance and breaking the social distancing norms. It also helps in bridging the gap of uneven distribution of healthcare personnel and infrastructure that exists between urban and rural, rich and poor, and aims to provide access to healthcare services irrespective of place. It also allows the patient to directly interact with the general duty doctor and at times specialists in a large secondary or tertiary care facility for consultation of illnesses that may be attended to on a nonurgent basis. It also increases safety and reduces the transmission of the disease. The real-time video call can be used not only to discuss symptoms but also to demonstrate clinical findings. This facility drastically triaged patients with trivial and minor complaints from overcrowding the hospital and screening those who need semiurgent care.

2.2 Distant patient monitoring and tele-ICU services: our experience

The COVID pandemic has led to an increased number of critically ill patients requiring mechanical ventilation and continuous monitoring. The shortage of intensivists relative to demand has created space for intensive care unit (ICU)-based telemedicine. The “Tele-ICU” makes use of electronic medical record systems and clinical information [26].

The centralized monitoring unit (CMU) notifies the patient vitals, cardiac rhythm, and rate-changes in digital tracking and call log database to each clinical nursing unit or a hub where critical care expert handles the information. Thus, CMU policy alerts the emergency response team in parallel with the bedside nursing team. Several commercial vendors including Philips-VISICU-eICU, Cerner, and iMDSoft enhance the concept of Tele-ICU [27]. It has been shown that staff satisfaction with centralized monitoring systems is generally favorable despite a high false alarm rate. However, future research and technological development are needed to further improve efficiency and reduce costs in telemetry [28].

The second wave of the COVID-19 pandemic taught us an important lesson regarding the shortage of ICU beds and ICU-trained specialist doctors and nurses. Our teaching hospital rapidly scaled the ICU capacity to more than 200 beds to meet the exponential demand. Despite adequate protection majority of the resident doctors, nurses, as well as some consultants, contracted the infection. To provide round-the-clock ICU services, and at the same time to reduce the spread of infection in already compromised physicians and nurses force we had to turn to Telehealth to meet the shortage of healthcare professionals.

Our institution collaborated with the King’s College London (KCL) to set up and run Tele-ICU services. KCL was already running a similar project known as Life Lines UK in over 180 NHS hospitals across the United Kingdom as an ultrarapid response to the COVID-19 pandemic, bringing together a unique partnership of clinicians, academicians, information technology (IT) personnel and companies, and British charities. KCL and their partners supported the setup of Indian servers, procurement of digital licenses, and providing 50 4G-enabled tablets to our hospital along with secure software through which doctors could run virtual e-ICUs and also communicate with external experts in-house as well as internationally. These tablets were used by eight ICUs run in collaboration with specialist departments (**Figure 1**). Using the secure communication software, doctors and nurses in the ICU could communicate with their consultants round-the-clock through audio and video calls. ICU consultants had remote access to patient's data on a real-time basis and could intervene by giving instructions to bedside nurses directly. Cardiologists, neurologists, nephrologists, internal medicine, and pulmonologists could be consulted directly by the on-duty nurses and resident doctors and provide virtual real-time access to patients' reports for providing their specialist input regarding management. The process had several advantages such as improved cost–benefit, ease of use, instant real-time advice on treatment, sending virtual reports, and importantly saving time along with maintaining patients' data securely. Even small procedures could be observed and guided by the attending physicians remotely through real-time videos on these tablets. Virtual e-ICU run by Telehealth is probably the answer to the shortage of trained healthcare professionals, especially in remote areas, reducing of the spread of infection and healthcare costs.

2.3 Kiosks

Kiosks are usually computer-based platforms installed in public places or specialized healthcare areas that can play an important role in healthcare delivery. In modern times, kiosks have improved in their capabilities and have become multidimensional [29]. The benefits associated with kiosks include increased efficiency, cost-saving, increased accessibility, improved self-care and management of chronic diseases, reduced medication errors, and many more [30]. Their use during the COVID pandemic has the added

Figure 1.
Tablets being used by the first-line healthcare workers in a COVID-19-positive patient on non-invasive ventilation to transmit real-time health data and obtain expert opinion from the consultant.

benefit of reduced in-person contact. Kiosks allow self-registration, referral, recording vital parameters such as pulse rate and blood pressure and uploading medical records among others. In a survey from Pennsylvania assessing healthcare kiosks, about 90% of the participants found the concept useful and would use the service again for health self-management [31]. However, concerns regarding the security and privacy of data, service costs, advertising protocols, and patient comfort must be addressed adequately [32]. During the pandemic, our institution used a number of patients or patients' attendant-operated kiosks for the above purposes with success and satisfaction (**Figure 2**). A nurse or a health worker would be present around to help and guide the functioning of the kiosks and also attend to minor technical issues.

Figure 2.
Multiple health kiosks for use by the patients for primary documentation, and blood pressure measurement.

2.4 Robotics and artificial intelligence

Artificial intelligence (AI) assists healthcare professionals in understanding patients' needs and, therefore, helps to provide better support and guidance to maintain a healthy lifestyle. Although AI was already being studied for understanding the complex molecular pathways, in clinical pathology, clinical diagnosis, and management of chronic conditions such as Alzheimer's and Parkinson's disease, its use has particularly expanded during the COVID-19 pandemic.

AI methods have enabled analysis of the geographical spread of the virus and identifying hot spots and clusters. A model was developed to predict the COVID-19 pandemic and evaluate the total infected and fatal cases to help fight the pandemic [33]. Various AI-powered applications have been developed to allow contact tracing and monitoring of individuals [34]. 5G-based patrolling robots equipped with infrared thermometers have been used in China to monitor preventive measures. Similar tele-operated robots have been used in Singapore to enforce social distancing norms in local parks [35, 36].

Research has also been conducted to design algorithms to estimate the severity of COVID-19 infection in a patient and predict their recovery which is believed to have an accuracy of an impressive 94% [37]. It aims to identify the infection rate and call attention to at-risk patients while at the same time suggesting individualized early treatment. AI algorithms have allowed for prioritizing faster testing of suspected patients and expediting the testing process while minimizing the exposure to manpower [38]. AI-based platforms have enabled radiologists to aid the clinical decision support system based on chest radiographs [39]. This clinical diagnostic capability helps to mitigate the shortage of trained and qualified healthcare practitioners, especially in low-resource areas, while at the same time, providing a high level of diagnostic accuracy.

Machine learning and AI-driven models have been introduced to allow drug development for COVID-19 treatment. This has allowed us to develop biomedical knowledge graphs and also predict drug–target interactions (DTIs) [40]. However, it is not only for human use. AI-based technology also promises to increase the efficiency of electronic gadgets. Inserting smart algorithms into the healthcare devices commonly used in the wards and critical care units can help reduce the "diagnosis-to-treatment" time, especially in the intensive care setting.

It goes without saying that e-Health is a step toward global digitalization. However, the countless practical hurdles are often overlooked. The rapid switch in technology has brought forth problems of cognitive overload, training, digitization of data, data entry, timely and accurate extraction of data, its analysis, and finally providing reliable clinical decisions. Most importantly, clinical studies and multicentric trials are needed hand in hand with technology development to test the validity and reliability of these AI-based developments. AI and related technology have the ability to ease our burnout while at the same time creating an automatic, user-friendly, intelligent interface such as Alexa and Siri in daily life that can be a great assistant to the clinician from trivial order entry to more complex accurate diagnosis and management.

2.5 Health and medical education: what we have learned

Like most other academic institutions, our teaching programs were closed during the pandemic, and virtual classes took over via various online platforms such as Google Meet, Zoom, Microsoft Teams. Many academic conferences, scientific meetings, and

CME programs were shifted to virtual platforms during the pandemic. Moreover, Zoia et al. observed a reduction of more than 70 percent in surgical exposure among neurosurgery trainees [41]. Amparore et al. also observed a similar outcome in the urology training program in Italy [42]. Overall, the pandemic has significantly reduced both hands-on and supervised training of surgical residents, as the emphasis has now shifted toward lesser operative time and a lesser number of people in the operative room, thereby decreasing the opportunity for juniors to observe [43]. The disruption of medical education during the pandemic is likely to have far-reaching consequences, especially in terms of hands-on training and situated learning of the medical students, residents, and fellows. This has led to more and more simulation and virtual training facilities and surgical master videos [44]. It has also decreased the surgical rotations among specialties, which are needed to fulfill the minimum requirement of surgical residency training. Over the last two years, our institution had to modify teaching-learning on virtual platforms, hybrid classes with social distancing and barrier norms, and surgical training was shifted more toward simulation sessions and sometimes instructor-led cadaveric dissections, procedures, and surgeries. Some sessions had to be video recorded for later transmission and online learning for those who missed the sessions due to emergency shifts. Many meetings and conferences too had to be done totally on virtual platforms or rarely made hybrid, especially when lockdowns were raised. This invariably decreased public gathering and transmission rate, and most importantly a huge cut down on the expenditure but at the same time academic engagement and environment, and face-to-face interaction were miserably missing.

The enforcement of social distancing and irregular duty shifts in the pandemic have introduced online education, classes, and meetings. These tend to have appeal among the students and residents as there is a good amount of liberty of attending these from anywhere and usually during comfortable hours [44]. In fact, an increase in both academic activities and resident attendance was observed with the initiation of virtual meetings, which were probably due to a reduced operative caseload [45], but overall satisfaction with tele-learning is not impressive [46]. This is probably due to lesser face-to-face learning from patient interaction and situated learning at the bedside and in the clinics. The impact on medical research is unforgiving. Although it might seem that more time is available for research due to lesser operative time, the ground reality is different. Irregular emergency duties clubbed with a significant decrease in the clinical material available for meaningful studies are the principal causes of a reduction in research activity [42]. The pandemic may return with newer peaks in the future with its associated lockdowns, social distancing, and barrier protocols. It is difficult at present to comment on how the vaccination program, which is at present not comprehensive and far from being total globally, will alter the scenario on the academic front. As we move forward, medical education may not be the same again and accrediting agencies may have to join in the transformation [47].

3. Challenges in e-health

The growth of e-health in various sectors of healthcare is not without its associated challenges. Its benefits are based on the fact that it can function independently and unsupervised while overcoming the barriers of socioeconomic disparity, professional availability, and geography. However, trouble arises when ensuring the reliability of the gathered data, its appropriateness along with the safety and standardization of the device. Besides the fear of losing the acquired patient data in case of device malfunction or corruption are important predicaments that need to be addressed.

The use of telehealth services is limited by the clinical specialty where it is used. There exists substantial variation in its application across various clinical specialties. Its use in specialties where the clinical examination is of utmost importance has been limited compared to others [16].

With the digital revolution, the discretion of privacy has been lost. Furthermore, with the advent of e-health, private medical data are now in the hands of the unknown. The protection of the data and ensuring its safety is one of the biggest challenges. With the development of password encryption, authorization protocols, and the assignment of unique patient identifiers (UPI) codes, the process for anonymization not only has improved in recent years but also has led to the development of re-identification hackers which mismatche the merging of new data of the same person with the old thus violating the laws of privacy [48].

e-Health enables patients to function as a participant instead of a subject. Clicking "I agree" without understanding the nature of consent is one of the important ethical challenges encountered. Digital health also makes patients instrumental in providing clinical data. Data-related misadventures question accountability and therefore require patient training modules to scratch off any liability issues.

Furthermore, access to these interventions requires comprehensive logistics to ensure successful implementation. The healthcare infrastructure in Latin America, sub-Saharan Africa, and most countries in Asia is not as robust and homogenous at all levels as in Europe and North America. The hospitals in low- and medium-income countries are largely concentrated in the metropolitan cities and only a few have the required level of technology, expertise, and resources that can affect the rollout of teleservices, particularly in rural areas [49].

Similarly, to ensure the proper functioning and allow the optimal impact of telemedicine, it must be fully integrated into the existing health systems. This requires changes through policies and regulations which include this new modality of service so that it is authorized by insurers. Global Health Intelligence (GHI) in 2020 reviewed the penetration of telemedicine in Latin America. A lack of understanding of the applications and their usefulness along with a lack of political support was identified as the main obstacle to its widespread application [50]. International literature and professional organizations have raised ethical concerns about the use of e-health services. As the use of these interventions is expected to expand even as the pandemic appears to wean, it is all the more important to revisit these pressing issues [51].

It is too early to compare the outcomes of telehealth with conventional clinical care. Although it is challenging to foresee the future, various elements hint at a return to the pre-COVID situation, at least partially. Students want to return to classrooms, and workers want to return to their workplaces. The pandemic has only proven the importance of human interaction physically more than ever before. However, healthcare is one area where these changes could be actually transformative.

In a pre-pandemic systematic review, Kruse et al. identified technology and training, and lack of computer literacy as top barriers to the application of telehealth [52]. With the need for distant patient interaction and care, the application of telemedicine has certainly improved postpandemic. However, physicians should feel confident that telemedicine will have little effect on patient satisfaction and will be adequately reimbursed. The administrators should feel confident in the technology while also ensuring confidentiality and data security. Lawmakers should bring legislations to remove or mitigate the barriers such as the availability of technology, connectivity, and literacy [53].

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4. e-Health: the way forward

Clinicians are central to patient care and thus form an integral part of any design of digital health solutions. They must be part of the design process early on because it will be difficult to get them on board at a later stage. Clinicians must have actionable data for care decisions. The data must be actionable and integrated with other relevant and contextual information. The true value of any data comes from myriad data points that leverage AI to combine clinical implications with the available data. In a survey by Accenture, clinicians were found to be interested in digital health but at least 60% mentioned lack of interoperability between IT systems as a top reason for not rolling out digital health [54].

The e-health interventions must fit into the existing system and integrate with technology systems used on a daily basis. Any attempt to motivate clinicians to leave the existing process and go for one more piece of data is going to be a challenge. The digital solutions must aim at augmenting the doctor and not replacing him. Doctors generally seek help to offload burdens that are not in lines with patient care, such as documentation, accessing patient education, treatment information, and guideline updates from one location. Digital solutions can help the clinician focus on patient care. Thus, any solution that is not designed keeping the doctor in mind is bound to fail acceptance [55]. Algorithms that could help track and come up with the best available treatments could help the doctor who can discuss those with the patient and families and arrive at the best solution after a careful risk–benefit–cost analysis.

As digital health interventions become more widely available, it also highlights some responsibility of the clinicians. Clinicians who understand the benefit of e-health and use them prudently improve the efficiency, effectiveness, and safety of the healthcare system. Therefore, in addition to increasing awareness about digital interventions, companies should focus on protecting patient data, resolving interoperability issues, better integration into the existing system, and training with AI/machine learning.

5. Conclusion

e-Health has come a long way since its limited application back in the 1990s. New avenues have since developed to allow wider use of e-health interventions. The COVID-19 pandemic will probably be a landmark in telemedicine history. It has had a significant global impact on the provision of healthcare with applications of telemedicine in various fields of medical practice. The need for digital aids such as e-health in patient care has never been more relevant. The COVID-19 pandemic has allowed the improved application of various e-health platforms that have existed for a long but have never been used due to regulations and funding limitations. Health systems are faced with an unprecedented opportunity to learn from the current situation and draw lessons for the future. Even as the pandemic has enabled the widespread adoption of e-health interventions, challenges remain regarding accessibility, particularly in rural areas. The ethical concerns arising with the use of teleservices need to be addressed as well.

Conflict of interest

The authors declare no conflict of interest.

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