Applications of 4.0 Technologies in Healthcare

Anwar Ahmed Khan, Shama Siddiqui, and Indrakshi Dey

Abstract The 4.0 industrial revolution, also known as Industry 4.0, is characterized by the integration of advanced technologies such as artificial intelligence, Internet of Things, cloud computing, augmented/virtual reality, and big data into various industries, including healthcare. The application of Industry 4.0 technologies in healthcare domain is referred as healthcare 4.0; adoption of these technologies can lead to improved patient outcomes, enhanced operational efficiency, while reducing costs. When it comes to mental healthcare delivery, the 4.0 technologies are expected to bring a revolution due to facilitating diagnoses as well as therapies. Some of the most prominent aspects that are expected to be affected by 4.0 technologies include predictive analytics, telemedicine, personalized medicine, and improved clinical decision-making by using decision support systems. In most of the healthcare scenarios, advanced sensing and analytics solutions can be used for providing early diagnosis and developing efficient care plans. This chapter presents a detailed analysis of applications of emerging 4.0 technologies in the healthcare domain.

Keywords Mental health · 4.0 technologies · Patient experience

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1 Introduction

The scope of connected devices and systems has extended far beyond automated manufacturing. Today, healthcare 4.0 technologies have been realized to ensure safe and reliable healthcare service delivery for the patients, regardless of their physical location or lack of resource [1]. Conventionally, healthcare has been delivered via simple interaction between the patient and a single clinician, where the diagnosis and treatment plan were solely dependent on the discretion of clinician. In major healthcare facilities, instead of relying on a single healthcare provider, multiple teams, clinicians, and healthcare facilities participate to provide the healthcare service. However, in such settings, the diagnosis is mostly based on the history provided by the patients, which may be inaccurate, biased, and misinterpreted [2]. In comparison to the physical health, the patients are more likely to provide falsified information about their mental health due to social taboos, emotional distress, and lack of medical knowledge [3]. Therefore, the use of computational technologies has been highly recommended for mental healthcare domain.

Wearables and cyber-physical systems are the basic elements of healthcare 4.0, including wearables, the Internet of Things (IoT), RFID, intelligent sensors, and medical robots [4]. These solutions are integrated with 4.0 technologies of IoT, big data analytics, machine learning, cloud computing, and decision support systems. Healthcare 4.0 connects the healthcare facilities, equipment/devices, and patient's homes and communities. To maintain the confidentiality, specific protocols have been developed to share patient-related information such as diagnosis, medication history, treatment plans, lab results, insurance, billing claims, etc. [5].

This chapter first presents a brief review of the 4.0 technologies that have been heavily adopted in the healthcare domain. Second, the applications of these technologies for specific domains of healthcare have been discussed. Finally, the emerging trends of using novel 4.0 technologies for healthcare applications are reviewed.

2 Healthcare 4.0 Technologies

2.1 Artificial Intelligence

Artificial Intelligence (AI) is the simulation of human intelligence in machines that are designed to think and act like humans. It deals with the development of algorithms and statistical models that enable computers to perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation. AI systems use advanced techniques such as machine learning, deep learning, and natural language processing to process large amounts of data, learn from it, and make predictions or decisions based on that

information. The goal of AI is to create systems that can perform tasks that would normally require human intelligence, making them faster, more accurate, and more scalable.

Artificial Intelligence (AI) has the potential to revolutionize the healthcare industry by improving the accuracy and efficiency of medical diagnosis, treatment, and overall patient care. Firstly, AI algorithms can assist medical professionals in analysing medical images, such as X-rays, CT scans, and MRI images, to identify and diagnose conditions. Secondly, AI can be trained to assist in medical diagnosis by analysing large amounts of patient data to identify patterns and predict potential diseases. This can help medical professionals in developing more effective treatment plans both for physical and mental health.

In addition to providing decisions based on the patient's physiological parameters taken from sensors and other connected equipment, AI can integrate well with other clinical information systems. For example, AI algorithms can be integrated into electronic health records (EHRs) to provide real-time recommendations for patient care based on the latest medical research and best practices. Similarly, AI can help healthcare organizations to predict patient outcomes and develop personalized treatment plans based on individual patient characteristics, such as age, gender, and medical history. In the era of predictive and precision medicine, AI helps to customize the drugs for patients based on their individual mental health state. AI can be used to analyse vast amounts of biological data to identify new targets for drug development and to optimize existing drugs for improved efficacy and safety.

The major applications of AI for mental health have been illustrated in Fig. 1 and described below:

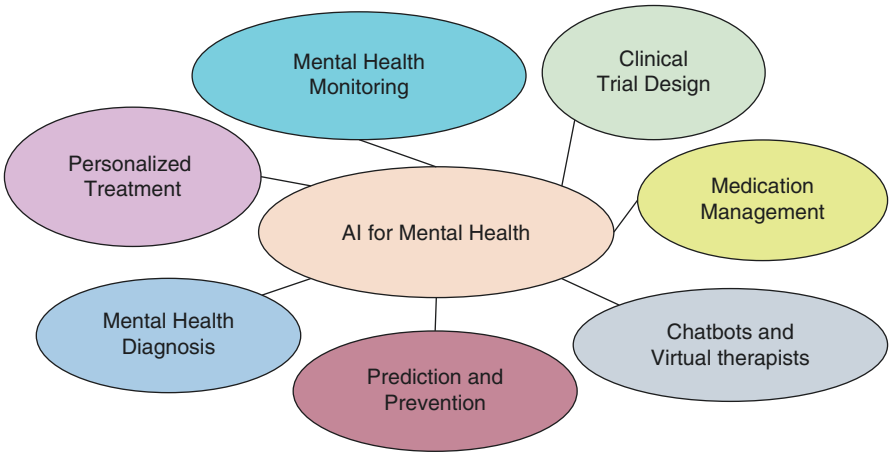

Fig. 1 Applications of AI for mental healthcare management

2.1.1 Mental Health Diagnosis

First and foremost, AI algorithms can monitor patients for symptoms and signs of mental health conditions, providing real-time data to mental health providers for informed decision-making. AI can be used to track symptoms and monitor changes over time, providing healthcare providers with valuable insights into a patient's mental health status. AI can assist with the analysis of medical images, such as MRI scans, to identify structural changes in the brain that may be associated with mental health conditions. Secondly, these algorithms can help diagnose mental health conditions based on medical history and demographic information. These algorithms may analyse patterns in data and predict future health outcomes, enabling mental health providers to intervene before a problem becomes more serious.

2.1.2 Chatbots and Virtual Therapists

AI-powered chatbots and virtual therapists can provide a convenient, accessible, and low-stakes way for people to get support and resources for their mental health. These bots can provide mental health screening tools and assessments that can help individuals determine if they are experiencing symptoms of a mental health condition. Chatbots can also provide emotional support and offer coping strategies for individuals who may be experiencing symptoms of anxiety or depression. This can help to alleviate feelings of loneliness and provide a sense of connection for those in need. Chatbots can provide educational resources and information on mental health conditions, treatments, and coping strategies. This can help individuals better understand their symptoms and find the support they need. As compared to human therapists, the chatbots may be more conveniently accessible. Chatbots can provide 24/7 access to mental health support, making it easier for individuals to seek help outside of traditional office hours or when they may not feel comfortable reaching out to a human therapist.

2.1.3 Facilitating Clinical Trials

AI also facilitates customized treatment plans, through analysing patients' data which significantly increases effectiveness and efficiency of mental health care. AI algorithms can be used to identify patient populations for clinical trials, increasing the speed and accuracy of research into new treatments for mental health conditions; this speeds up the recruitment process and reduces the time it takes to enrol participants. AI can analyse large amounts of patient data to identify potential outcomes and predict which patients are most likely to respond to a particular treatment. This can help to optimize patient selection and improve trial efficiency.

A crucial challenge for successful clinical trial is data management. AI can assist with the analysis of medical images, such as MRI scans, helping to more accurately and efficiently evaluate treatment outcomes and monitor disease progression. AI

can assist with the management of large amounts of clinical trial data, helping to ensure that data is accurately captured and analysed in real time. This can help to improve the accuracy and efficiency of clinical trials. Also, AI can be used to monitor patient safety during clinical trials, detecting potential adverse events and alerting healthcare providers to take appropriate action.

2.1.4 Medication Management

AI technology in integration with sensor and other data help to manage medication schedules and dosages, improving patient outcomes and reducing the risk of adverse side effects. AI can use machine learning algorithms to analyse data from wearable devices, such as smartwatches, to monitor medication adherence in real time. This can help healthcare providers to identify when patients are not taking their medications as prescribed and intervene to address any issues. Similarly, dosage can be optimized using AI; AI algorithms can help healthcare providers to optimize medication dosing by analysing patient data, such as weight, age, and medical history, to determine the most effective dosages for each individual.

The advanced AI algorithms can identify the impact of medication on mental disorders. AI can use natural language processing to analyse patient data and detect potential drug interactions, which can help to prevent adverse drug events and improve patient safety. Moreover, AI can use predictive analytics to identify patients who may be at high risk for adverse drug reactions and alert healthcare providers to take appropriate action.

2.1.5 Limitation of AI for Mental Health Management

While AI is not a substitute for human-led mental health diagnosis, it has the potential to provide valuable support to healthcare providers. By using AI to analyse large amounts of patient data, healthcare providers can make more informed diagnoses and develop personalized treatment plans, leading to improved patient outcomes.

For the present time, it is important to note that mental health diagnosis can be complex and is best performed by qualified mental health professionals, who take into account multiple factors, including a patient's medical history, personal and family history, and symptoms. AI can assist in the diagnostic process, but it should not be relied upon as the sole source of information.

2.2 IoT

The Internet of Things (IoT) refers to the interconnected network of physical devices, vehicles, home appliances, and other items that are embedded with sensors, software, and network connectivity, enabling them to collect and exchange data.

This interconnected network allows these devices to communicate with one another and with central systems, such as cloud-based servers, allowing for the creation of smart systems and the automation of many tasks. IoT connects everyday objects to the internet and allows them to send and receive data. This opens up new possibilities for automation, monitoring, and control of a wide range of devices and systems, ranging from home appliances and personal fitness devices to industrial equipment and infrastructure. The goal of IoT is to make our lives more convenient, efficient, and sustainable by allowing us to better manage and control the things we use every day.

Due to the continuous sensing and communicating functionalities, IoT promises to revolutionize the conventional healthcare as well as psychiatry. The patients are no longer required to recall and share all the details with the therapists on their scheduled sessions, rather the information about the patient's mental health state is continuously available to the therapists on their customized dashboards and mobile applications. IoT dashboards can provide real-time data on a patient's mental health status, allowing therapists to quickly identify changes or patterns in behaviour and respond accordingly; IoT dashboards can provide valuable insights into a patient's mental health, which can be used to develop personalized treatment plans. This can help therapists to better understand a patient's needs and provide more targeted and effective treatment. Moreover, IoT dashboards can provide a platform for collaboration between therapists, allowing them to work together to develop treatment plans and monitor patient progress. Using IoT solutions targeting mental health, the therapists have even become able to categorize the risks of patients for specific mental disorders such as anxiety.

The physiological and environmental sensors as well as digital media usage today play a key role for monitoring the emotional and mental health state of the patients. Various fields such as psychology, neurology, psychophysiology, neuropsychology, and cognitive psychology all are integrated in IoT platforms to ensure timely and reliable mental health assessment and care delivery. The availability of massive amount of data captured through IoT sensors helps to realize the intersection between diverse fields of neurosciences, psychology, and physiology [6], as illustrated in Fig. 2. As a result, interaction and collaboration between experts belonging from different domains become possible and cost-effective regardless of their location and time zones. In short, IoT helps healthcare by providing real-time data, improving clinical decision-making, improving patient outcomes, better managing chronic conditions, and increasing efficiency and reducing costs.

2.2.1 Limitation of IoT for Mental Health Management

Although IoT has the potential to play a significant role in mental health management by enabling real-time monitoring and data collection. However, there are some limitations to the use of IoT for mental health management. One of the main concerns with the use of IoT for mental health management is the protection of sensitive patient data. IoT devices often collect large amounts of personal data, which

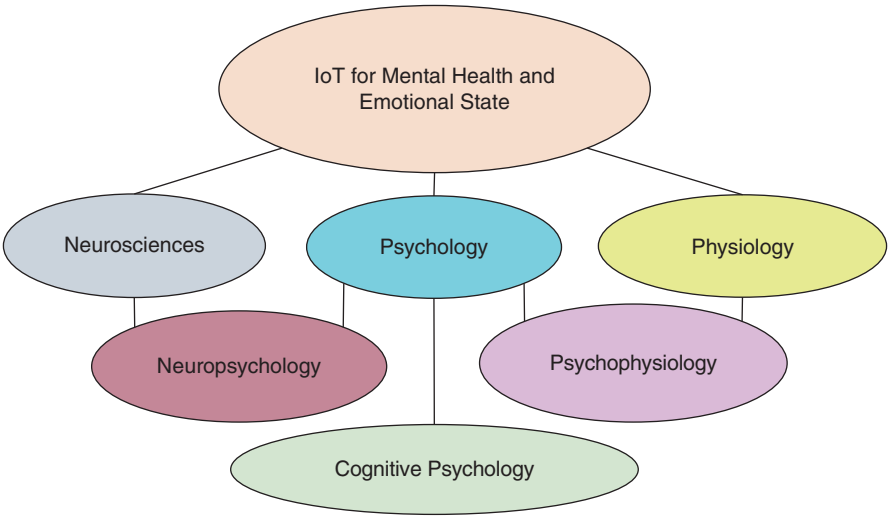

Fig. 2 Integration of IoT with psychology, neurosciences, and physiology

can be vulnerable to cyber-attacks or unauthorized access. Moreover, IoT devices can be prone to technical failures or malfunctions, which can impact their ability to accurately monitor and collect data. In addition, compatibility issues can arise when integrating different IoT devices into a single system. To be effective, IoT devices for mental health management need to be used regularly and consistently. This requires a high level of patient engagement and participation, which may be difficult to achieve for some patients.

IoT devices can be expensive, and many patients may not have the resources to purchase and maintain these devices. This can limit their availability to those who need them most. The accuracy and reliability of data collected by IoT devices can be a concern, particularly when it comes to mental health management. While these devices have the potential to provide valuable insights into a patient's mental health, the data they collect must be validated by clinical professionals to ensure its accuracy and clinical validity.

Despite the above limitations, the use of IoT for mental health management has the potential to provide valuable support to healthcare providers and improve patient outcomes. It's important to carefully consider these limitations and address any concerns before incorporating IoT devices into mental health management programs.

2.3 Cloud Computing

Cloud computing is a model for delivering information technology services in which resources are made available to users over the internet, rather than being provided from local servers or personal devices. The services provided by cloud

computing can include servers, storage, databases, networking, software, analytics, and intelligence. This technology allows users to access and use these resources on-demand, without having to manage the underlying infrastructure themselves. This results in increased efficiency, agility, and scalability, as well as lower costs and increased flexibility for both users and providers of the services.

The technology of cloud computing brings numerous advantages to the conventional and mental healthcare sectors. It mainly enables healthcare organizations to store, manage, and process vast amounts of electronic health records (EHRs) and medical imaging data, securely and at scale. Subsequently, it allows healthcare providers to collaborate and share data securely, enabling better coordination of care and improved patient outcomes. The major goal of cloud computing is to make information accessible from anywhere any time, that reduces the constraints of physical boundaries. With cloud computing, healthcare providers can access patient information from any location, using any device with an internet connection. This enables care to be delivered more efficiently and effectively, particularly in remote or underserved areas.

Since treating mental disorders often requires lifelong information about patient's diseases, family, lifestyle, choices and preferences, cloud computing promises to aid the therapists and experts significantly. By collecting data from sensors and other devices, cloud computing ensures prolonged availability of massive information sets. The technology provides robust disaster recovery options, ensuring that critical patient data is safe and secure, even in the event of a catastrophic event. Similarly, the cost of mental healthcare delivery also reduces due to cloud computing as tens of experts may have access to the stored data and they may collaborate in no time. Therefore, by leveraging the economies of scale of cloud computing providers, healthcare organizations can reduce their IT costs, freeing up resources for other critical initiatives.

2.4 Big Data Analytics

As previously discussed, the history of healthcare industry started from generating minimal amount of data generated during sessions of patients with their practitioners. However, today, not only patients but also many sensors, wearable devices, and automated devices generate data about the patients. Furthermore, the electronic medical records and decision support systems also participate in data generation and filtering processes due to which the volume has drastically increased. As a result, advanced big data analytics techniques have been developed to examine, clean, and model the large healthcare datasets. Machine learning and statistical algorithms have frequently been used for analysing and extracting insight from large and complex datasets. These techniques help to discover useful patient's information, reach informed decisions, and improve the overall healthcare quality not only for individuals but also for communities.

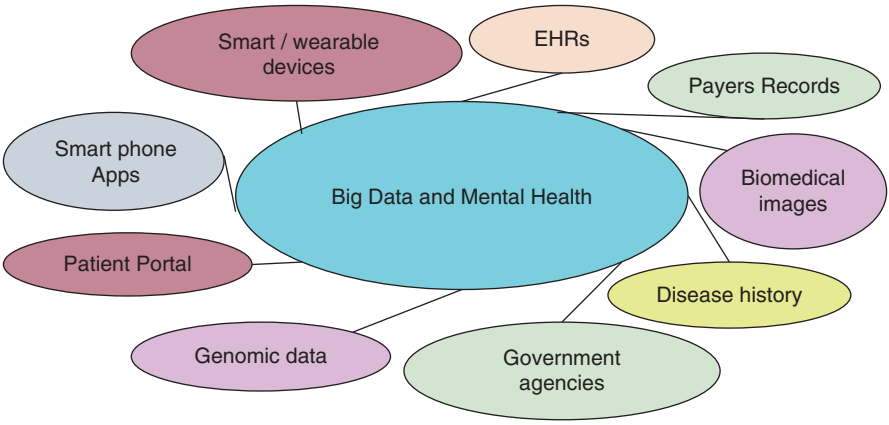

Fig. 3 Areas of mental health supported by big data techniques

Fundamentally, the goal of applying big data to the domain of healthcare is to identify patterns and trends in patient health, which allows healthcare providers to make more informed decisions about treatment and prevention strategies. Some of the major applications of big data for healthcare are illustrated in Fig. 3. Since big healthcare data is not only about patient's diseases history but also includes lifestyle and genetics information, healthcare providers can tailor treatment plans to the individual needs of each patient. Big data offers an opportunity to mental healthcare providers for developing a better understanding of a patient's mental health and make more accurate diagnoses. The patients may not be able to inform the practitioners about various important symptoms as they may consider them irrelevant. However, through the massive data collected via automated devices and sensors, it becomes possible to develop personalized treatment plans that are more effective.

Big data also identifies the problems and inefficiencies in the healthcare system which are used to optimize processes, leading to cost savings and improved outcomes.

2.5 Augmented/Virtual Reality

If displays, cameras, and sensors are used to overlay the real world with digital information, the application scenario is referred as Augmented Reality (AR). The creation of an entirely new vision and surrounding, the scenario is referred to as Virtual Reality (VR). AR enables bringing useful information from the digital world inside the perceptions and feelings of our own physical world. Over the recent years, we have seen promising advances in the sensor and camera technology. This advance has enabled software researchers in AR area to develop new technologies and ground-breaking applications. Though we are still in the regime of early developments of AR-based applications, over the next decade, AR devices are going to

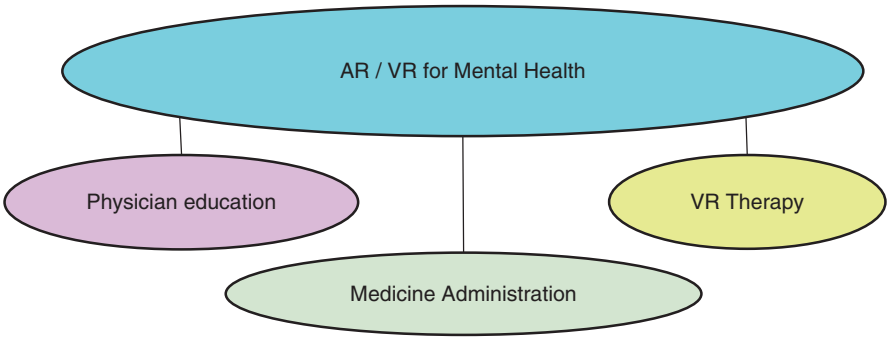

Fig. 4 Applications of AR/VR for mental health

invade every walk of life and going to impact over day-to day life in a big way. AR/VR are gradually finding different promising applications in healthcare, and doctors and nurses are interacting more and more through AR/VR applications for improving patient education and outcomes. Investment from different commercial agencies and companies over the recent years towards developing AR/VR technologies for healthcare has also pumped up the innovation in this area. Some emerging applications of AR/VR for healthcare are illustrated in Fig. 4:

2.5.1 Medicine Administration

Medicine administration has also been facilitated by novel ways introduced by AR/VR. Vein visualization is another emerging application of AR/VR. Many patients feel uncomfortable or get scared with too much pricking for drawing blood or injecting medicines/saline water. AR/VR can help project a map of the patient's veins onto their skin, making it easier for healthcare workers to find the right vein for injecting. Furthermore, since it often becomes troublesome for the family/physicians of patients suffering from mental disorders to convince them to take medications, AR/VR scenes may be set to persuade the patients.

Other most common examples of AR/VR applications in medicine and healthcare are as follows: (a) AR/VR can save lives by showing defibrillators nearby, (b) Google Glass can help new mothers with breastfeeding through interaction between counsellors and the mother herself with a projection of the reality, and (c) educating the public or kids about human physiology.

2.5.2 Physician's Education

One of the most prevalent applications of AR/VR in healthcare is education. Learning about how the body works and how they incorporate autonomy in the body functions is extremely important for the healthcare workers. AR applications

can enable healthcare workers to learn and visualize with three-dimensional representation of the human bodies. On the other hand, AR/VR tools can also be used to educate patients about how to take medicines, shots, or use other simple instruments or understand surgical procedures they went through and how the after treatment will work. Another application in the same thematic area is the use of AR/VR techniques by surgeons to visualize the area on which they are to operate or improve accuracy of surgery through three-dimensional projection of the patient's anatomy.

2.5.3 Virtual Therapies

Specifically for mental health, AR/VR has been used for providing virtual therapies including "Virtual Reality Exposure Therapy (VRET)" to patients. Using these technologies, the therapies are designed in a way that patients feel completely immersed in the virtual situations. Instead of just talking and providing imaginary situations to the patients during conversations, the therapists may develop customized situations in real time using AR/VR technologies. The therapies offer full control to the therapists to put their patients under extremely customized and seemingly real, virtual scenarios; these scenarios created by the experts aid the patients to realize and modify their behaviours. Virtual therapies are more practical for the therapists and much lesser stressful for the patients [7]. VR has been found effective for providing therapies in various disorders including generic anxiety and depression, social anxiety disorder, Autism Spectrum Disorder (ASD), post-traumatic stress disorders (PTSD), schizophrenia, claustrophobia, and eating disorders.

One of the major applications of VRET is to expose the patients to their own fear. The patients are fully engaged using a 3D interactive environment to face their fear and assess the level of anxiety they may generate. For example, someone having fear of heights will be exposed by making him sit on skyscrapers using VR environment. Although various research studies have reported benefits of VRET, there are certain challenges associated with this technology at present: first, the patients may not be comfortable to be engaged in the VRET interaction due to having extreme fear; second, practical creation of the scenarios which may cause similar level of anxiety in patient as the real-world situation may not be possible; and third, the therapists may also not be very confident about the use of VRET due to their limited awareness about the technology and its possible consequences for the patients.

2.6 Recommendation Systems

Recommender systems, also known as recommendation systems, are a subclass of information filtering systems that seek to predict the "rating" or "preference" a user would give to an item. Recommender systems are utilized in a variety of areas and are most commonly recognized as playlist generators for video and music services, product recommenders for online stores, or content recommenders for social media

platforms. In addition to generating customized contents and offering customized product advertisements, recommender systems also have applications for healthcare industry. They may offer personalized treatment recommendations, where they could analyse a patient's medical history, demographic information, and current symptoms to make personalized treatment recommendations. For example, a recommender system could recommend specific medications, therapies, or lifestyle changes based on a patient's unique needs.

One of the most crucial aspects for efficient mental healthcare delivery is identifying the best suited therapist and clinical facility. Mental healthcare is considered highly customized because mental health conditions are complex and can affect individuals in unique ways. Due to the highly diverse nature of mental disorders, recommender systems may offer significant advantage to the mental health practitioners as well as patients. Mental health conditions can manifest differently in different individuals and can be influenced by a variety of factors such as genetics, environment, and personal experiences; these conditions can be influenced by a person's unique life circumstances, such as family dynamics, work stress, and financial stability [8]. Moreover, Mental health conditions are complex and can involve multiple interacting factors such as biological, psychological, and social factors. Finally, mental healthcare treatment plans must take into account a person's personal preferences, such as their comfort level with certain types of therapy or medication. Therefore, recommender systems could assist patients in finding the best healthcare providers based on factors such as their location, specialty, and patient reviews. Furthermore, recommender systems could provide personalized health and wellness recommendations to individuals based on their lifestyle, physical activity, and dietary habits.

Also, recommender systems could match patients with clinical trials that are most suitable for their specific medical conditions and demographics. This would help to increase patient participation in clinical trials and ultimately speed up the development of new treatments.

3 Application of Healthcare 4.0 Technologies

3.1 Cost Reduction

The use of artificial intelligence, machine learning, IoT, cloud computing, etc. can significantly reduce the healthcare costs. First and foremost, the efficiency of overall healthcare delivery improves due to reducing redundancy and errors and increasing productivity. Second, the smart healthcare equipment can inform about needs of predictive maintenance, reducing the downtime as well as cost of repair. Third, telemedicine and remote patient monitoring can reduce hospital readmissions, outpatient visits, and overall costs by allowing patients to receive care from home.

Personalized medicine powered by AI tools can also help the physicians to make more accurate and timely diagnosis.

Particularly for mental health, the use of healthcare 4.0 technologies brings numerous benefits. The cost of therapy has significantly reduced due to the emerging use of mobile apps and web-based platforms for continuous monitoring and assessment. Instead of needing to visit the therapist at the physical facilities, patients could easily consult them online. The cost also reduces as the patients become able to identify their disorders at an early stage, providing more opportunity to deal with it in a cost-effective manner. Moreover, the technologies such as machine learning and big data analytics facilitate the therapists by identifying the most prevalent mental disorders in specific populations. Using this information, the practitioners may develop efficient prevention and treatment strategies in advance.

3.2 Predictive Analytics

Healthcare 4.0 technologies including big data can help mental healthcare providers anticipate and prevent potential health issues by analysing patterns and trends in patient data. IoT sensors, patient's handheld devices, and other connected medical equipment provide massive amount of data for facilitating predictive analytics. The machine algorithms can analyse vast amounts of data and identify patterns, relationships, and trends that would be difficult or impossible to detect manually. AI-powered predictive analytics tools can identify trends and predict future outcomes, allowing therapists and other care team members to take proactive measures to prevent problems or capitalize on opportunities. Moreover, since the use of social media has been increasing among all population sectors, social media analysis and opinion mining have also been emerging. The social media profiles and posts of populations may be assessed by the advanced Natural Language Processing (NLP) tools to identify any mental disorders. In short, the predictive analytics enable mental health professionals to make more informed decisions, improve operational efficiency, and stay ahead of potential health risks.

3.3 Telemedicine

Access to mental healthcare significantly enhances via telemedicine as the barriers such as distance, mobility, and scarce availability of mental healthcare professionals are reduced. Various tools and technologies facilitating telemedicine have been applied for mental healthcare, as illustrated in Fig. 5 and discussed below:

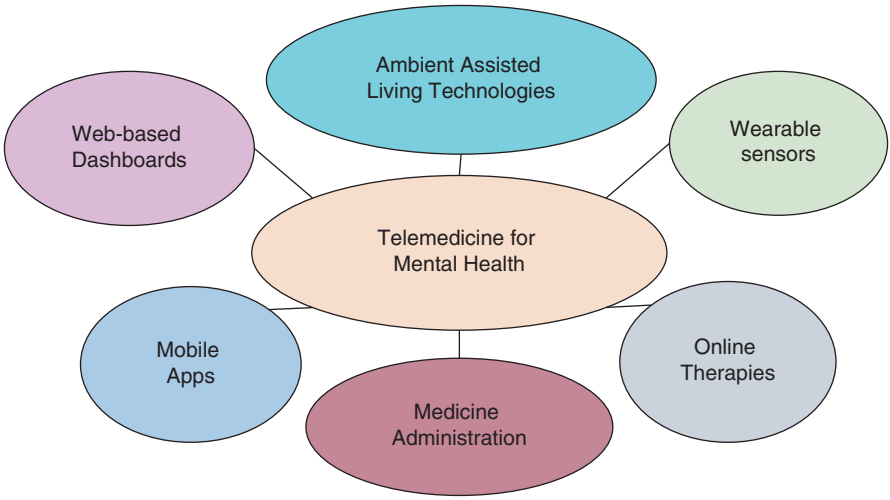

Fig. 5 Emerging healthcare 4.0 trends for mental health

3.3.1 Web-Based Dashboards and Mobile Apps for Online Therapies

Dashboards are the most common form of interfaces between man and machine for an IoT network or any other cyber-physical system. They collate, organize, analyse, and transform digital information (data) communicated in our physical world to represent them in a format that can be easily understood by everybody when read from or displayed on a mobile phone, computer, or any other user interface. The major advantages of dashboards are that they can monitor and control input/output devices in the network, can be used both for global and individual benefits, and can be operated over cloud-based data storage platforms.

There has been a recent surge in the design and development of real-time COVID-19 or pandemic-related IoT dashboards. Such dashboards have mainly been used for monitoring and managing patients, and for assisting the state authorities and healthcare professionals in situation awareness and critical decision-making. The real-time dashboard developed in [9] targeted prioritizing emergent, urgent, and semi-urgent cases requiring surgery in order to reducing risk of COVID-19 exposure for surgeons, nurses, technicians, and other health-care staff. The focus of the dashboard in [10] is to provide information on the status and location of clinical trials for avoiding any duplication and increasing chances of collaboration for vaccine development. The dashboard developed in [11] populated information about the number of patients tested, test results, availability of beds and ventilators, etc. for supporting operational decision-making like isolation procedure, etc. An interactive web-based mapping dashboard is developed in [12] for assessing changes in mobility patterns of individuals, and then reporting them over the ArcGIS dashboard. Similarly, visualization dashboards have been developed [13] to help remote consultants, tele-health operators, and emergency service

providers. These dashboards provide real-time information on the number of patients requiring hospitalization, user needs, etc., which help the service providers in taking critical decisions regarding management of resources and patients. It helps authorities to keep check on whether social distancing norms are followed or not, while informing individuals about their health risk possibility owing to their mobility.

The platforms such as web-based dashboards and mobile apps have increasingly been used to provide counselling and therapy services through simple phone calls or video conferencing. The telemedicine technologies have particularly been useful for the patients who live in far off remote locations or have physical impairments. Since there is a considerable shortage of mental health professionals worldwide and also, it is not always realistic for the population to afford the high fees of clinical visits, alternative methods have been developed using healthcare 4.0 technologies. The situation of mental health is particularly worsening for the population residing at developing countries and those belonging from low socio-economic status. In fact, majority of the patients suffering from mental disorders are not even aware of their situation.

In the above scenario, the easily accessible mobile apps and web-based dashboards are being developed to assess the mental health states and manage the diseases/disorders through online service delivery. On the one hand, such services improve the accessibility to mental healthcare services, and on the other hand, they ensure accessibility while maintaining the patient's confidentiality. As previously discussed, mental health issues are yet considered taboo and people are often not comfortable to share such issues with their family. The mobile apps and other online platforms ensure that patients could avail the services of automated therapy or consultancy services at a minimum cost.

3.3.2 Medicine Administration

An important aspect of telemedicine is the possibility of regularly monitoring the patients to observe the impact of any medicine or treatment plan suggested in the past. With the help of various sensors and equipment, mental healthcare providers may track the patient's progress and response to treatment over time, which enables them to adjust a patient's treatment plan as needed. Regarding continuous monitoring, a revolutionary change is an opportunity for the physician be informed about medication administration. The novel development of digital pills ensure that the patients have taken medicine, as an alert is sent to the medical professional. Generally, Bluetooth connectivity is used to transmit an alert from the ingested tablet to patient's handheld device, which subsequently signals the remote healthcare professional; the fundamental operation of digital pill has been illustrated in Fig. 6. The digital pill technology is particularly beneficial for the patients suffering from mental diseases such as Alzheimer who tend to forget taking their medication, which could further worsen their condition.

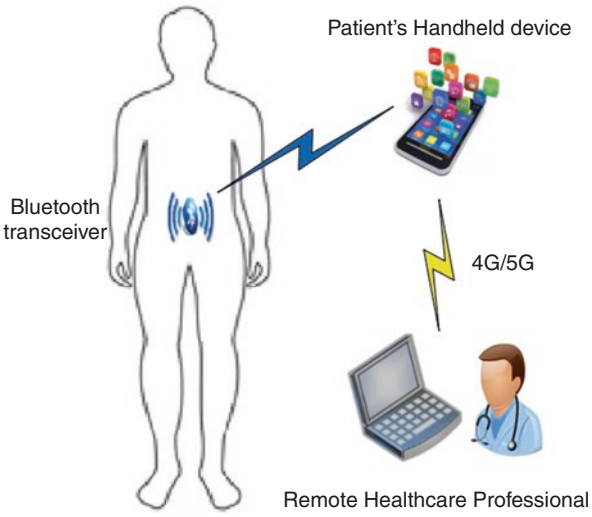

Fig. 6 Fundamental operation of digital pill

3.3.3 Wearable Sensors

Various chemical, physical, and biological sensors have been developed and sold in the wearable form to offer continuous telemedicine facilities. The most common example of wearable sensor is smart watch/Fitbit. Generally, these sensors are embedded with wearable clothing or gadgets and coordinate with the handheld devices of users via technologies such as Bluetooth/Wi-Fi. Subsequently, the information is sent over wireless links to the remote stations. Usually, the databases are managed over cloud so the remote physicians may remain informed about the users' conditions. The wearable technology has already been playing a leading role in the management of various physical and mental health conditions. It reduces the cost of care and improves the quality by real-time communication of the patient's state. Furthermore, instead of only relying on the patient as a source of information, the experts get an opportunity to have a real insight into the patient's condition through monitoring the physiological and psychological parameters of interest. For example, for various anxiety and depression use cases, the parameters such as pulse rate, SpO_2, and blood pressure are shown to be of interest.

The wearable sensors are configured according to the customized requirements of each patient. For example, the frequency of transmission of vitals or the threshold value may be set independently for each patient. The risk for patients may also be identified based on the data provided by the wearable sensors by monitoring the threshold values for each parameter. This approach facilitates the monitoring of patients for their mental health state; instead of maintaining generic appointment schedules for the patients, it becomes possible to prioritize the patients requiring immediate care which reduces the healthcare burden both on patients and providers.

3.3.4 Ambient Assisted Living Technologies

Ambient Assisted Living (AAL) is a field of research and development that focuses on using technology to improve the quality of life of elderly and disabled people, enabling them to live independently in their own homes for longer. AAL technologies aim to provide support and assistance in the home environment, by using sensors, communication systems, and other devices to monitor and respond to the needs of individuals.

The main objective of AAL is to develop intelligent systems that can detect and respond to changes in an individual's behaviour, routines, or health status, and provide them with the necessary assistance or intervention to help them maintain their independence and quality of life. This can include, for example, reminders to take medication, alerts for falls, and automatic adjustments of lighting, temperature, and other environmental factors.

AAL technologies can also provide a means of communication and connection to family members, caregivers, and healthcare professionals, improving social interaction and reducing isolation. The ultimate goal of AAL is to create a supportive, comfortable, and safe living environment that promotes independence, autonomy, and dignity for elderly and disabled people.

3.4 Personalized and Precision Medicine

4.0 technologies are providing significant novel opportunities for customizing the treatment plans. In this context, personalized and predictive medicine are two emerging domains. Personalized medicine refers to the tailoring of medical treatment to the individual patient, considering their unique characteristics such as genetic makeup, lifestyle, and environment [14]. On the other hand, precision medicine is a subset of personalized medicine, but it focuses more on using genetic and molecular information to identify the specific cause of a disease in a patient and target treatment to that specific cause. Clearly, the precision medicine is expected to be more effective as compared to standard treatment plans. All the computing technologies, specifically IoT and big data analytics play a leading role to provide an in-depth insight into the patient's lifestyle and its impact on their health. As a result, customized treatment plans and medicine may be suggested for each patient instead of the conventional generic treatment strategies.

Technologies such as machine learning and big data analytics integrate the fields of genomics to identify the genetic causes of mental disorders. The advanced computing technologies aid to identify the genetic patterns and their influence on the patient's personality since childhood. As a result, it is not only the therapist's diagnosis of patient based on their and family's history, but the facts are all stored and analysed over the patient's lifetime. Genomics facilitates creating personalized medicines for diseases such as tumours, cancers, arthritis, and Alzheimer's disease.

Both the personalized and precision medicine are particularly relevant for mental health of individuals. It is generally not possible to develop standard treatment plans for the patients requiring assistance with their mental health. Therefore, it is expected that healthcare 4.0 shall bring a revolution for psychiatry by providing a detailed insight into the health state of each patient, which shall subsequently be used for developing therapies.

3.5 Facilitating Interconnections

Healthcare 4.0 technologies are used to provide interconnection between diverse aspects of healthcare sector to create an efficient information network. The interactions between different healthcare stakeholders being facilitated by 4.0 trends are shown in Fig. 7. Firstly, the interactions between patients, caregivers, and other team members are realized using advanced hardware and software technologies to diagnose and treat the mental health conditions. This interaction between different stakeholders is vital for ensuring patient safety and mental healthcare quality. The patients and caregivers not only need to be informed about the diagnosis but their continuous engagement is crucial throughout the treatment and care process. This would enable the patients to better understand about their needs and would involve actively in the implementation of their care plan. Since mental illnesses may be chronic and complex, the engagement of patients and their caretakers becomes even more critical. In this regard, various information technology tools such as electronic medical records, patient portals, IoT data, assistive technologies, mobile apps, and video conferencing platforms all facilitate the patients and caregivers.

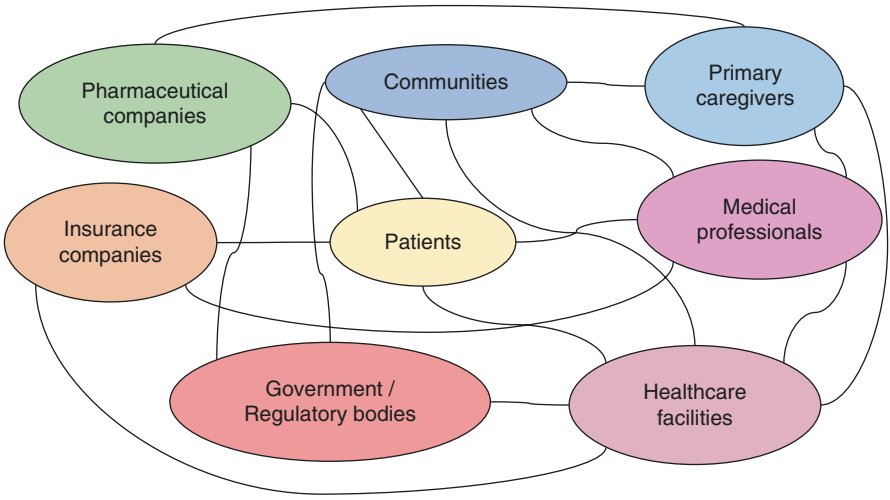

Fig. 7 Interaction between healthcare stakeholders

In addition to interaction with patients and their caregivers, the healthcare 4.0 technologies also facilitate interaction between the professional teams so they may coordinate and communicate efficiently. Particularly, when diverse team members come together to deliver therapies and other care elements, it becomes vital to use computing tools and emerging 4.0 technologies to update the status and monitor the patient's progress in the context of strategies developed by the individual team members. All team members can easily coordinate and share information using real-time dashboards. These dashboards may be integrated with the data streams being communicated via wearable and environmental sensors, patients' handheld gadgets, and any other equipment to further enhance the team's information.

Since one of the core objectives of healthcare 4.0 is to connect all the devices and equipment, it has become possible to centrally collect and maintain data generated by geographically dispersed sensors and systems. These devices facilitate additional diagnosis, prediction, and analysis with the advent of fog, edge, and cloud computing. Similarly, diverse organizations and communities may connect with other stakeholders such as small practitioner groups, pharmacies, clinics, individuals, long-term facilities, hospice care facilities, public and regional healthcare systems using advancing communication infrastructure. The collaboration between individuals and healthcare organizations would improve the quality of care. However, appropriate policies, procedures, protocols, and legislations shall be required for granting the access of data generated by each entity to others.

Due to the possibility of continuous data collection and analysis, it would become possible to study the complete mental health state of a person since their childhood. All the details about any past disease history, emotional traumas and physical accidents or incidents such as bullying shall be readily available for the therapists and other caregivers. In the present practice, where it takes multiple sessions of psychologists just to collect the details about patients' habits, their routines, lifestyle habits, social preferences, eating habits, etc., significant amount of time and cost are incurred. These details are collected to develop the treatment plans and despite spending numerous resources, it is of no guarantee that patients provide accurate details. In comparison, healthcare 4.0 technologies shall improve the situation by providing all lifestyle and health-related details in a chronological fashion, starting from the birth of patients. In future, when all the healthcare facilities worldwide will be connected, the care transition across time and space will be realized in its true sense.

In addition to the primary stakeholders of healthcare sector, patients and medical professionals, healthcare 4.0 also serves interactions between others such as pharmaceutical and insurance companies. For example, insurance companies play a significant role in determining which drugs are covered and reimbursed, as they often negotiate prices with pharmaceutical companies. If a drug is not covered or is only partially covered by insurance, it can affect its overall accessibility and affordability to patients. Using the connectivity, the pharmacy and patients may immediately know their insurance coverage. Similarly, pharmaceutical companies invest significant resources in the development of new drugs, and insurance companies often play a role in funding these research and development efforts through their

payments for covered drugs. Moreover, the patients may be benefited in monetary terms through the interaction between pharmacies and insurance companies. Insurance companies and pharmaceutical companies work together to balance the cost of drugs with their effectiveness. Insurance companies often negotiate with pharmaceutical companies to reduce the cost of drugs for their clients and may encourage the use of lower-cost alternatives.

4 Future Trends

4.1 Maintaining Confidentiality

Confidentiality is a critical aspect of healthcare, and it is becoming increasingly important in the era of healthcare 4.0. In the future, smart health technology will likely include advanced security measures to protect patient information and ensure confidentiality. Data transmitted between medical devices and healthcare providers will be secured by using advanced encryption techniques to prevent unauthorized access. Encryption can be applied at the device level, network level, and data storage level. Access control policies are expected to be designed efficiently and implemented strictly. Medical devices and healthcare systems can be configured to allow access only to authorized personnel. This can be achieved through the use of passwords, biometrics, or smart cards.

Although IoT and other technologies discussed in the chapter tend to generate massive amount of data, confidentiality will require minimizing the generated data. Only the minimum amount of data necessary for a specific use case will be collected, transmitted, and stored. This strategy would reduce the potential harm that could be caused in the event of a data breach. Moreover, as hackers always remain ahead in technology, it will be crucial to ensure that even more advanced security schemes are used to maintain the patient's confidentiality. In this regard, medical devices and healthcare systems should receive regular security updates to address any newly discovered vulnerabilities. Finally, The IoMT must comply with relevant regulations, such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States, which sets standards for protecting medical information [15].

4.2 Integration of Blockchains

Confidentiality and privacy appear to be the major hurdle in extending the mental healthcare services to individuals and populations. In addition to the appropriate legislation in place, the computing technology of blockchain has also been integrated with healthcare solutions to ensure immutability, traceability, transparency,

security, and fault tolerance. Blockchain is based on distributed ledger, where central ledger is maintained by a trusted entity and distributed ledger is shared, replicated, and synchronized among multiple locations. Blockchain will not only ensure security, but at the same time, it will also help to maintain standardization of information across the healthcare network, which will in turn improve the accessibility of information.

As previously discussed, advancing computing and communication technologies aim at facilitating interaction between numerous healthcare stakeholders; this shall be realized by deploying secured blockchains. Since blockchain holds the inherent property of tracing the information throughout the network, only trusted entities will be allowed to update/edit the entries. The confidentiality of patients shall be guaranteed and the payment system will also become secured. Therefore, the risk of breaches will be minimized by using effective blockchain infrastructures for mental healthcare platforms. The integration of blockchain with the healthcare sector is still in infancy, and there are technical and regulatory challenges that must be overcome before its full potential can be realized.

4.3 Enhanced Use of Big Data

In future, the big data techniques are expected to be used to support large scale clinical trials and other research initiatives. Big data can provide detailed insight into the population disease patterns and treatment outcomes. Thus, based on the population information, big data techniques shall be used for identifying the best participants for any clinical trials; this will reduce the time and cost involved in conducting a trial. The design of clinical trials may be efficiently guided by big data analytics techniques, which shall increase the success of trials. The predictive analytics shall also be served by big data techniques for developing trials as well as treatment strategies.

The conventional electronic health records will be integrated with big data analytics algorithms to perform population health analytics. The worldwide demographics of patients shall guide the states and practitioners to develop predictive and preventive strategies for the most prevailing diseases in each population. For example, the exact mental disorders will be identified for each population, and the risks will be categorized based on parameters such as age, culture, etc. Subsequently, instead of offering generic mental healthcare strategies to the populations, specific therapy targeted at the prevalent mental disease or disorder shall be developed.

4.4 Robotics Process Automation

Robots and automated processes have already pervaded multiple quarters of the new industrial world. One more area where they are going to be prevalent is healthcare 4.0. One of the applications that is emerging and will be very common and affordable in future is the use of automated limbs, like robotic arms and legs, to replace damaged ones in individuals. Gradually, we are witnessing customized solutions for individuals who cannot move their limbs or entire body. For example, just by capturing the movement of the eye, it is possible to bring close an object or perform a particular task, like combing the hair, eating soup with a spoon, etc., through automated systems. The idea is to understand what the patient wants even though the individual cannot speak or move their limbs. As long as, it is possible to capture certain kind of gesture and map those gestures to preferred needs, the preferred action can be executed through automated processes. Another important application is the use of haptic arms in medical procedures. Smaller procedures like stitching and sutures after surgery, fitting patches, etc. can be done to utmost precision using a controlled haptic arm, sometimes even better than actual human hand. Even though, till now, actual personal care and nursing is irreplaceable, it is possible in future to have human robots or humanoids understanding our personal needs. Such humanoids can offer care, sympathy, the very needed human touch necessary for healing and overall care-and-cure of individuals.

4.5 Extended Reality

Extended Reality (ER) is a phenomenon that is going to be introduced in many possible quarters of life. It is a vision of what present reality may look like when extended to another space, verse, and time. It is a kind of a vision of the future and can be really helpful when dealing with psychological ailments. ER can assist in certain situation of clinical depression and stress in order to alleviate anxiety level. For example, a patient who is feeling traumatized in his/her current scenario that is conducive to his/her mood. Collecting extensive data on a patient, what makes the individual feel safe and complacent, it is possible to create a vision of that world. The patient in an elevated state of anxiety can actually feel safe, secure, and calm in the formulated appropriate vision of reality. ER in conjunction with AR/VR can create a vision of the alternate universe which can be used in other applications too, like gaming, metaverse, etc.

4.6 Customized Patient Experience

Customized patient experience is another application that can be unleashed through healthcare 4.0. By analysing data on both physiological and psychological parameters of a patient and applying different forms of learning and transfer learning algorithms, it will be possible to formulate customized care procedure for individual patients. A very promising example is the application of automated music therapy for treating anxiety and depression. Depending on the personal liking of the patient, list of music that helps individuals calm down, concentrate, it is possible to create a list of customized music for individual patients. If the patient is suffering from an anxiety attack, then the custom list of music can be played on the preferred choice of the individual's handheld device. This will be able to bring down the anxiety level of the patient under control. This kind of customized experience may not be able to provide ultimate solution in case of an emergency condition; but can scale down level of stress/depression and provide enough time for the actual care procedure to be implemented.

4.7 Digital Twins

Digital twins, in future, is going to offer a wonderful way of creating a digital clone of any physical entity or system. Digital twins are going to also offer emulator platform for an entire data, communication, or energy networks. With digital twins, therefore, it will be possible to monitor any system, any network in real time. Depending on the scenario, it will be possible to monitor any system, any network in real time. Depending on the scenario, it will be possible to analyse real-time signals, data, and information and then predict any impending actionable situation. It is also possible to probe the digital twin with a real signal and monitor how that will flow through a system or a network. Based on the observables, it will be possible to optimize system and network design and obtain preferable outcomes. Digital twins in healthcare 4.0 will be in the form of twin of the tele medicine platform and the monitoring dashboard with which it will be possible to monitor multiple patients/individuals cover a wide geographical area. Any patient about to suffer an impending condition can be intercepted and emergency help can arrive right on time.

4.8 Network Strategies

While so many promising applications are coming up, the possibility of cyber-discrepancies is also growing manifold. The most important feature in all applications of healthcare 4.0 is the personal data (physiological, psychological, environmental). Whether it is personalized or custom care procedure, or use of

autonomous systems, robotic arms, haptic arms, it is important to use, learn, and analyse personal data gathered from individuals over a certain period of time. Sharing sensitive, personal data over the network, can be intrusive in certain cases and vulnerable to encroachment and breach of privacy. Especially, health-related data can be sensitive and very personal to a particular individual. Therefore, it is paramount to consider privacy and encryption aspects when formulating and designing network data learning and sharing strategies and protocols. Cybersecurity and data privacy are broad areas of research in itself and are beyond the scope in this short chapter.

5 Summary

The healthcare 4.0 technologies are expected to transform the healthcare delivery by providing a detailed picture of patient health. The major goal of these technologies is to enable healthcare providers to make informed and timely decisions about diagnosis and treatment strategies. At the same time, the access to mental healthcare services is expected to become more available and accessible via use of advanced computational technologies. In short, the healthcare 4.0 technologies have a potential to improve the quality and efficiency of mental healthcare delivery by providing mental healthcare providers with more accurate and actionable information about their patients.

References

1. Pavitra AR, Lawrence ID, Maheswari PU. To identify the accessibility and performance of smart healthcare systems in IoT-based environments. In: Using multimedia systems, tools, and technologies for smart healthcare services. 2023. pp. 229–245.
2. Awotunde JB, Jimoh RG, Oladipo ID, Bhoi AK. Internet of medical things for enhanced smart healthcare systems. In: Implementation of smart healthcare systems using AI, IoT, and blockchain. 2023.
3. Abbasi OH, Horowitz CD, Dauer G. Mental health stigma. In: Cases on diversity, equity, and inclusion for the health professions educator. 2023.
4. Ilangakoon TS, Weerabahu SK, Samaranayake P, Wickramarachchi R. Adoption of industry 4.0 and lean concepts in hospitals for healthcare operational performance improvement. Int J Product Perform Manag. 2022;71:2188–213.
5. Wu Z, Xuan S, Xie J, Lin C, Lu., C. How to ensure the confidentiality of electronic medical records on the cloud: a technical perspective. Comput Biol Med. 2022;147:105726.
6. Gyrard A, Boudaoud K. Interdisciplinary IoT and emotion knowledge graph-based recommendation system to boost mental health. Appl Sci. 2022;12:9712.
7. Wiebe A, Kannen K, Selaskowski B, Mehren A, Thöne A-K, Pramme L, Blumenthal N. Virtual reality in the diagnostic and therapy for mental disorders: a systematic review. Clin Psychol Rev. 2022;98:102213.
8. Rubeis G. iHealth: the ethics of artificial intelligence and big data in mental healthcare, vol. 28. Internet Interv; 2022. p. 100518.

9. Wick EC, Pierce L, Conte MC, Sosa., J. A. Operationalizing the operating room: ensuring appropriate surgical care in the era of COVID-19. Ann Surg. 2020;272:e165.
10. Thorlund K, Dron L, Park J, Hsu G, Forrest JI, Mills EJ. A real-time dashboard of clinical trials for COVID-19. Lancet Digital Health. 2020;2:e286.
11. Reeves JJ, Hollandsworth HM, Torriani FJ, Taplitz R, Abeles S, Tai-Seale M, et al. Rapid response to COVID-19: health informatics support for outbreak management in an academic health system. J Am Med Inform Assoc. 2020;27:853–9.
12. Gao S, Rao J, Kang Y, Liang Y, Kruse J. Mapping county-level mobility pattern changes in the United States in response to COVID-19. SIGSpatial Special. 2020.
13. Dixit RA, Hurst S, Adams KT, Boxley C, Lysen-Hendershot K, Bennett SS, et al. Rapid development of visualization dashboards to enhance situation awareness of COVID-19 telehealth initiatives at a multihospital healthcare system. J Am Med Inform Assoc. 2020;27:1456–61.
14. Ho D, Quake SR, McCabe ER, Chng WJ, Chow EK, Ding X, Gelb BD. Enabling technologies for personalized and precision medicine. Trends Biotechnol. 2020;38:497–518.
15. Hireche R, Mansouri H, Pathan. A-SK. Security and privacy management in internet of medical things (IoMT): a synthesis. J Cybersecurity Privacy. 2022;2:640–61.