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REVIEW

Smart healthcare: making medical care more intelligent

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ABSTRACT

With the development of information technology, the concept of smart healthcare has gradually come to the fore. Smart healthcare uses a new generation of information technologies, such as the internet of things (loT), big data, cloud computing, and artificial intelligence, to transform the traditional medical system in an all-round way, making healthcare more efficient, more convenient, and more personalized. With the aim of introducing the concept of smart healthcare, in this review, we first list the key technologies that support smart healthcare and introduce the current status of smart healthcare in several important fields. Then we expound the existing problems with smart healthcare and try to propose solutions to them. Finally, we look ahead and evaluate the future prospects of smart healthcare.

1. Introduction

Today's era is the one of informatization. With the advancement of technology and scientific theory, traditional medicine with biotechnology as its core, has gradually begun to digitize and to informationize. And smart healthcare incorporating a new generation of information technology has emerged. Smart healthcare is not just a simple technological advancement, but also an all-round, multi-level change. This change is embodied in the following: medical model changes (from disease-centered to patient-centered care), informatization construction changes (from clinical informatization to regional medical informatization), changes in medical management (from general management to personalized management), and changes in the concept of prevention and treatment (from focusing on disease treatment to focusing on preventive healthcare).[1] These changes focus on meeting the individual needs of people while improving the efficiency of medical care, which greatly enhances the medical and health service experience, and represent the future development direction of modern medicine. This review will start from the concept of smart healthcare, then briefly introduce the key technologies supporting smart healthcare and explain the achievements and challenges of it by reviewing the application status of these technologies in important medical fields, before finally putting forward the future prospects of smart healthcare.

2. The concept of smart healthcare

Smart healthcare was born out of the concept of “Smart Planet” proposed by IBM (Armonk, NY, USA) in 2009. Simply put, Smart Planet is an intelligent infrastructure that uses sensors to perceive information, transmits information through the internet of things (IoT), and processes the information using supercomputers and cloud computing.[2] It can coordinate social systems and integrate them to realize the dynamic and refined management of human society. Smart healthcare is a health service system that uses technology such as wearable devices, IoT, and mobile internet to dynamically access information, connect people, materials and institutions related to healthcare, and then actively manages and responds to medical ecosystem needs in an intelligent manner. Smart healthcare can promote interaction between all parties in the healthcare field, ensure that participants get the services they need, help the parties make informed decisions, and facilitate the rational allocation of resources. In short, smart healthcare is a higher stage of information construction in the medical field.[3]

3. Key technologies of smart healthcare

Smart healthcare consists of multiple participants, such as doctors and patients, hospitals, and research institutions. It is an organic whole that

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involves multiple dimensions, including disease prevention and monitoring, diagnosis and treatment, hospital management, health decision-making, and medical research. Information technologies, for example, IoT, mobile Internet, cloud computing, big data, 5G, microelectronics, and artificial intelligence, together with modern biotechnology constitute the cornerstone of smart healthcare. These technologies are widely used in all aspects of smart healthcare. From the perspective of patients, they can use wearable devices to monitor their health at all times, seek medical assistance through virtual assistants, and use remote homes to implement remote services; from the perspective of doctors, a variety of intelligent clinical decision support systems are used to assist and improve diagnosis. Doctors can manage medical information through an integrated information platform that includes Laboratory Information Management System, Picture Archiving and Communication Systems (PACS), Electronic Medical Record, and so on. More precise surgery can be achieved through surgical robots and mixed reality technology. From the perspective of hospitals, radio-frequency identification (RFID) technology can be used to manage personnel materials and the supply chain, using integrated management platforms to collect information and assist decision-making. The use of mobile medical platforms can enhance patients' experiences, From the perspective of scientific research institutions, it is possible to use techniques such as machine learning instead of manual drug screening and to find suitable subjects using big data.[4] Through the use of these technologies, smart healthcare can effectively reduce the cost and risk of medical procedures, improve the utilization efficiency of medical resources, promote exchanges and cooperation in different regions, push the development of telemedicine and self-service medical care, and ultimately make personalized medical services ubiquitous.[5]

4. The application status of smart healthcare

The service targets of smart healthcare can be roughly divided into three categories: clinical/scientific research institutions (e.g., hospitals), regional health decision-making institutions, and individual or family users. The application of smart healthcare can be divided as follows, based on different needs:

4.1. Assisting diagnosis and treatment

With the application of technologies such as artificial intelligence, surgical robots, and mixed reality, the diagnosis and treatment of diseases has become more intelligent. Using artificial intelligence to built the clinical decision support system, it has achieved certain results, such as the diagnosis of hepatitis, lung cancer, and skin cancer. The accuracy of artificial intelligence diagnosis results exceeds that of human doctors.[6–8] Machine learning-based systems are quite often even more accurate than experienced physicians, especially in pathology and imaging.[9] The most outstanding and representative product in the field of clinical decision support systems is IBM's Watson,[10] an intelligent cognitive system that provides an optimal solution through in-depth analysis of all clinical data and literature data. The program has a great effect on the diagnosis of diabetes and cancer.[11] Through the use of the clinical decision support system, doctors can give expert advice based on algorithms to improve the accuracy of diagnosis, reduce the incidence of missed diagnosis and misdiagnosis, and enable patients to receive timely and appropriate medical treatment.

Based on smart diagnosis, the patient's condition and disease status are more accurately described, which helps to develop a personalized treatment plan, and the program has been affirmed by experts.[12] The treatment process itself will become more precise. For example, in tumor radiotherapy, the patient's radiotherapy process can be monitored dynamically throughout the process with the help of smart radiomics. Doctors can optimize the radiotherapy program, observe disease progress, and avoid the uncertainty of manual operation.[13] In terms of surgery, the birth of surgical robots has pushed surgery to a new level. More famous robot systems include the Da Vinci system (Intuitive Surgical, Sunnyvale, CA, USA), Sensei X robotic catheter system (Hansen Medical, Auris Health, Inc., Redwood City, CA, USA), and Flex® Robotic System (Medrobotics, Raynham, MA, USA). Compared with traditional endoscopic surgery, patients will have better results and faster recovery, and surgeons will enjoy equipment providing them with greater flexibility and compatibility. The implementation of remote surgery will also be more convenient.[14] The application of mixed reality technology makes the development and implementation of the surgical plan easier. Professor Ye Zhewei of Wuhan Union Hospital has done a lot of work in this area. His team implemented the world's first mixed reality-guided hip surgery for a 15-year-old patient with a left femoral neck fracture. By modeling the target and projecting it to the real world for exact matching, an interactive information loop is built between the virtual world, the real world, and users. The emergence of this technology will bring subversive changes in medical education, research, communication, and clinical treatment.[15]

4.2. Health management

Since the beginning of the 21st century, chronic diseases have gradually occupied the top of the human disease spectrum and become a new epidemic. Chronic diseases have a long course of disease and are incurable and costly;[16] therefore, the health management of the disease is particularly important. However, the traditional hospital- and doctor-centered health management model appears to be incapable of adequately dealing with the increasing number of patients and diseases.[17] The new health management model under smart healthcare pays more attention to patient self-management. It emphasizes real-time self-monitoring of patients, immediate feedback of health data, and timely intervention of medical behavior. The emergence of implantable/wearable smart devices, smart homes, and smart health information platforms connected by IoT technology provides a solution to this situation. Third-generation wearable/implantable devices can combine advanced sensors, microprocessors, and wireless modules to continuously sense and monitor various physiological indicators of patients in an intelligent manner, while reducing power consumption, improving comfort, and allowing the data to be combined with health information from other channels. This approach involves a leap from scenario monitoring to continuous perception and integrated care. It further reduces the associated risks caused by the disease while making it easier for medical institutions to monitor the prognosis of the disease.[18] The emergence of smart phones, smart watches, etc., provides a new vehicle for this kind of monitoring. Attempts have been made to integrate biosensors into smartphones. While further improving portability, users can use a high-performance smartphone to monitor the environment and their body more easily.[19]

Smart homes provide home assistance to the elderly and the disabled. Smart homes are special houses or apartments with sensors and actuators integrated into the residential infrastructure that monitor the residents' physical signs and environment. Smart homes also perform operations that improve the living experience.[20] The role of smart homes in healthcare is mainly divided into two aspects: home automation and health monitoring. These technologies can provide some simple services while collecting health data, helping people who need care to reduce their reliance on health care providers and improve their quality of life at home.[21]

Patients can self-manage their condition through apps and a health information platform. For example, the Stress Detection and Alleviation system uses a wearable medical sensor to continuously monitor human body pressure levels and automatically help the body reduce stress.[22] It is also possible to integrate health data from multiple portable devices into a clinical decision support system to create a hierarchical health decision support system that can make full use of the collected data for effective disease diagnosis.[23] While assisting clinical decision-making, it can predict possible risks for patients and give advice through the cloud calculator and big data in advance. Another idea is to create an open mHealth framework that allows doctors, patients, researchers, and others to engage other doctors, patients, researchers, and others by reducing barriers to entry. It allows patients to easily access telemedicine advice and services, while doctors can dynamically monitor patient status. Clinicians can also be assisted by peer experts and researchers.[24] Mobile architectures such as m-Health can help reduce medical errors, reduce the difficulty of medical treatment, improve the timeliness of medical services, and provide an economical option for health services.[25]

4.3. Disease prevention and risk monitoring

Traditional disease risk prediction is based on the initiative of the health authorities to collect patient information, compare that information with the guidelines of the authoritative organization, and finally release the prediction results. This method has a certain lag in time and does not provide accurate advice to individuals. Disease risk prediction under smart healthcare is dynamic and personalized. It enables patients and doctors to participate, proactively monitor their disease risk, and conduct targeted prevention based on their own monitoring results. The new disease risk prediction model collects data through wearable devices and smart apps, uploads them to the cloud through a network, and analyzes the results based on big data-based algorithms to feed back the predicted results to users in real time via short message service. These measures have been proven to be effective.[26] They help doctors and patients adjust their medical behaviors and lifestyles at any time and also help decision-makers to develop regional health strategies to achieve the goal of reducing disease risk. For example, in a study aimed at preventing diabetes by predicting the postprandial blood glucose response, after monitoring the blood glucose response of 800 people for 46,898 meals per week, researchers used algorithms that integrated blood glucose parameters, eating habits, anthropometry, physical activity, intestinal microbiota, and other factors to successfully predict changes in glycemic response and reduce the risk of diabetes through a personalized diet.[27]

4.4. Virtual assistants

A virtual assistant is not an entity, but an algorithm. Virtual assistants communicate with users through techniques such as speech recognition, rely on big data to obtain information sources, and respond according to user's preferences or needs after calculations. Microsoft Cortana (Redmond, WA, USA), Google Assistant (Mountain View, CA, USA), and Apple Siri (Cupertino, CA, USA) are all virtual assistants. Virtual assistants use session experience and language-understanding technology to help users complete various tasks, from reminder creation to home automation.[28] In smart healthcare, virtual assistants mainly assume the role of a bridge to communicate with doctors, patients, and medical institutions. They make medical services more convenient. For patients, the virtual assistant can easily convert common, everyday language into one using medical terminology through the smart device, so as to seek the corresponding medical service more accurately. For doctors, the virtual assistant can automatically respond to relevant information based on the patient's basic information, helping doctors to manage patients and coordinate medical procedures more conveniently, so that doctors can save more time. For medical institutions, the application of virtual assistants can greatly save manpower and material resources and respond to the needs of all parties more efficiently. Nuance technology can also be used to achieve dialogue between different virtual assistants, especially between general assistants and highly specialized assistants,[29] thereby greatly improving the experience of medical service participants. Virtual assistants can also be used to aid in the treatment of diseases, such as the use of virtual assistants to improve the mental health of humans,[30] which can improve the state of inadequate supply of human psychotherapists and bring spiritual health to more patients.

4.5. Smart hospitals

Smart healthcare consists of three important components: regional, hospital, and family. Smart hospitals rely on information and communication technology-based environments, especially those based on IoT optimization and automated processes, to improve existing patient care procedures and introduce new features.[31] There are three main types of services for smart hospitals: services for medical staff, services for patients, and services for administrators. The demands of these service users must be considered in hospital management decisions. In hospital management, the information platform that integrates multiple digital systems based on the IoT connects digital devices, intelligent buildings, and personnel. This technology can also be used for the identification and monitoring of patients in hospitals, the daily management of medical staff, and the tracking of instruments and biological specimens. Smart healthcare is also employed in the pharmaceutical industry for drug production and circulation, inventory management, anti-counterfeiting, and other processes. To achieve safe, reliable, stable, and efficient circulation of hospital materials,[32] through RFID technology, a separate RFID tag can be assigned to each individual and the information can be stored in a database that can be easily tracked and accessed via mobile devices.[33] In terms of decision-making, the establishment of an integrated management platform can realize functions such as resource allocation, quality analysis, and performance analysis, and can reduce medical costs, maximize the utilization of resources, and help hospitals make decisions regarding development.[34] In terms of patient experience, patients can access multiple functions, such as physical examination systems, online appointments, and doctor-patient interactions.[35] These automated systems make patients' medical treatment processes more concise. Patients wait for a shorter time and receive more humanized service. In sum, integration, refinement, and automation are the future directions of smart hospitals.

4.6. Assisting drug research

With the application of big data and artificial intelligence in scientific research, drug research and development will become more precise and convenient. A complete drug development process includes target screening, drug discovery, clinical trials, and more. Traditional drug target screening manually crosses the known drugs with various potential target molecules in the human body, in order to find effective action points. This method is not only slow, but also often overlooked. The automatic screening of the effects of drugs and targets by artificial intelligence has greatly increased the speed of screening. For example, the identification of ribonucleic acid-binding proteins in amyotrophic lateral sclerosis[36] and genomics studies on tumors[37] was conducted using the Watson system. In addition, the artificial intelligence system can also collect the latest information from the outside world in real time and can optimize or correct the screening process at any time.

Drug excavation relies mainly on high-throughput screening; a large number of compounds are synthesized in an automated manner and tried one by one. However, as the variety of compounds increases, so does the cost and risk. The use of artificial intelligence for virtual drug screening can effectively solve this problem. Through computer pre-screening, the number of drug molecules actually screened can be reduced. It can also improve the discovery efficiency of lead compounds and predict the possible activity of drug molecules, find potential compounds and finally, construct a collection of compounds with reasonable properties.[38]

Clinical trials of drugs involve the combined use of the IoT, big data, and artificial intelligence. First, using artificial intelligence to analyze and match a large number of cases can facilitate screening for exclusion criteria and determine the most suitable target subjects, saving the time of recruiting the subjects and improving the targeting of the target population. Subsequently, patients are monitored in real time using smart wearable devices to obtain more time-sensitive and accurate information, such as the use of smart devices to monitor lung disease clinical trials.[39] In the design of the trial protocol, the participation of technologies such as blockchain can enhance patient protection and the credibility of testing.[40] All data is collected and aggregated onto the appropriate platform for analysis by researchers.

5. Problems and solutions

Since the arrival of smart healthcare, mature concepts and systems have been formed. However, with the emergence of new technologies and new problems, there is still considerable room for development, and many challenges are now emerging. Currently, smart healthcare lacks macro guidance and programmatic documents, which leads to unclear development goals and ultimately a waste of resources. Furthermore, medical institutions, lack uniform standards among different regions and different organizations, and improvements are needed in ensuring data integrity. The amount of data is too complicated and too large, which leads to difficulties in data sharing and communication. There are also problems with compatibility between different platforms and devices. From a patient's perspective, smart healthcare lacks relevant legal norms, and there are risks with regard to personal information and privacy breaches. Some users even have difficulty using the technology. Technically speaking, some technologies related to smart healthcare are still in the experimental stages and require a large amount of funding to be maintained and upgraded. There is also an unknown risk if applied rashly.

Therefore, to solve the above-mentioned problems, we need to focus on two aspects: technology and regulation. Firstly, in terms of technology, we can accelerate the maturity and stability of related technologies through upgrades. Improving the ability to analyze information from big data is also important. Secondly, establishing a unified technical standard to achieve maximum compatibility between different devices and platforms is important. In this way, we can improve data integrity and remove barriers to information exchange. Finally, data security and transmission stability are to be ensured as much as possible by applying techniques such as blockchain.[41] In terms of regulation, professionals from relevant fields can work together to clarify the development goals of the industry. Legislation is a practical road to guarantee the privacy of relevant personnel and make smart healthcare more secure.

6. Summary

In sum, the prospects for smart healthcare are vast. For individual users, smart healthcare can facilitate better health self-management. Timely and appropriate medical services can be accessed when needed, and the content of medical services will be more personalized. For medical institutions, smart healthcare can reduce costs, relieve personnel pressure, achieve unified management of materials and information, and improve the patient's medical experience. For research institutions, smart healthcare can reduce the cost of research, reduce research time, and improve the overall efficiency of research. With regard to macro decision-making, smart healthcare can improve the status quo of medical resource inequality, push the process of medical reform, promote the implementation of prevention strategies, and reduce social medical costs.[42] However, there are still some problems in the development process. The solution to these problems depends not only on technological progress, but also on the joint efforts of patients, doctors, health institutions, and technology companies.

Competing interests

The authors declared that they have no competing interests.

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