Toward establishing a comprehensive public health service platform for chronic disease management and medication in China: A practice in building a smart hypertension medical system

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Abstract. This research proposes a solution to establish an effective chronic disease prevention and control mechanism to strengthening public health management in China. This approach is to change from passive medication to active healthcare, which aims to prevent chronic diseases at early stage. The practice in developing one key subsystem of the proposed solution is demonstrated. It provides an intelligent medical platform that links hospitals, patients and community healthcare centers via the Internet to effectively achieve self-monitoring of health conditions and personalized medical treatment of hypertension.

Keywords: Chronic disease management, Blood pressure self-management, Remote health monitoring, Intelligent medical system, Health service platform.

1   Introduction

With the dynamic development of China's social economy and rapid progress of technology, people's living standard has been constantly improved. While the average life span of Chinese residents is prolonged, the disease spectrum also experiences a major change. Chronic diseases, including cardiovascular disease, diabetes, chronic obstructive pulmonary disease, and chronic non-communicable cancer diseases, have occupied the first place in resident disease spectrum. According to statistics, in China the number of existing diagnosed patients with chronic diseases has reached 260 million. Annually, over 8 million people died from chronic diseases, which accounts for 85% of total death. The caused disease burden is 70% of the total measure, which already becomes a serious problem that hinders the social and economic development in China.

The occurrence of chronic diseases is closely related to various factors, such as dietary, lifestyle, sports, environment and heredity. Simply relying on existing healthcare

system and medical model makes it hard to control and prevent chronic diseases effectively. By enhancing the management of public health, as well as providing Chinese residents with a comprehensive health management system that is based on modern science technology, it is able to change the care mode from passive medical treatment to active healthcare. The approach aims to prevent chronic diseases at early stage. It is essential to establish effective chronic disease prevention and controlling system, providing big data based, individualized treatment services that take each relevant factor into consideration. By this means, the effectiveness of disease treatment will be improved. It is imperative to build an integral public service platform, which is driven by residents' individual health needs, integrates contemporary scientific and technological achievements, and can provide residents comprehensive health management and personalized medical treatment.

The rapid and dynamic advance of contemporary science and technology, especially the network technology, cloud computing, big data, mobile Internet and wearable devices, has delivered fruitful outcomes in life science. Besides, the established regional medical information platform has provided a foundation for sharing medical treatment data. All these achievements make it technically possible to establish a comprehensive public health service platform, which can be employed to provide the public with synthetic health management information and personalized medical therapy based on big data applications.

This paper provides an overview of the comprehensive public health service platform, followed by an introduction of our first attempt of its implementation. The design and development of the 1j1 Smart Hypertension Medical System are presented with some preliminary results.

2 Overview of a comprehensive public health service platform

It is perceived that a health service platform is an integral system of telemedicine, care management programs and e-health, which together would effectively prevent and control chronic diseases [1,2,3,4,5,6].

2.1 Telemedicine

Chronic disease therapy is over a long-term period, which needs continuous monitoring. The physiologic indexes of patients should be repeatedly observed in order to guide treatment or to promptly send interventions to patients. In traditional therapy methods, such as face-to-face patient-to-provider encounters, the medical instruments are devised to be operated by professional physicians in the clinical laboratory of hospitals. This leads to the instruments not practical for patients to be used at home for self-monitoring. Chronic disease patients have to take clinical examinations and therapies in hospitals or intensive care units, which would cost patients and physicians a great amount of time, money and energy. On a comprehensive health service platform, the functionality of telemedicine is designed to solve such a problem. By employing information and communication technologies, especially wearable devices

together with Smartphone technologies, medical personnel could provide patients with professional healthcare remotely when such professional care services are not available face to face [7,8].

Telemedicine is designed to deliver healthcare and medical assistance from remote locations with help of latest telecommunication means. Wherever the health service is needed, professional medical care will be provided [9]. Presently, with the advance of telecommunication technology, the telemedicine can be implemented over ubiquitous wired or wireless communication methods, which makes it possible to employ telemedicine in a health service platform [10,11]. As a result, highly expert-based medical care can be accessible to a wider range of patients, especially those who are in understaffed areas, such as rural health centers, vehicles, and airplanes, as well as for home monitoring [12]. In Europe, the telemedicine technology has been employed to manage heart failure, which is aimed to prevent crisis, treat heart disease and empower patients to manage their own health [13].

By integrating the telemedicine to the platform, the physiologic information that doctors receive will have a longer time span than it can be collected during the patients' normal hospitality stays [14]. On one hand, the information that collected by telemedicine is essential for treatment of chronic diseases and has good long-term effects on healthcare at home. On the other hand, based on the data derived from a considerable number of chronic disease sufferers, the experts have more information to study and research, thus more effective therapies can be provided to patients. The iterative process would also result in better health services. Patients therefore could save money, time and energy, as well as get better healthcare at home [15].

The monitoring over chronic diseases, for instance hypertension, is regarded as a complex process. Telemedicine in this case allows continuous monitoring of patients' physical index readings. In China, with rapid arise of obesity and ageing population, the risk of stroke, heart disease and kidney attack increases correspondingly. Although the primary cause of hypertension is yet unknown [14], the blood pressure of patients can be easily observed and controlled via various means. For example, many hypertension sufferers usually measure their blood pressure at home on a regular basis. The measured systolic and diastolic blood pressure can be used in the telemedicine function to determine whether an alert message needs to be sent, or the system should automatically request further actions. Once a patient connects to a telemedicine network, the blood pressure readings together with other relevant physiologic information will be transmitted to healthcare professionals or medical science web services. Feedback would then be returned to inform the patient about his/her physical condition.

Furthermore, on such a health service platform, challenges such as a lack of social care personnel and continuous healthcare are addressed. This patient-based approach is able to improve the existing chronic healthcare services. The approach integrates telemedicine with care management, which would promote data exchange between patients at homes, healthcare providers in hospitals, and clinical units [1]. It is aimed to use physiologic information to identify at-risk patients promptly and effectively. For instance, patients with hypertension could choose to upload physical condition changes onto a telemedicine program. The information can include the rise of blood

pressure, adverse reactions, or behavior changes. The telemedicine program, which receives and analyses such information, will then send feedback to both patients and their care managers for taking further actions. By utilizing telemedicine tools, the care providers will gain more access to their patients, and therefore obtain more information from interactive communications.

2.2   Care management

Care management incorporates an exception handling approach, which would intervene in the occurrence of some exceptional cases. For instance, if some parameters exceed the pre-defined limits, the care management function would alert medical personnel to pay attention to a particular patient. The approach is designed to firstly identify the patient who appears to be at risk based on the analysis of patient's physical signs and symptoms. Second, care management program determines whether there is a need for care management interventions, and informs corresponding care managers [16]. At last, the care manager would contact the patients who are potentially at risk to ensure that they will receive in time and appropriate treatment. By this means, care managers will be able to intervene before their patients being sent to emergency units.

Another merit of integration of care management and telemedicine is to empower patients to be experts in managing their own health conditions through the provision of personalized health information and personal health records [17]. Interaction with the program would enable patients to obtain good knowledge of both their own health conditions and effective methods to better manage their own health. Patients thus are stimulated to participate in health management matters [18,19].

2.3   E-health

In addition to care management and telemedicine, the health service platform also incorporates e-health functionality. E-health is originally aimed at transforming medical records from paper to electronic format. By using well-designed computer systems, the billing and scheduling for patients can be automated, which would be cheaper, faster and more convenient than the manual approach. Such an EMR (Electronic Medical Record) or EHR (Electronic Health Record) system replaces handwritten medical notes to record patients' medical history [20,21]. Based on it, doctors are able to access and review patients' medical history conveniently, and to prescribe medicine or treatment more accurately and specifically. A few countries have adopted EMR/EHR systems, including U.S., Australia and China. In China, the government propels forward the EMR/EHR systems since 2005 [22,23,24].

Besides, e-health has a medical database foundation to support decision making on medication. Based on the customized information about a patient's medical problems, including physical data, symptoms, health complication, medical history of patients, allergy reaction and drug-drug interactions, an e-health system computes appropriate dosing and therapy for a particular patient [20]. By applying the best practice standards, an e-health system can also generate a list of patients who are identified to be at

risk and need intervention. In addition, the data format of EMR/EHR in e-health system should be standardized to realize interoperability. The uniform data standard enables the EMR/EHR data to be shared and incorporated by different medical organizations or hospitals, and would help to overpass the obstacle of data transmitting in different units. The Ministry of Health (MOH) in China has ratified the study and research on the standards and specifications of EMR/EHR [22]. Using uniformed data standards makes it possible to gather patients' medical records from various sources. For instance, over 450 organizations have employed BlueButton+ API and promoted patients to access and download medical information, which would enable patients manage and improve their own health. In addition, the health information exchange could be promoted across different health organizations by using BlueButton [25,26]. The uniformed data standards would also help both the health service platform and various health organizations to share clinical information. All collected data would eventually be streamed to a data cloud managed by the health service platform for further research, analysis and reporting.

3 China National Health Big Data Framework and the 1j1 Practice

This research associates with a larger project "The development and application of a comprehensive health service platform based on big data applications" that is under the National Health Big Data Science and Technology Support Programme. In this framework, a "Learning Health System for Chronic Disease Management and Medication" is proposed and will be tested in heart health, specifically in monitoring and managing blood pressure of diagnosed patients. The final product will have three types of users, including patients, community practitioners, and medical specialists at hospitals. The collected data derived from patients would be assembled into a data cloud managed by the National Chronic Disease Centre for further study. The project aims at delivering an innovative and leading "self-Learning Healthcare System" (LHS). In LHS, the data cloud managed by the National Chronic Disease Centre would be designed to collect data routinely from patient care and clinical laboratories. The ever-growing data cloud is employed for LHS to "learn" iteratively via the following: (1) collecting and analyzing data; (2) studying existing data together with data from prospective studies to formulate updated treatment plans; (3) treating patients with new plan; (4) evaluating the treat outcomes from patients; and (5) putting forward new hypotheses for further research. Through such progress, LHS is able to provide quality and patient-centered health services as well as innovation continuity [27,28,29].

3.1 1j1 Smart Hypertension Medical System

The 1j1 Smart Hypertension Medical System aims at delivering a content service application, supported by China National Health Big Data Programme. The goal is to build a countrywide intelligent medical platform that links hospitals, patients and

community healthcare centers via the Internet to effectively achieve self-monitoring of health conditions and personalized medical treatment of hypertension. At the stage of writing this paper, the development of intelligent medical software and hardware platforms will be soon released for clinical trial. Cooperations are carried out with the medical school at Shanghai Fudan University, where experienced clinical research professors are in charge of clinical trials designed for this research.

3.2   Conceptual framework

The major architectural components of the proposed Smart Hypertension Medical System include a patient personalized service module, a care manager, a doctor module, and a central medical server, which are introduced below respectively:

The patient personalized service module is attached to monitoring devices, for instance a blood pressure monitor. It runs a monitoring application that receives patients' physiologic information, such as blood pressure systolic and diastolic values and heart rate. The patient frontend will activate alarms when interventions are received, and periodically exchange data with other modules, including the central monitoring server through the Internet. By this means, the patient service module is able to upload medical data onto the monitoring server and receive interventions from the care manager or the doctor module to alert corresponding patients.

Care manager is the module operates an observing application, which receives data transmitted from the patient service module, as well as feedback from the doctor module. The care manager sends interventions to the patient module when selected parameters exceed certain limits. It also notifies the doctor module to provide medical treatments to the patients that are at risk.

The doctor module receives messages from the care manager. It also refers to appropriate dosing and therapy generated by the central medical server. Within this module, doctors interact with patients directly, prescribing medicine or therapy with reference to clinical therapies retrieved from the central medical server. After applying medical treatment, doctors will assess the referral therapy based on the following factors: whether the therapy computed by the central medical server is useful to patients of a specific disease; how to improve the therapy; and how to alter the dosing in practical treatment. Such feedback will be sent to the central medical server.

A central medical server provides data persistence and management services, which store patient medical records, receive and persist updated medical information from the patient personalized service module and feedback from the doctor module. Its most important function is to compute appropriate dosing and therapy for a particular patient based on patient-specific information of a medical problem. The core of the central medical server is an ontology for the management of chronically ill patients together with the implementation of personalization. The ontology is consisted of medical management knowledge, including the knowledge of various diseases, corresponding signs and symptoms, as well as relevant interventions and treatments. When encountering with a patient, the personalization process is started. The medical information stored in patient's EHR system would be extracted and combined with the ontology. Based on pre-designed rules, the reasoning would be accomplished by a

reasoner. By this means, the possible disease that the patient suffers, together with corresponding interventions and treatments, would be inferred and computed automatically. The personalized ontology that contains inferred knowledge will be relevant to a given patient and used for his/her treatment [30]. The foundation of such ontology is based on big data analysis. The medical data of patients diagnosed of the same disease are analyzed together with associated therapies. As a result, the most effective therapy will be recommended to the patient. Also based on doctor feedback, the therapy and intervention knowledge in ontology could be updated and adapted to different patients. This iterative process is employed to seek the most effective therapy for specific groups of patients, and to ensure the output can better facilitate doctors to make informed medical decisions.

The above four components interact with each other to accomplish the telemedicine, care management, and e-health functionalities that have been introduced in the previous section. The conceptual framework of this smart medical system is illustrated in Figure 1.
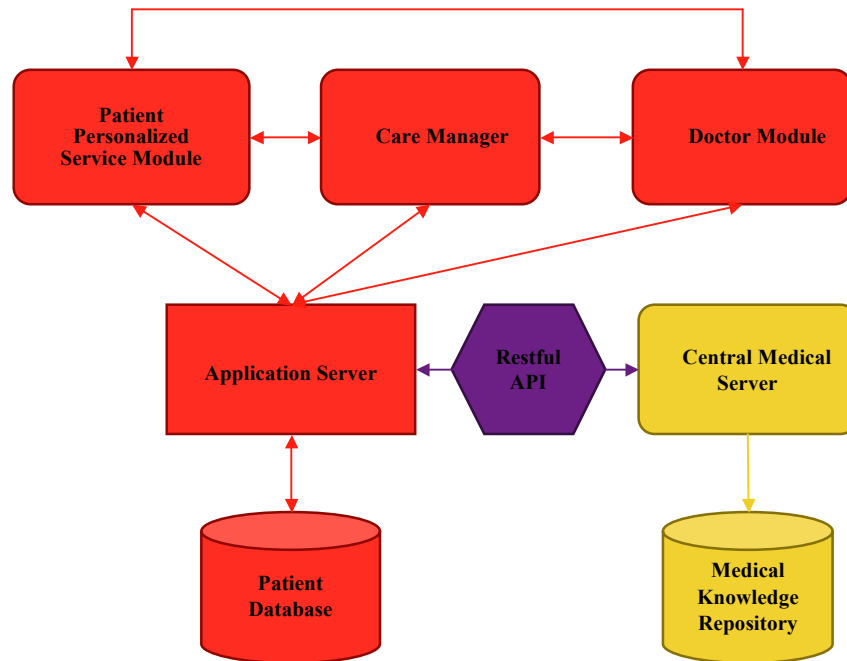

Fig. 1. Conceptual framework of the proposed Smart Hypertension Medical System

A patient's medical information is firstly transmitted and persisted into the patient database through an application server. The patient's information is subsequently conveyed to the central medical server. The central server will analyze the information to determine whether or not the patient is at risk. If so, the central server will send an alert to the care manager. Otherwise, the latest medical information of the patient

will just be recorded in the patient database, and the patient's medical status will be updated accordingly. Doctors or care managers can access and enquiry the present and historical medical information of their patients.

After receiving an alert message about a particular patient, the care manager would choose an appropriate case doctor for the patient who has been identified at risk. It then will send a message to the doctor module in order to notify the case doctor that the patient needs to be treated immediately. The doctor will need to take immediate action to arrange medical treatment for the patient. Since the medical information of the patient is already transmitted to the central medical server, the server is able to suggest referral therapies based on the patient's medical data and relevant information retrieved from the medical knowledge repository. The doctor will then treat the patient accordingly with reference to suggested therapies. After the treatment is performed and completed, the doctor can send feedback on utilised therapies to the central medical server, which in turn will improve the service incrementally.

4   Conclusions

In China, chronic diseases, especially hypertension, have occupied the first place in public disease spectrum. The long-term treatment of chronic disease patients and the corresponding intensive expenses in both finance and time allocation impose great challenges. One innovative solution is to establish a comprehensive health service platform, which can diminish the geographical, financial, and temporal access problems faced by patients with chronic diseases. The philosophy behind this is the transition from passive medical treatment to active healthcare. By incorporating telemedicine, care management, and e-health functionalities in medical data analysis and patient interactions, the platform is able to actively assist patients in performing interventions and sending emergency alerts. Moreover, via the analysis of big data of heterogeneous patient information, effective therapies can be quickly sought and accurately utilised. With reference to abundant clinical experience and feedback from experienced doctors, the reliability of the platform can be iteratively improved. The platform takes advantage of ubiquitous wired or wireless communication methods and online processing to enable active monitoring and modern healthcare. Also, the platform can empower patients to have in-depth understanding of their health conditions, as well as to obtain relevant knowledge on medical treatment and self-health management methods.

In this paper the conceptual framework of a smart medical system is presented for monitoring and medication of chronic diseases, the hypertension in particular. The system aims to meet the diverse needs of physician-diagnosed patients, minimizing cost and maximizing extensibility and reliability. Further research will be conducted to implement the proposed architectural components, and to test its usefulness and usability with patients and doctors through controlled clinical trials. The intelligent features of the system will be further investigated to enable automated learning from abundant patient information and effective treatments so as to generate useful therapy recommendations.

Acknowledgement

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