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1. Introduction

Telemedicine changes conventional medical practice and enables patients to access medical service via telecommunication. Telemedicine thus establishes a new kind of relationship between smaller hospitals and larger ones, and between patients and hospitals generally. Patients and subordinate hospitals may benefit from the resources of large hospitals, via teleconsultation, telediagnosis and telemonitoring. This is particularly beneficial for patients living in rural areas, where the health-care system is less well developed than in cities.

China is the largest developing country in the world in terms of both population and area, and 70% of its people live in rural areas. Its overall health-care system performance is ranked number 144 in the world.[1] Furthermore, there are serious disparities in medical resources between rural areas and cities. Only 20% of China's medical resources are available to the 900 million rural population.[2] Telemedicine has great potential to help unbalanced and underdeveloped health.

Telemedicine in China began in the mid-1980s and the early Chinese telemedicine activities were mostly based on store-and-forward technologies such as the telegraph and email. Realtime telemedicine was not used initially as the telecommunication infrastructure required was not available. In recent years, telemedicine in China has developed quickly with the rapid growth of telecommunication networks. China now has three major telemedicine networks: the Golden Health Network (GHN), the International MedioNet of China (IMNC) network and the People's Liberation Army (PLA) telemedicine network.

Data transmission is required in any telemedicine network. A variety of telecommunication media have been used for telemedicine networks in China, such as the digital data network (DDN), asynchronous transfer mode (ATM), integrated services digital network (ISDN), very small aperture terminal (VSAT) and ordinary telephone lines. Various types of equipment, such as the PC, Personal Digital Assistant (PDA) and mobile phones, have also been employed.

2. Telemedicine Systems Based on the Internet

2.1 IMNC Network

The IMNC network which started functioning in 1997 is primarily based on telephone lines and the Internet.[3] The telemedicine system in this network

includes two subsystems: a teleconsultation system and an online medical information system. The IMNC network connects medical specialists, equipment and information between different sites. However, it employs low bandwidth communication, which limits the transmission of high-volume medical data. To overcome this problem, a highly efficient image compression algorithm has been developed by the IMNC to reduce the file sizes. So far, about 300 hospitals across China have become members of this network via which some 3000 specialists practice telemedicine. The IMNC plans to upgrade its telemedicine network by incorporating broadband technologies.

2.2 Shanghai Medical University Telemedicine System

The telemedicine system developed by Shanghai Medical University makes use of a client/server architecture. A database server is used to store medical record information. Desktop videoconferencing is used for teleconsultations. The system is adapted to different bandwidth (64 kbit/s-2 Mbit/s), particularly low bandwidth, to support face-to-face consultation between remote sites and local sites, which satisfies the technical requirement of traditional medical treatment 'observe, listen, query, feel'. A module for virtual sharing in the system is used for text communication. The system can transfer medical images (e.g. X-ray images, CT scans and ultrasonograms) with no distortion. It has been successfully demonstrated for a teleconsultation between Shanghai and Beijing via a 128 kbit/s line.[4] In its first six years, the telemedicine network dealt with 3300 cases. These cases came from secondary or tertiary hospitals across China.[5]

2.3 Telemedicine System Based on Multicasting

The multicasting technique was applied in a telemedicine system by He[6][7] because it may reduce the cost for senders, receivers and networks. In addition, the multicast technique is in accordance with the telemedicine system in terms of multiple users connected through networks. The software component of the telemedicine system includes the main control module, human-computer interface module, consultation information module, diagnosis information module and multicast control module. The consultation information module uses IP audio conversation and a virtual sharing blackboard. The diagnosis information module retrieves electronic patient records and examination information from the hospital information system, and retrieves images, video and audio information from a picture archiving system (PACS).

2.4 Teleconsultation System in Gansu

In August 2004, the first telemedicine system based in a county-level hospital was lauched in Jingchuan county, Gansu province.[8] The system is networked with four ISDN lines as the backbone and supplementary ADSL lines. It has multimedia data channels gathering point-to-point audio, video, image, text and data. This system can synchronously connect remote telemedicine centres based

in Lanzhou No.1 hospital, the China-Japan Friendship hospital in Beijing and Osaka hospital in Japan at a speed of 512 kbit/s. It is designed to conduct tele-diagnosis, teleconsultation, telecare and manage medical information queries.

2.5 Telemedicine Systems Based on Satellite Communication

The advantages of telemedicine during military operations motivated the PLA to invest in telemedicine.[9] A part of China's national Golden Health Project was to build a nationwide military health information network to transmit health information and conduct telemedicine. A military telemedicine network using a satellite channel was established in 1997 and has two main telemedicine centres: one based at the Chinese PLA General Hospital in Beijing and the other based at the PLA Hospital in Nanjing. Each telemedicine centre in the network employs a 4.5 m satellite antenna, 40Wtransceiver, GPS receiver, DVB modulator, network switch, SUN workstation and application server. This telemedicine network connects 211 hospitals (114 military hospitals and 97 civil hospitals) and more than 300 specialists. About 60 telemedicine satellite stations have been established in remote military camps to provide telemedicine services to soldiers.[10] The telemedicine network has dealt with 3560 cases since its first operation.[11]

3. Telemedicine Systems Based on Wireless Communication

3.1 Personal Telemedicine System Based on RegPoint

In 2004, the Beijing Health Administration, Motorola and MedDay Inc. launched a project to provide a telemedicine service (RegPoint) for patients suffering from diabetes and high blood pressure at several hospitals in Beijing.[12] RegPoint is a disease monitoring and management system developed by MedDay and it integrates patient information in a Motorola A760 mobile phone. Through the mobile phone, RegPoint can provide customized treatment for each patient, no matter whether the patient lives in urban or rural areas. It sets up a telemonitoring link between patients and doctors by transmitting information about the prescription, blood pressure, blood glucose and bodyweight. This is the first large-scale commercial trial of a telemedicine service using mobile communication in China. Approximately 300 patients participated in the six month trial.

3.2 Medical Records System Based on a Wireless LAN

Shanghai Eastern Hospital employs a wireless medical records system based on a 54 Mbit/s wireless LAN in wards.[13] Doctors use a PDA to record patients' medical information such as prescription, diagnosis and patient cautions, transfer the information via the wireless LAN, and store the information in the hospital information system. This reduces the daily paperwork required by the medical staff, improves the efficiency and quality of medical services, and prevents the negligence or duplicate implementation of medical advice.

3.3 Appointment System Based on Short Message Service

The first affiliated hospital of the Harbin Medical University adopted an appointment system based on the mobile phone short message service (SMS).[14] Patients can use their mobile phones to send their appointment requests to a particular number and then receive confirmations or replies regarding their appointments from hospitals. They can also send messages to this particular number to acquire medical information such as medical specialists, medicine instructions and so on. This system makes patients' visits to the hospital more convenient and improves the efficiency and quality of the hospital's service.

3.4 Telemonitoring System Based on Bluetooth

Yao[15][16] designed a telemonitoring system for the rural areas, based on Bluetooth transmission. The system can remotely monitor physiological variables such as heart rate, blood pressure and body temperature. It consists of physiological signal monitoring devices, remote monitoring centres and a wireless gateway. Bluetooth is a low cost and reliable technique for short distance wireless communication, which is suitable for data transmission between physiological signal monitoring devices and the wireless gateway. The system is still at its trial stage and has not yet been commercially adopted.

3.5 Telemonitoring System Based on Mobile Phone Transmission

Several telemonitoring systems based on the General Packet Radio Service (GPRS) mobile phone communication have been designed and implemented in China.[17] These systems usually include physiological monitoring devices, GPRS modules and remote medical centres. Physiological data collected by monitoring devices are transmitted in realtime via the GPRS network to the remote medical centre. A medical information system in the medical centre stores and analyzes the received physiological data, and then alerts medical staff to take corresponding measures if exceptional conditions occur. For example, An developed an ECG telemonitoring system based on GPRS communication.[18][19] The system includes a portable ECG device, a GPRS communication module and a remote control centre.

Figure 1: GPs in Zhejiang No.2 People Hospital conducting a teleconsultation with a patient and GPs in Shaoxing Hospital via the Golden Health Network (GHN).

4. Discussion

Telemedicine has long been a well-known medical technique in industrialized countries. Compared with these countries, research and application of telemedicine is at a relatively early stage in China. This is the result of several factors:

1. China is a developing country and cannot afford to invest heavily in the infrastructure required for telemedicine. Most Chinese people cannot afford the cost of telemedicine services. Thus, the market for telemedicine is very small, although China has a large population in rural areas, which represents a potentially large telemedicine market;
2. Chinese patients are used to the traditional methods of diagnosis and prefer a face-to-face consultation with a doctor, rather than a remote (telemedicine) consultation;
3. Chinese doctors do not have any motivation to practise by telemedicine, as there is no incentive to change and they would not be paid differently, whether they practised telemedicine or not;
4. Many Chinese hospitals suffer from a lack of qualified IT professionals who are able to operate and maintain telemedicine systems. Senior managers in Chinese hospitals usually have little IT knowledge and do not fully understand the advantages of telemedicine. Thus, they cannot advocate the use of telemedicine and will not invest in telemedicine facilities;

5. Most Chinese rural areas have insufficient telecommunication infrastructure to support telemedicine systems. Some rural villages do not even have electricity;
6. A large proportion of the people in rural areas have not received much education and many of them have not even seen a computer;
7. The lack of a uniform health data standard prevents efficient and accurate data exchange with any telemedicine system. There is no national health data standard, although several international health data standards such as HL7, DICOM and SNOMED do exist;
8. The lack of national telemedicine regulations also limits telemedicine development in China, as there are no regulations to follow when legal disputes regarding telemedicine practice occur.

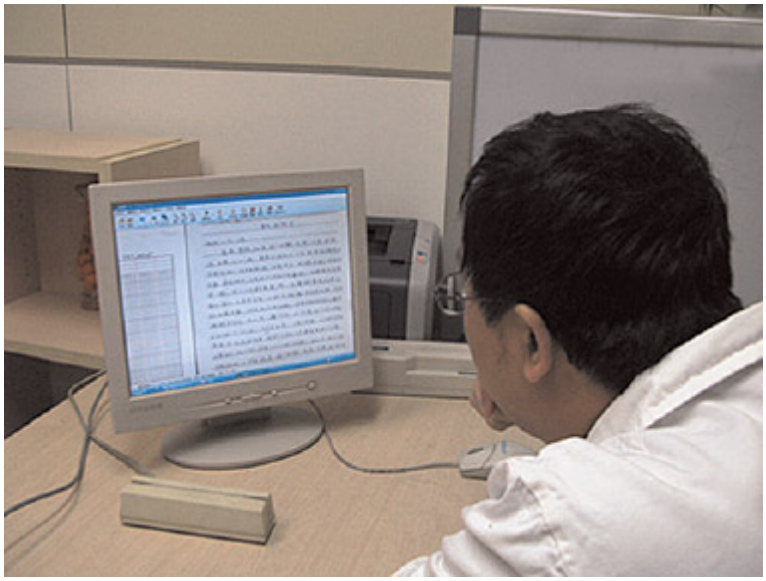

Figure 2: A GP reading a patient's medical record.

Figure 3: A patient and GPs in Shaoxing Hospital.

All these problems affect the development of telemedicine in China. To solve them, we suggest that the Chinese government needs to make a policy in favour of rural people and invest more in telemedicine, so that they can enjoy low-cost telemedicine services and foster a large telemedicine market. The government also needs tomake a uniformhealth data standard for telemedicine and the standard should take account of the characteristics of the Chinese health-care system and the Chinese language. National telemedicine regulations should be made as soon as possible to regulate telemedicine practices. Doctors should be given more telemedicine training and encouraged to practice telemedicine by introducing appropriate guidelines and rewards. Meanwhile, IT training and telemedicine demonstrations are also necessary for people living in rural areas to gain a basic telemedicine knowledge, change their conventional medical culture and receive telemedicine services (Figures 1-4). Senior managers in Chinese hospitals should give higher priority and more resources to developing telemedicine. A wide alliance including government, hospitals, IT vendors, research institutes and doctors needs to be set up to enhance cooperation with each other, which will speed up the development of telemedicine in China.

Figure 4: GPs in Zhejiang No.2 People Hospital discussing a case with GPs in Shaoxing Hospital via the GHN.

5. Conclusion

There is much telemedicine in China, including major telemedicine systems developed and adopted in various Chinese hospitals and clinical applications of these systems, as well as emerging telemedicine research in China. There are also several problems inhibiting the further development of telemedicine in China. The solutions to these problems will be relevant in other developing countries.

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