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REVIEW PAPER

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Telemedicine in the management of hypertension: Evolving technological platforms for blood pressure telemonitoring

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Abstract

The prevalence of hypertension is high and still increasing in almost all communities regardless of high, middle, or low income. The control rate remains low in most countries. Telemedicine offers possibilities to improve blood pressure control. The past two decades witnessed the fast evolving telecommunication from telephone transmission to smart mobile phone technology for telemedicine. There is some evidence

from randomized controlled trials that telemonitoring improves blood pressure control. However, it requires co-interventions. The emerging new technology may offer even more possibilities in telemonitoring and co-interventions, for instance, an interactive platform between patients and health professionals for the management of hypertension. Telemedicine might ultimately change the situation of the unsatisfactory management of hypertension in many communities. It helps fully utilize antihypertensive treatment, the most effective cardiovascular prevention, to achieve the goal of ending atherosclerosis and arteriosclerosis in humans.

1 | INTRODUCTION

With the increasing availability of antihypertensive drug treatment in the past two decades, the control rate of hypertension substantially increased in many countries. For instance, in China, according to the most recent nationwide hypertension survey between 2012 and 2015 in 451 755 adults (≥18 years), the awareness, treatment, and control rates of hypertension were 46.9%, 40.7%, and 15.3%, respectively.[1] If this survey would be compared with the preceding one in 2002 in 141,892 people of at least 18 years,[2] the awareness, treatment, and control rates of hypertension increased from 30.2%, 24.7%, and 6.1%, respectively,[2] and relatively by 55.3%, 64.8%, and 150.8%, respectively.[1,2] Nonetheless, not only the awareness in the general population, but also the control rate in treated hypertensive patients in China (37.6%) remained low.[1]

In several countries with a higher control rate of hypertension, for instance, the United States of America (USA) and Canada, hypertension has been recently redefined as 130/80 mmHg or higher instead of 140/90 mmHg or higher.[3,4] This approach might help in these countries to further improve hypertension control, by treating "earlier" and "tougher." However, it might not work in other countries, such as China, because about half the hypertensive patients defined by the 140/90 mmHg threshold are not aware of their blood pressure, and more than half the treated hypertensive patients do not reach the target.[1,5] How are we going to tackle this problem ? There is no clear answer, nor easy way.

Emerging technology, such as telemedicine, might help in populous countries, such as China. The Chinese government provides health insurance and affordable antihypertensive medication.[6] The issue is to detect people with elevated blood pressure timely and extensively and to treat people with diagnosed hypertension appropriately and intensively. For both detection and treatment, telemedicine may play an important part. In the past two decades, telemedicine technology has been evolving rapidly from blood pressure telemonitoring, to the combined monitoring with interventions, and more recently to interactive platforms between physicians and patients. The present review paper describes the evidence along this evolving path and attempts to provide some insights and perspectives in this regard.

TABLE 1 Technology for communication and transmission and co-interventions used in randomized controlled trials on home blood pressure telemonitoring

Technology for communication and transmission
Telephone transmission, text messaging or emails, smartphone APPs
Co-interventions
Feedback (web or phone feedback, education, counseling or tele-counseling)
Involved health professionals (physician, nurse, pharmacist)
Treatment adjustment (behavioral, self-titration)

2 | BLOOD PRESSURE TELEMONITORING

Home blood pressure monitoring is a pioneering field of research in telemonitoring or telemedicine. Since automated electronic blood pressure monitors became available for blood pressure measurement at home, researchers had started investigations for possible effects of telemonitoring on blood pressure control. The first randomized controlled trial on home blood pressure telemonitoring was conducted in 267 patients recruited from communities in the United States.[7] The results of the trial were published in 1996. Telemonitoring with an automated telephone transmission system improved treatment adherence and blood pressure control by 4.7/4.4 mmHg of greater clinic systolic/diastolic blood pressure reductions than the usual care control group ($P \leq .02$).[7]

In 2013, a systematic review and meta-analysis of trials on home blood pressure telemonitoring was published with 23 randomized controlled trials.[8] These randomized studies had a high level of heterogeneity, especially with regard to technology (Table 1), and altogether included 7037 patients. Home blood pressure telemonitoring significantly improved clinic systolic/diastolic blood pressure control by a mean difference of −4.71/−2.45 mmHg ($P < .001$) and a +16% ($P < .001$) higher control rate (<140/90 mmHg nondiabetic patients and <130/80 mmHg diabetic patients) relative to the usual care control. Home blood pressure telemonitoring increased antihypertensive treatment intensity and costs. No difference was observed in the risk of adverse events.[8]

In spite of the heterogeneity in home blood pressure telemonitoring technology, it is proven to be useful for the management of hypertension.[8] The evidence is consistent and strong.[9,10] However, from the technological point of view, home blood pressure telemonitoring may not be sufficient. Home blood pressure monitoring does not provide information on circadian rhythm as the ambulatory monitoring technique does.[9] Recent studies therefore expanded to ambulatory blood pressure telemonitoring.[11] In the VASOTENS (Vascular health ASsessment Of The hypertENSive patients) Registry, ambulatory blood pressure monitoring was performed in 1200 study participants with the data automatically transmitted to and then analyzed by a web-based telemedicine platform.[11] We also established a web-based platform for ambulatory blood pressure telemonitoring in China.[12] With this platform, data analysis will be performed in a remote server. The output results will be generated and interpreted by an expert. Then, the output will be sent to the patient and, if there is one, the physician as well. The diagnostic and therapeutic decisions then can be taken on the basis of the ambulatory blood pressure measurements.

Home blood pressure monitoring helps but does not suffice to improve awareness of hypertension in the general public, because many people tend to believe that their blood pressure is normal. Easy-access blood pressure telemonitoring facilities are needed and may encourage people to perform blood pressure measurement. In the United States, such a facility has been established in "Higi" stations (www.higi.com), which provided users with free health screening measurements, including blood pressure, heart rate, body weight, and body mass index at food, drug, and club retail locations nationwide.[13] In China, we established a nationwide blood pressure telemonitoring system in public places within easy reach of people. Blood pressure and pulse rate readings can be automatically transmitted to a telemedicine platform for evaluation of abnormality. This system was used to measure blood pressure in a large number of people who had not measured their blood pressure in the previous year in the framework of the international May Measurement Month (MMM) project.[14-16] The system is now used by hundreds of people every day in various public places, such as airports, shopping malls, and office buildings. It is hoped that with a sufficiently large number of blood pressure monitors deployed in the next few years, the system will substantially improve detection and management of hypertension in China.[12]

3 | TELEMONITORING WITH CO-INTERVENTIONS

Telemonitoring provides blood pressure and other health status information for patients and physicians, and possibility of interaction between them. In most, though not, all of the published randomized controlled trials on blood pressure telemonitoring, there were some forms and levels of intervention from the automated electronic system or provided by health professionals for either behavioral or medication management of hypertension (Table 1).[17,18] The intervention varied from one study to another. Nonetheless, the intervention has also to be validated as an essential component of a telemedicine system.

A recent meta-analysis of trials, based on individual-patient data, provided crucial evidence on the clinical relevance of the co-interventions.[19] In 15 studies with the data for 12-month change in mean clinic blood pressure in 7138 randomized participants, self-monitoring alone had no systolic/diastolic lowering effect. However, self-monitoring in conjunction with co-interventions, such as systematic medication titration by doctors, pharmacists, or patients, education, or lifestyle counseling, had up to −6.1 (95% confidence interval [CI] −9.0, −3.2)/−2.3 (95% CI −4.0, −0.6) mmHg greater reductions in systolic/diastolic blood pressure than the usual care control.[19] Although the studies included in this meta-analysis were heterogeneous in many aspects, such as inclusion criteria, self-monitoring regimes, and target blood pressure, the results of the analysis suggested that self-monitoring in hypertension might have to be implemented with co-interventions.

Health care system differs between countries, and even between regions or communities within a country. It is probably not realistic to standardize co-interventions as the telemonitoring techniques. Nonetheless, various co-intervention approaches can be investigated. The experience of the international MMM project can be learnt. The MMM project involved millions of people from more than 100 countries/regions. A single implementation protocol was applied. The data were pooled and provided useful information on the status of hypertension management worldwide.[20-22]

4 | INTERACTIVE PLATFORM BETWEEN PATIENTS AND HEALTH PROFESSIONALS

The new telecommunication technology, for instance, 5G, makes it possible to interact between people. People with hypertension may discuss their blood pressure management with their doctor or other health professionals on such a platform remotely. This new platform may theoretically change the detection and management of hypertension and other chronic diseases substantially. Such a platform is being established in various communities and tested for validity in observational or randomized controlled studies in hypertension or other chronic diseases.

In a recent implementation study in Scottish practices, Hammersley and colleagues reported a so-called Scale-Up BP telemonitoring system.[23] Participants with hypertension were provided with an automated electronic oscillometric blood pressure monitor. They were shown how to submit their blood pressure readings via a low-cost third-party text-based telemonitoring system using their mobile phone. These blood pressure readings were stored in a central server and made available to practices via an Internet link. In 8 evaluation practices with 905 patients enrolled and followed up for a year, the system seemed to improve blood pressure control, with reduced number of clinic visits and consultation time.

In China, in the framework of an intelligent Hypertension Excellence Centre (iHEC) initiative, we are establishing an interactive platform between patients and health professionals for the management of hypertension.[12] The system integrates clinic and out-of-clinic blood pressure readings, and risk assessment and management. Patients access the blood pressure readings via an APP, and physicians work with the data during their routine clinical work. Several implementation studies are being undertaken in the established centres across the country, including a project for primary aldosteronism screen.[24]

Wearable blood pressure monitors also offer the possibility of instant interaction between patients and physicians.[25] A wrist-worn watch-type oscillometric device has been recently validated against conventional ambulatory blood pressure monitoring.[26,27] Because the oscillometric technique is used, such wearable devices cannot provide beat-to-beat real-time blood pressure readings. However, such device offers many more blood pressure readings over a longer period of time than conventional ambulatory blood pressure monitors. It is therefore envisaged that this will be able to improve detection and management of hypertension by increasing the number of measurements in different situations, such as detecting masked hypertension in the morning and in the working environment.

5 | CONCLUSIONS AND PERSPECTIVES

The past two decades witnessed the fast evolving telecommunication from conventional telephone transmission to smart mobile phone technology for telemedicine. The emerging new technology may offer many more possibilities in telemonitoring and co-interventions. Telemedicine might ultimately change the situation of suboptimal management of hypertension in many communities. It may help fully utilize antihypertensive treatment, the most effective cardiovascular prevention, to achieve the goal of ending atherosclerosis and arteriosclerosis in humans.

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CONFLICT OF INTEREST

JG Wang has received consulting and lecture fees from AstraZeneca, Novartis, Omron, Servier, and Takeda. YC Chia has received speaker honorarium and sponsorship to attend conferences and seminars from Boehringer Ingelheim, Omron, Pfizer, Servier, and Xepa-Sol and investigator-initiated research grants from Pfizer and Omron. HM Cheng has received speaker honorarium and sponsorship to attend conferences and continued medical education (CME) seminars from AstraZeneca, Bayer, Boehringer Ingelheim, Daiichi-Sankyo, Eli Lilly, Menarini, Novartis, Pfizer, Sanofi, Servier, and Takeda, and served as an advisor or consultant for ApoDx Technology, Inc S Siddique has received honoraria from Bayer, ICI, Novartis, Pfizer, and Servier; and travel, accommodation, and conference registration support from Atco Pharmaceutical, Hilton Pharma, Highnoon Laboratories, Horizon Pharma, and ICI. K Kario has received research grants from Omron Healthcare, Fukuda Denshi, A&D, and Pfizer Japan, and honoraria from Omron Healthcare. All other authors report no potential conflicts of interest in relation to this review paper.

AUTHOR CONTRIBUTIONS

Ji-Guang Wang contributed to the conception and prepared the first draft of the manuscript. All authors critically commented and revised the manuscript and gave the final approval.

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