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REVIEW

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Is remote blood pressure monitoring and management a better approach for patients with hypertension? A narrative review

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Abstract

Hypertension is a global public health problem which affects the physical and mental health of individuals. The management of hypertension is a long-term process that requires the cooperation of both doctors and patients, and the blood pressure variability is closely related to the clinical prognosis. In recent years, the development of telemedicine has promoted better blood pressure monitoring and management for patients, as well as better medical intervention and health education for patients by medical staff. This article provides a review of remote blood pressure monitoring and management.

KEYWORDS
blood pressure, home blood pressure monitoring, hypertension, telemedicine, remote blood pressure monitoring

1 | INTRODUCTION

Hypertension is the most common chronic disease and a major risk factor for cardiovascular disease, stroke, kidney failure, and other diseases. It has a serious impact on global public health. In 2019, the number of people with hypertension worldwide exceeded 1.2 billion.[1] According to a national hypertension survey of 451 755 adults in China from 2012 to 2015, the prevalence, awareness, treatment, and control rates of hypertension were 23.2%, 46.9%, 40.7%, and 15.3%, respectively.[2] One study reported an insignificant decrease in the average blood pressure of hypertensive patients worldwide during 1975–2015.[3] The low control rates of hypertension may be associated with poor drug adherence, autonomic dysfunction, excess sympathetic activity, excess dietary sodium, fluctuations in body weight, atherosclerosis due to aging, sleep disorders, and nonprescription drugs (such as Nonsteroidal Antiinflammatory Drugs (NSAIDs) and some cold remedies).[4] Currently, blood pressure management mostly includes pharmacological treatment and lifestyle interventions.[5] Blood pressure monitoring includes monitoring office blood pressure, ambulatory blood pressure, and home blood pressure, among which home blood pressure monitoring is crucial for the long-term management of hypertension.[6–8] Home blood pressure monitoring can be used to detect white coat hypertension and masked hypertension as well as assess baseline blood pressure levels and increase patients' self-management ability and compliance with other interventions. In recent years, several studies have been conducted on home blood pressure monitoring methods, among which blood pressure monitoring and management via remote electronic devices are popular.[9,10]

2 | BLOOD PRESSURE MONITORING METHODS AND DEVICES

With the rapid development of telecommunication technology, internet technology has gradually been applied to various fields of social work with the advantages of being timely, efficient, fast, and easy, and it has become an increasingly indispensable part of the tedious workflow in various fields. Chronic diseases such as hypertension can be managed systematically, meticulously, and effectively and its management can be standardized with the support of internet technology,

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TABLE 1 Advantages and disadvantages of remote blood pressure monitoring

Advantages	Disadvantages
• Detection of white-coat and masked hypertension	• Higher cost than office blood pressure and ambulatory blood pressure
• Measurement in daily activities	• User training required
• Assessment of daytime blood pressure	• Nighttime blood pressure assessment is less effective
• Assessing the effects of anti-hypertensive drugs	• Poor morning blood pressure surge assessment
• Facilitates long-term follow-up of hypertension	• Assessment of duration of drug action is not as good as ambulatory blood pressure
• Improve patient compliance	• May cause anxiety and too frequent monitoring
• Improve hypertension control rates	• Some patients adjust their own medications based on blood pressure readings
• Predict cardiovascular events	• Some patients are measured only while sitting at home and do not reflect daily activities
• Cost-effectiveness	• Inequity due to the costs of technologies
• Better for long-term BP control	• The digital divide

involving several chronic disease management aspects such as remote online consultation, remote blood pressure monitoring, remote blood pressure assessment, remote medication guidance, remote dietary guidance, remote health education, and prognosis follow-up. Email, smartphone applications, and other means can be used to provide information regarding the patient's hypertension condition to the doctor. Thus, the analysis of the effect of antihypertensive drug treatment and the patient's lifestyle and other conditions can be individualized, and patients can receive timely treatment advice and health education via the corresponding platform. The use of internet technology for the monitoring and management of hypertension has many advantages; however, there are also some limitations (Table 1).

Blood pressure monitoring methods can be divided into two types: invasive monitoring and noninvasive monitoring. Invasive monitoring involves placing the pressure sensor into the arterial blood vessels to detect pressure changes. This method can directly and continuously measure the blood pressure value in the arteries, and the measured data are also the most accurate. However, because of the invasive nature, it is only indicated for patients undergoing major surgery.

In contrast, noninvasive monitoring methods include auscultation andoscillometric methods, oscillometric measurement at the wrist, the applanation tonometry method, and photoplethysmography as well as measuring the pulse transit time.[11] According to these blood pressure monitoring methods, the current remote blood pressure monitoring devices mainly include upper-arm electronic automatic devices (wired or wireless), smartphone applications with external wireless blood pressure monitors, smartphones acting as sleeveless blood pressure monitors, smart watches, smart bracelets, and finger photoplethysmography. Data can be transferred via smartphones, home centers, smart boxes, tablets, desktop computers, laptops, etc.[12] The blood pressure results can be sent directly to mobile terminal devices or computer storage centers, where the monitoring data can be observed and evaluated in real-time; simultaneously, remote interventions can be provided to patients, including medication adjustment and health guidance.

Patients transmit their blood pressure monitoring values to the management platform using blood pressure monitors with data transmission function and cell phone APPs, which are recorded through the network system. Clinical pharmacists and doctors use the data summarized by the system and the medical visit records to instruct patients to perform blood pressure monitoring or enter the treatment plan adjustment phase through various communication methods such as SMS, Email, and telephone. In addition, standard workflows for patient enrollment registration, drug titration, and maintenance treatment can be developed, and tasks can be automatically assigned by the system. For example, for patients who meet the enrollment criteria, the system reminds them to take sufficient blood pressure measurements and then arranges for pharmacists and doctors to guide them to enter the titration phase, and then makes treatment decisions based on the patient's medical history, blood pressure measurements, and clinical guidelines. The system will automatically remind the patient to perform regular monitoring during the maintenance phase of drug therapy and arrange for the patient to continue the original treatment regimen or titrate again based on the monitoring results (Figure 1).

3 | EFFECTIVENESS OF REMOTE BLOOD PRESSURE MONITORING

In recent years, several studies have demonstrated the feasibility and effectiveness of remote blood pressure monitoring. The TASMINH2 study showed that after 12 months of follow-up, blood pressure decreased in both the non-self-administered and self-administered groups, with an average decrease of 12.8 mmHg systolic and 3.4 mmHg diastolic in the non-self-administered group and 18.3 mmHg systolic and 7.7 mmHg diastolic in the self-administered group.[13] Self-management is the ability to manage psychosocial and lifestyle factors in addition to symptom monitoring, blood pressure monitoring, and medication adherence.[14] Recently, several studies have demonstrated that remote monitoring can better enhance self-management in patients with hypertension.[15–17] Lu and colleagues recruited 432 patients for remote blood pressure monitoring and management, worked with public health nurses in public health care centers, and eventually, 408 patients completed data collection. Their study showed

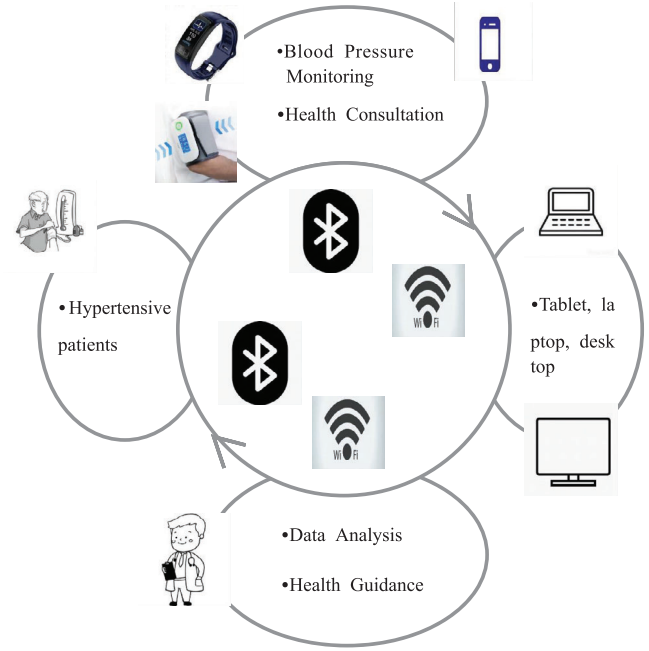

FIGURE 1 Workflow of remote blood pressure monitoring

a mean reduction in systolic blood pressure of 22.1 mmHg in patients after 1 year.[18] In addition, a recent meta-analysis that included 18 articles on remote blood pressure monitoring (all randomized controlled trials) showed that the weighted mean blood pressure decreased by 7.07 points (SBP) and 5.07 points (DBP) in the intervention group compared with 3.11 points (SBP) and 3.13 points (DBP) in the control group.[19,20]

A recent study found that remote blood pressure monitoring and management significantly improved blood pressure control in patients with acute ischemic stroke, whereas intensive blood pressure management reduced stroke recurrence by 22%.[20,21]

Some researchers have used telemetric blood pressure monitoring for the monitoring of blood pressure and screening for complications during pregnancy. Their results suggest that telemetric blood pressure monitoring may help in the management and improvement of hypertension during pregnancy, but most of the evidence is limited to assessing the feasibility of the trial and maternal satisfaction.[22,23] Hoppe and colleagues showed that remote blood pressure monitoring and management reduced readmission rates at six weeks postpartum in patients with hypertension during pregnancy.[24,25] In contrast, the results of the BUMP 1 Randomized Clinical Trial, published in 2022, showed that remote blood pressure self-monitoring did not have a more significant detection rate compared with usual care in pregnant women at a higher risk of pre-eclampsia.[26] Results from the BUMP 2 Randomized Clinical Trial in the same year showed that in pregnant women with chronic or gestational hypertension, remote monitoring of blood pressure did not significantly improve blood pressure control rates compared with usual care.[27] The feasibility and safety of remote blood pressure monitoring and management were both confirmed in the above clinical trials, but its effectiveness needs to be further evaluated in additional studies.

Hypertension is a chronic disease that accompanies patients throughout their lives. Our goal is long-term management of blood pressure and improvement of prognosis. In the current studies, the follow-up time was mostly within 1 year, and we expect more studies to prove the effectiveness and safety of remote blood pressure in long-term management.

4 | BLOOD PRESSURE AND TARGET ORGAN DAMAGE

Hypertension can damage target organs, including the heart, brain, and kidneys, resulting in acute and chronic cardiovascular diseases, stroke, renal insufficiency, and even renal failure. This can seriously affect the health and quality of life of patients, of which blood pressure variability (BPV) is a crucial assessment indicator. The concept of BPV first appeared in the 18th century, and it refers to the fluctuation of blood pressure over time. Many studies have shown that BPV is inextricably linked to blood pressure and can lead to cardiovascular diseases, such as coronary artery disease and stroke, independently of blood pressure. With the discovery of the close correlation between BPV and clinical prognosis, hypertension treatment has changed from lowering mean blood pressure to lowering BPV, which can help protect target organs, improving patient prognosis.[28–30] According to the time-domain index, BPV is divided into ultra-short-time variability (variability during the cardiac cycle, also called immediate variability), short-time variability (BPV within 24 h), medium-time variability (BPV over several consecutive days or weeks), and long-time variability (BPV over several months and during a long-term follow-up). According to the frequency-domain index, BPV is divided into high-frequency variability (.15–.30 Hz), low-frequency variability (.04–.15 Hz), and very low-frequency variation (<.04 Hz). BPV can be divided into systolic, diastolic, and pulse pressure variability according to blood pressure components. Furthermore, BPV can be divided into physiological, pathological, and drug-induced variability according to the cause of occurrence. Physiologic variation is blood pressure variation in normal people, usually manifested as dipper-pattern blood pressure and morning blood pressure surge. Dipper-pattern blood pressure is a certain circadian rhythm, that is, 10%–20% decrease in blood pressure at night than at daytime. A morning blood pressure surge is when the body changes from sleep to wakefulness and starts routine activities, the blood pressure will rise rapidly from a relatively low level to a relatively high level to meet bodily needs. Such regular changes in blood pressure are important for protecting target organs, such as the heart, brain, and kidneys. Pathological blood pressure variation is an increase in BPV, which can occur when arterial elasticity is reduced, blood volume is increased, and neuroendocrine regulation is impaired. The main types are non-dipper pattern (nighttime blood pressure is <10% lower than daytime blood pressure), extreme-dipper pattern (nighttime blood pressure is >20% lower than daytime blood pressure), reverse-dipper pattern (nighttime blood pressure higher than daytime blood pressure), and morning blood pressure surge. The main indicators for assessing BPV are standard deviation, coefficient

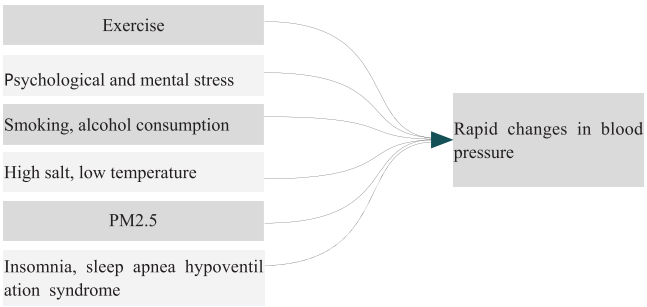

FIGURE 2 Common factors that cause rapid changes in blood pressure

of variation, variation independent of mean, and average real variability. Exercise, psychological and mental stress, smoking, and alcohol consumption can cause rapid changes in blood pressure (Figure 2).[11] Furthermore, morning blood pressure surge is associated with various forms of target organ damage, including an increased risk of stroke and cerebral hemorrhage.[31–37] In contrast, reverse-dipper and non-dipper patterns increase the risk of target organ damage and cardiovascular events.[38–42] Thus, the accurate detection of factors causing rapid changes in blood pressure in daily life can lead to necessary interventions to reduce cardiovascular risk and adverse cardiovascular and cerebrovascular events. With a remote blood-pressure monitoring system, more blood pressure data can be collected from patients to assess their BPV, predict the risk of cardiovascular and cerebrovascular diseases, guide medication, and improve lifestyle to better control blood pressure as well as to improve prognosis and the quality of life of patients.

5 | CONCLUSIONS

The economic burden on individuals and countries has increased considerably because of the persistently high prevalence of hypertension, and without new surveillance and management methods, this trend will not decline. Simultaneously, the coronavirus disease 2019 (COVID-19) outbreak in recent years has severely increased the global economic burden, and as the pandemic is still recurring, accessing care is difficult for many patients with chronic diseases. Cardiovascular diseases, especially hypertension, are a common co-morbidity in COVID-19, increasing the risk of adverse outcomes.[43] Telemedicine can potentially improve this situation. East Japan used a remote blood pressure monitoring system in one affected town after a major earthquake, effectively controlling home blood pressure in hypertensive patients and minimizing seasonal blood pressure variations over a period following the disaster.[44] In addition, remote blood pressure monitoring can also help better control blood pressure in rural and low-income population.[45]

Remote blood-pressure monitoring can improve the self-management ability and quality of life of hypertensive patients, reducing treatment and care costs. Such a system is especially suitable for patient groups where outpatient follow-up is difficult or where follow-up awareness is less and treatment compliance is poor. In addition to blood pressure monitoring, such a remote monitoring system can also monitor vital signs, including temperature, electrocardiogram, and blood sugar levels, benefitting the management of more diseases. However, the development of telemedicine also has many problems: (1) The imperfect blood pressure monitoring equipment and the purchase and maintenance of infrastructure, including computer hardware and related software; secondly, the security and privacy of data transmission, as well as the cost of related personnel; (2) The poor level of informatics skills of doctors or patients is an important barrier to telemedicine, especially for the elderly, and some people with poor health and cognitive impairment, or limited digital literacy; (3) Hypertension is a lifelong disease, and long-term management of blood pressure is crucial. Some patients who lack motivation and lack understanding of the clinical use of telemedicine are difficult to adhere to remote blood pressure monitoring and self-management.[46,47]

We believe that through continuous improvement and perfection, telemedicine will bring great benefits to mankind.

AUTHOR CONTRIBUTIONS

Yan Li, Yi Jiang, and Yuping Tang: Conception and design; Data analysis and interpretation; Manuscript writing; and Final approval of manuscript.

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CONFLICT OF INTEREST

We declared no conflict of interest.

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