NEW SYSTEMS OF CARE FOR HYPERTENSION

Digital hypertension and telemedicine for home blood pressure-centered management of hypertension

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1. What is digital Hypertension

Hypertension is increasing dramatically worldwide, yet its control rate remains poor, with significant disparities among countries and regions.[1] We are confronted with numerous challenges in detecting and controlling hypertension, spanning from healthcare to medicine. Recently, in the digital era, individuals could connect with healthcare providers and medical professionals, leading to the emergence of virtual management of hypertension. Telemedicine has gained significant position in clinical practice during COVID-19 pandemic.[2,3] In 2022, the International Society of Hypertension released a timely consensus paper on virtual management of hypertension, emphasizing the importance of mutual feedback interactions between patients and medical professionals. This approach includes educational publications, phone call education, online group sessions, and interactive digital tools, among other options, which can be selected by patient preferences.[4]

Scientifically, "digital hypertension" is a novel academic research field that leverages the latest digital technology to add value in resolving unmet needs for challenges in hypertension management (Table 1).[5] At a macro-level, it involves conducting population research to provide recommendations for healthcare policy. On a micro-level, it offers optimal individualized medical care by consolidating data on individual blood pressure (BP) variability, control status, lifestyle, medication adherence, laboratory values, and health insurance claims through the use of digital technology. This includes the development of wearable BP monitors, the creation of new indices through the analysis of big data, the use of artificial intelligence (AI) for risk prediction, and the development of BP applications aimed at lowering BP.[5] The goal of digital hypertension research in clinical practice is to establish personalized anticipation medicine.

2. Home blood pressure-centered approach

The home BP-centered approach is the most reliable and practical approach for digital hypertension management. This recommendation is based on evidence indicating that home BP serves as a significant predictor of cardiovascular, cerebrovascular and kidney disease in patients with hypertension.[6,7] Furthermore, the integration of a lifetime personalized health record (PHR)-based home BP monitoring system with telemonitoring, along with co-interventions has demonstrated more effective BP reduction than the traditional approach based on office BP measurements. Thus, home BP emerges as a key metric for lifelong personalized anticipation medicine **(Figure 1)**. Morning home BP assumes a primary role as the initial target and a metric of quality control of antihypertensive medication. This is because the efficacy of antihypertensive medication is at the weakest in the morning, just before taking the pills.

An example of the practical implementation of digital remote management of hypertension can

Figure 1

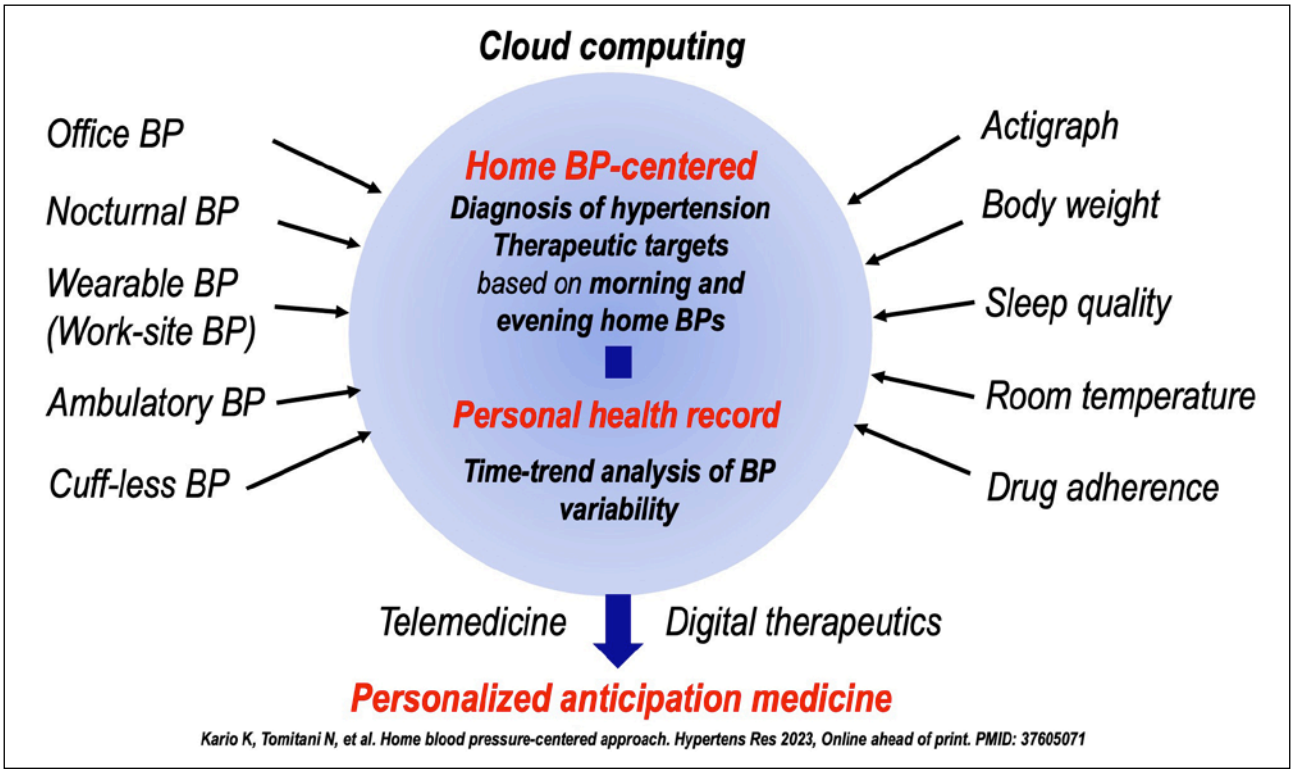
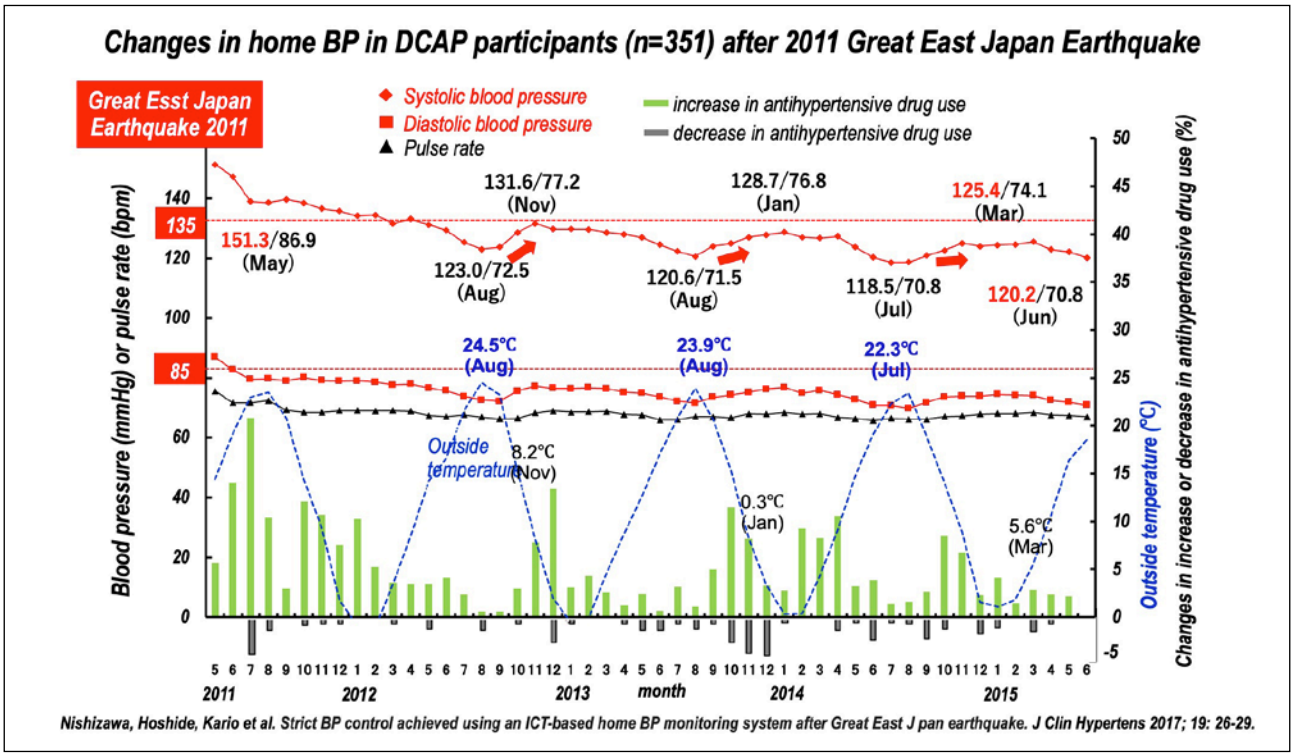


Figure 2



be observed in a study conducted after the Great East Japan Earthquake on March 11, 2011. The Disaster Cardiovascular Disease Prevention (DCAP) network system was introduced into the major shelter in Minamisanriku town devastated by the earthquake and subsequent tsunami, enabling strict BP management to be conducted at home. It is a system using remote ICT BP monitoring with cloud computing. This system has proven successful in minimizing seasonal BP fluctuations for several months to years following the disaster and during COVID-19 pandemic **(Figure 2)**.

3. Blood pressure variability is the master biomarker of digital health

The primary role of digital healthcare lies in "connecting information across time and place." It involves integrating signals emitted by various organs and applying them to current medical practice. Among these signals, BP stands out as the most vital clinical biomarker. BP varies overtime, including changes over the years, throughout the seasons, daily fluctuations, and variations with each heartbeat. They are also influenced by lifestyle conditions (diet, salt intake, exercise, sleep patterns, etc.) and environmental conditions (temperature, humidity, etc.). BP can also be seen as an indicator of one's psychological and organ conditions. Mechanical pressure loads resulting from BP surges play a significant role in triggering various cardiovascular events. In other words, when BP is at its highest, a person's cardiovascular event risk is at its peak. This surge BP is generated by the resonance of each BP surge with difference time-phases (the resonance hypothesis of blood pressure surge).[8]

4. Wearable blood pressure monitoring device and digital technology for anticipation medicine

The development of non-restrictive high-precision wearable BP monitoring devices allows the accumulation of long-term 24-hour BP data with simultaneous environmental data.[9] By analyzing the chronological BP data with environmental and other biological parameters using AI, it becomes possible to assess the risk of organ damage and predict future cardiovascular disease risk. Through the prediction of dynamic pathological surge BP, which trigger cardiovascular events, based on BP variability data and by adjusting the necessary behavioral modifications and medication dosages optimally, personalized anticipation medicine can be achieved. One prerequisite for achieving this is the development of high-precision cuffless BP measurement technology. While various cuffless BP measurement devices are under development, unfortunately, none of them have yet proven suitable for clinical use. Furthermore, data processing and detection of abnormal signals of big chronological data, and developing algorithms to predict risks from obtained data and verifying the accuracy in individual cases represent important directions in the field of digital hypertension. In addition to automated detection of abnormal BP signals, the development of algorisms utilizing machine learning techniques to predict BP changes and the onset of hypertension is needed.

Achieving personalized and predictive healthcare based on individual BP variability is the ultimate goal of digital health. However, there remain numerous challenges to be addressed in the pursuit of individualized and anticipation medicine.

5. Digital therapeutic apps

In recent years, the development of therapeutic apps has become increasingly active. Notably, in 2021, an open-label randomized controlled trial demonstrated the effectiveness of a digital therapeutic system for hypertension, marking the first such achievement worldwide.[10] This digital therapeutic app received regulatory approval in 2022 and is now available for clinical use in Japan through medical insurance. Digital interventions can help facilitate uptake of important guideline-recommended lifestyle modifications such as salt reduction, body weight reduction, exercise, sleep improvement, alcohol reduction, stress management, promoting home blood pressure monitoring, decrease therapeutic inertia, and improve medication adherence. These lifestyle improvements are personalized for each patient through the app. Responders to digital hypertension therapeutics tend to have a higher body mass index and report higher salt intake scores at the baseline, which they can subsequently reduce. Additionally, the effectiveness of digital therapeutics is partly influenced by daily self-reported behavioral efficacy records (SER), which are the number of times a patient inputs daily activity recall into the app. These records are affected by self-efficacy and the app's user-friendliness.

6. Hypertension is now on the stage of implementation medicine

We have a clear understanding of the significant risk hypertension poses to our health, and effective management can mitigate this risk. However, the real-world scenario shows that hypertension is under recognized and untreated among community-dwelling people and is poorly

controlled in medicated hypertensive patients. Digital technology holds the potential to address these unmet needs. Hypertension is now on the stage of implementation medicine, focusing on how to improve detection through screening and how to achieve BP control below target BP thresholds throughout 24-hours. Facilitating research in digital hypertension and integrating telemedicine into clinical practice are promising directions for better management of hypertension.

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