

# Cuffless Measurement of Blood Pressure: Not Good Enough for Diagnosis and Treatment of Hypertension

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## Introduction

Current diagnosis and treatment of hypertension are based on office and out-of-office cuff measurements of blood pressure, which is obtrusive and inappropriate for continuous measurement. In contrast, many wearable devices can provide a convenient cuffless measurement of blood pressure that has the potential to track blood pressure change with activities around the clock. Moreover, the huge number of blood pressure readings obtained directly from users' various smart devices may provide an unprecedented opportunity for digital transformation and precision medicine, which may dramatically change the practice of hypertension management in the future. However, concerns about the accuracy of cuffless blood pressure measurements have been raised [1] and recent hypertension guidelines do not support the use of smartphone/smartwatch-based cuffless blood pressure measurement for routine hypertension diagnosis and treatment [2, 3], why?

## Quest for More Accurate Blood Pressure Measurement

One fundamental reason is that recent advances in hypertension management have always involved the application of a more accurate blood pressure measurement device or protocol. For example, the Systolic Blood Pressure Intervention Trial demonstrated that treating high blood pressure to a target systolic blood pressure goal of less than 120 mm Hg was better than treating to a goal of less than 140 mm Hg, using a more *rigorous blood pressure measurement protocol* and *unattended automated office blood pressure monitoring* [4]. Recently, *home blood pressure monitoring* has become an essential component of any hypertension management plan because home blood pressure has been shown to provide better prognostic information than office blood pressure [5]. Furthermore, it has long been recognized that the accuracy of current brachial cuff blood pressure measurement is less than optimal. Cuff blood pressure has variable accuracy for measuring either brachial or aortic intra-arterial blood pressure, and this adversely influences correct blood pressure classification [6]. Thus, next major advances of hypertension management are expected to be associated with the development of stronger accuracy standards for blood pressure measurement devices, and not the other way around [6].

## **Cuffless Blood Pressure Measurement Is Not Accurate**

As pointed out by Avolio et al. [7] in the current issue, the main types of cuffless blood pressure measurement devices are wrist-worn, watch-type devices with sensors that typically record a photoplethysmography (PPG) signal with or without electrocardiography. The devices do not actually measure blood pressure but estimate a blood pressure value using a time delay (pulse arrival time, PAT, or pulse transit time, PTT) from the PPG+ electrocardiography signals, based on a rough and highly variable inverse relationship between the time delay and blood pressure, derived from the positive but moderate relationship between arterial stiffness (pulse wave velocity) and blood pressure measured within an arterial segment. In theory, use of the pressure-dependency of arterial stiffness phenomenon alone could never provide an accurate blood pressure estimation even in the absence of noises because of the regional and temporal variability of arterial stiffness and blood pressure along the arterial tree (e.g., the pulse pressure amplification phenomenon) and the dynamic change of pulse wave velocity and blood pressure relationship. Furthermore, the PPG sensor is sensitive to slight movement, so it is imperative to hold still while taking blood pressure, and therefore, it is very difficult to provide reliable blood pressure readings during ambulatory conditions, even with motion detection or signal quality assessment algorithms [7].

Avolio et al. [7] also present experimental data to illustrate the variability and inconsistency of the blood pressure and transit time (PTT or PAT) relationship and the inevitable calibration errors introduced in the cuffless blood pressure measurement that requires cuff-based calibration. The cuffless device could not reliably register the changes in blood pressure to various physiological interventions. Moreover, the calibration metrics (slope and intercept) were not stable over time. This then suggests that a calibration should be done before each measurement when using a cuffless blood pressure device, which would severely undermine the advantages of the cuffless device. For calibration-free cuffless devices, accurate blood pressure measurement is even harder to obtain.

Current cuff-based blood pressure devices are validated against reference blood pressure measurements to be performed with mercury sphygmomanometers or accurate nonmercury devices, under stable and static conditions, according to a universal standard for the validation of blood pressure measuring devices [8, 9]. However, the

standard was not intended for cuffless blood pressure measuring devices to be used during activities in changing body positions over time. Current cuffless devices are usually validated with reference to a cuff-based oscillometric blood pressure device. Data on the comparisons between cuffless blood pressure and invasive blood pressure measurement are limited. Simply fulfilling the standard of 5 mm Hg mean blood pressure difference (test vs. reference) and 8 mm Hg standard deviation is not sufficient to prove the accuracy of a cuffless blood pressure device [2].

### **Is the Smartphone/Smartwatch-Based Cuffless Blood Pressure Measurement Useful for Improving Hypertension Awareness and Facilitating Early Detection of Hypertension in the General Population?**

Epidemiological studies consistently found that young adults usually have low awareness of hypertension. Since the accessibility to the validated cuff blood pressure monitors is still limited for the general population, smartphone/smartwatch-based blood pressure measurement is conveniently available and could encourage young adults to pay attention to high blood pressure and start hypertension treatment early [2]. However, this potential benefit of increasing hypertension awareness must be cautiously weighed against the potential harm to true hypertensive individuals who may consistently receive low blood pressure readings from the inaccurate cuffless devices and may thus have a false belief of normotension.

In summary, an inaccurate blood pressure measurement device, no matter how smart, comfortable or convenient it is, is not useful for the daily hypertension diagnosis and treatment. Cuffless blood pressure measurement based solely on the relationship between time delay (PAT or PTT) and blood pressure will not have a major impact on the practice of hypertension management any time soon.

### **Conflict of Interest Statement**

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## Author Contributions

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