

The saga of blood pressure measurement: New faces of an old method

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For almost a century blood pressure (BP) measurement has been extensively used as an essential test in clinical medicine^{1,2}. BP measurement has two faces: first is to assess a “vital sign” in all patients by all clinical doctors, and second to identify a cardiovascular “risk factor” in people with hypertension. The evolution of “clinical hypertension” has been exclusively based on this measurement, and despite advanced biomedical achievements it remains the only test to detect people at high risk due to elevated BP and to guide treatment-induced BP decline. Although BP measurement was introduced as a diagnostic tool for professionals in the healthcare setting¹⁻³, several new methods and devices have been developed aiming at providing additional and BP information (**Figures 1-2**), which are discussed below.

BP measuring devices

The true “measurement” of BP is intraarterial which is invasive and thus appropriate only for critical care and not for wide clinical use. The manual auscultatory BP measurement has been developed as a non-invasive method, which however gives lower systolic and higher diastolic BP values than the intraarterial measurement. Interestingly, the classic mercury

sphygmomanometer is still being used, mainly in research settings, and amazingly it still remains as the reference method for validating novel BP measurement technologies and devices^{4,5}. Automated oscillometric devices have been developed to avoid observer bias and errors and to provide similar BP values as the auscultatory measurement.

Current guidelines for hypertension management recommend the use of properly validated automated upper arm cuff devices, not only for ambulatory and home BP monitoring, but also for office/clinic BP measurement^{1,2}. Unfortunately, less than 10% of the automated BP devices which are available on the market have been independently validated for their measurement accuracy using an established protocol^{4,5}. Lists of properly validated devices for office, home and ambulatory use in adults, children and pregnant women are available at www.stridebp.org (**Figure 3**).

Office BP measurement

The measurement of BP in the office or clinic by a healthcare professional remains the basis for the detection and management of hypertension, and very often is the only method available and used for de-

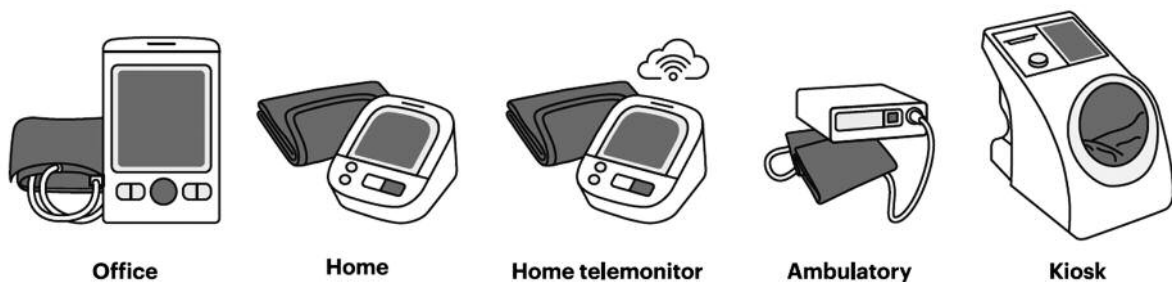


Figure 1. Different types of cuff blood pressure measuring devices [from ref. 6].

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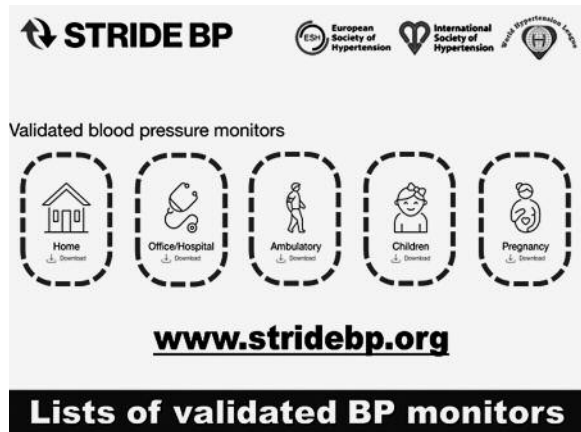


Figure 2. Lists of validated blood pressure measuring devices recommended by STRIDE BP (www.stride.org) endorsed by the International Society of Hypertension, the European Society of Hypertension, and the World Hypertension League [from ref. 9].

cision making in people with elevated BP across the world^{1,2}. However, office BP is affected by the “white coat” and the “masked hypertension” phenomena and by observer bias and error. Automated oscillometric BP devices are devoid of some of the observer issues, and unattended office BP measurement (repeated automated measurements while the patient remains alone in the examination room) avoids some of the white coat reaction. However, unattended BP measurement has been shown to underestimate office BP in unpredictable way and thus requires a different (lower) threshold for diagnosing hypertension, which is rather uncertain¹.

More importantly, it is recognized that, even if meticulously performed using appropriate methodology and reliable equipment, office BP can be misleading in almost one third of both untreated and treated individuals, leading to considerable overdiagnosis and unnecessary treatment, or underdiagnosis and exposure to preventable cardiovascular risk^{1,2}. At the present time, it is important to standardize the methodology of office BP measurement by using properly validated automated upper arm cuff devices, take triplicate measurements per occasion, and use the average of the last two^{1,2,6}. Nevertheless, repeated office visits and confirmation with out-of-office BP evaluation are necessary in many cases^{1,2}.

Ambulatory BP monitoring

24-hour ambulatory BP monitoring is currently recommended as the best available method for diagnosing hypertension^{1,2}. This method provides mul-

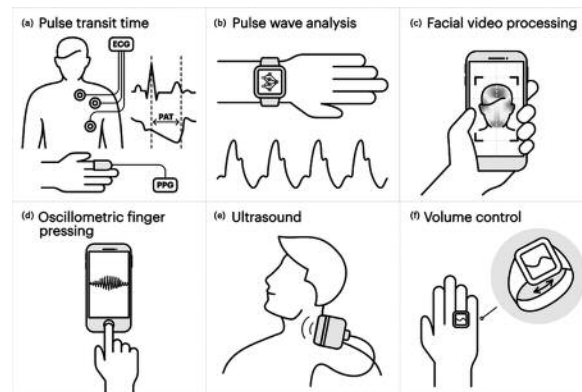


Figure 3. Different types of cuffless blood pressure measuring devices [from ref. 7].

iple BP measurements away from the office/clinic setting in the usual environment of each individual at home, at work, and even during nighttime sleep. However, it has several and important drawbacks. First, it is not available in most healthcare settings. Second, the cuff inflation causes discomfort mainly at work and during sleep, and several patients are reluctant to use it, particularly when repeated. Third, although it is more reproducible than office BP measurements, its reproducibility is not perfect, and more than a single 24-hour recording is needed for a reliable diagnosis¹. Thus, although indeed ambulatory BP monitoring is a valuable tool for assessing BP, it is unlikely that it can be the solution for the global evaluation and management of hypertension in clinical practice.

Home BP monitoring

Home BP monitoring is being widely used by patients with hypertension in many countries. As with 24-hour ambulatory monitoring, this method provides multiple BP measurements away from the office/clinic setting at the individual's home. Although home monitoring does not provide information for BP at work or during sleep (some novel home monitors can provide automated measurements during nighttime sleep), it has the advantage of allowing long-term monitoring for weeks, months, or years, which has been shown to improve patients' adherence with drug treatment and thereby BP control^{1,2}. Thus, it is currently recommended for all patients with treated hypertension, unless they cannot obtain reliable measurements or self-monitoring is stressful to them. A weak point of self-BP monitoring is the so called “reporting bias” as patients may select which measurements to report to their doctor (often

omit the highest ones), which can be avoided using devices that automatically store all measurements and calculate the average, or by home BP tele-monitoring (see below).

Cuffless BP measurement

Cuffless BP measurement technologies have considerable potential to change (improve) the screening, diagnosis, and long-term monitoring of hypertension (Figure 3)^{7,8}. First, wearable cuffless BP devices in wristbands, smart-watches, rings, etc, have the potential to provide more detailed and accurate information on the BP behavior during the day and night and in different settings (home, work, other) for days, weeks, or months. Second, cuffless BP measuring technologies embedded in smart-phones will allow billions of people to have repeated assessment of their BP levels without purchasing a dedicated BP device but using a device which they already have in their pocket.

Despite high interest and intense efforts by many companies, including mega-companies, start-up companies, and others, to date the development of a cuffless BP technology with adequate accuracy for clinical use has not been achieved. Most technologies have been based on photoplethysmography with electrocardiographic estimation of pulse transit time and require “calibration” for each individual user with classic measurement of her/his BP using a cuff BP device and/or with demographic information (e.g., age, sex, height). In addition, cuffless devices differ considerably according to their principles of measurement, output frequency, measurement mode, calibration type, position of sensor, and intended use (Figure 3). Thus, their validation is very different and much more complex than for cuff BP

devices^{4,5,7,8}. In a recent statement by the European Society of Hypertension nine different types of cuffless BP devices were recognized and a new validation protocol was recommended with 6 tests which are selected according to the device type (Figure 4)⁸. Thus, despite the considerable potential of cuffless BP technologies, at the present time they are not recommended for clinical use in the diagnosis and management of hypertension.

BP telemonitoring

Home BP telemonitoring and related telemedicine services allow a remote assessment of BP with multiple and unbiased measurements as the device and software can automatically store, average, interpret, and transfer all the readings of weeks or months to the healthcare professional^{1,9}. BP telemonitoring may be useful for screening, or long-term monitoring people with elevated BP managed with nonpharmacological or antihypertensive drug treatment. It may be particularly useful when access to healthcare services is difficult, and in patients with uncontrolled hypertension, at high cardiovascular risk, or with poor treatment adherence.

The cost of setting up a telemonitoring system might be challenging. However, there are basic, advanced, and complete models for virtual care in hypertension (Figure 5)⁹, depending on the resources of the healthcare system. Given the unique advantages of telemedicine tools and their low maintenance costs (for basic models), they have considerable potential, and eventually they will become a standard method for facilitating the long-term management of hypertension as soon as technological advancements in the field will provide optimized models with clinically relevant impact on patients' care.

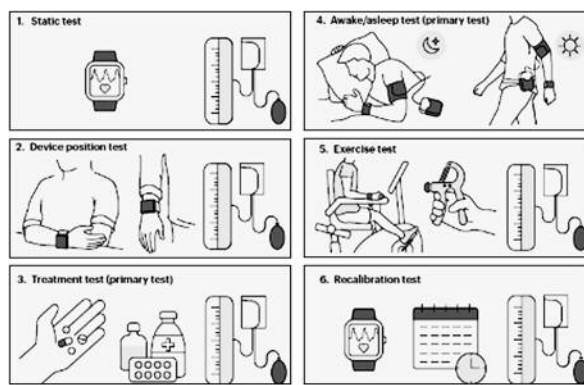


Figure 4. Validation tests for cuffless blood pressure measuring devices recommended by the European Society of Hypertension [from ref. 8]

Perspective

The measurement of BP has been essential in clinical medicine for almost a century. The classic measurement in the office has been incredibly useful in detecting people at high cardiovascular risk and guiding treatment-induced BP decline. However, out-of-office BP evaluation is often necessary for the precise diagnosis and appropriate management. Novel technologies with cuffless BP devices and BP telemonitoring are expected to improve considerably the screening of hypertension, to provide more accurate evaluation of the BP profile and behavior, and to facilitate long-term monitoring.

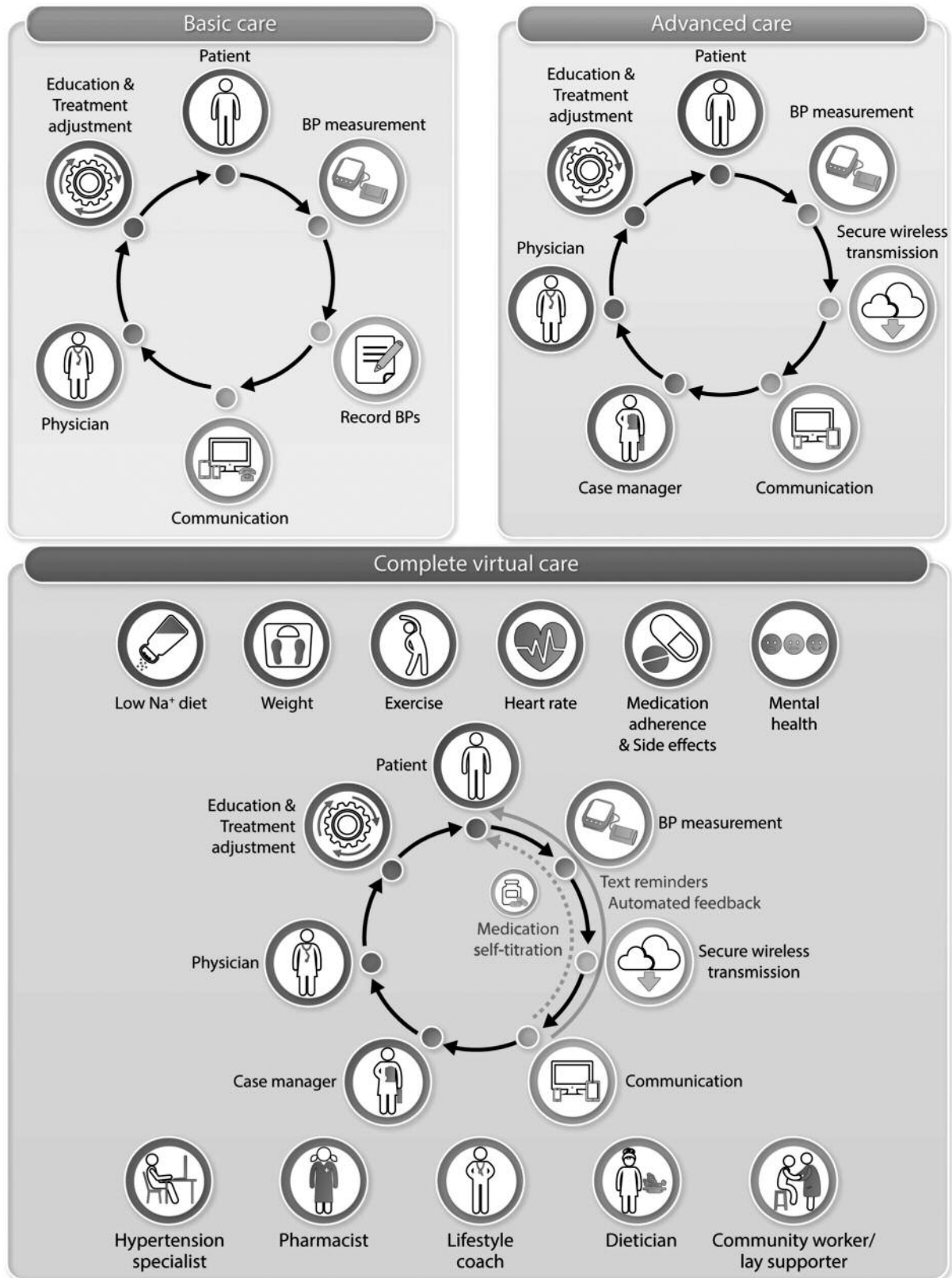


Figure 5. Basic, advanced, and complete models for virtual care in hypertension [from ref. 9].

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