INDIAN SOCIETY OF HYPERTENSION
World Hypertension League
CURRENT MEDICAL CONCEPTS
HTNJ
CrossMark

Review Article

Blood Pressure Measurement in Clinical Practice Methods and Emerging Options

V. Dayasagar Rao

Consultant Cardiologist, KIMS Hospital, Hyderabad, Telangana, India

Abstract

Accurate measurement of blood pressure (BP) is pre-requisite for diagnosis and therapy of hypertension (HTN). The standard clinical method of estimating BP in office, by inflatable rubber cuff, using Korotkoff sounds is obsolete and is used more often for standardization of other indirect methods. The oscillometric technique is the current standard for the measurement of BP. Alternative methods of indirect estimation of BP – applanation tonometry, vascular clamp method, and pulse transit time, are under evaluation and need refinement, before recommending for routine clinical application. Current clinical standard mandates, blood pressure measurement not only in office but also out of office for the diagnosis and therapy of HTN.

Key words: Blood pressure, measurement, mercury manometer, oscillometry, out of office measurement

Introduction

"*Whatever the measurement system is, it needs to be consistent, repeatable, and as unbiased as possible*"

Pearl Zhu[1]

William Harvey discovered circulation in 1628 and century elapsed before Reverend Stephen Hales performed his famous experiment in 1733, demonstrating the rise of blood to height of eight feet, three inches, in glass pipe placed in artery of Horse. It was not until non-invasive occluding arm cuff devised by Scipione Riva Rocci in 1896 that clinical measurement of blood pressure (BP) became reality. He inflated cuff, until it occluded pulse distal to cuff. This application of external counter pressure until the pulse disappeared by palpation corresponds to peak systolic BP (SBP). Quantification of counterpressure was done by connecting the inflatable bag to mercury manometer. In April 1905, Russian surgeon-Nikolai Sergeevich Korotkoff described the measurement of BP by auscultation-peak systolic pressure corresponding to onset of audible sounds by Stethoscope distal to occluding cuff and disappearance of sounds to end-diastolic pressure. Alternative methods of BP measurement, using oscillometry, applanation tonometry, volume clamp method, and analysis of various parameters of arterial pulse wave, have been utilized for non-invasive measurement of arterial BP.

The evolution of methods of BP measurement continues and the latest technique of non-invasive measurement of BP using Android smartphone, is commercially available but not yet approved by regulating organizations and professional societies.

Direct intra-arterial pressure measurement by cannulation of the vessel is gold standard, but it is not practical for routine clinical measurement of ambulatory patients, as it is invasive and requires technical skill and is associated, although rarely with potential major complications of occlusion of vessels and injury to adjacent structures.

Thus, indirect non-invasive measurement of BP is currently clinical standard. Most of these methods base the measurement of pressure, indirectly by applying counter pressure to blood vessels or analyzing various components of pulse wave recorded indirectly by device/sensors applied to blood vessels, transcutaneously.

Address for correspondence:
V. Dayasagar Rao, Consultant Cardiologist, KIMS Hospital, Hyderabad, Telangana, India. E-mail: dsraovala@gmail.com

Received: 14-04-2019; Accepted: 16-05-2019
doi: 10.15713/ins.johtn.0161

These Methods Include

- Conventional inflatable rubber bag method (RivaRocci-Korotkoff [RRK] - method)
- Oscillometry
- Vascular clamps method
- Applanation tonometry
- Pulse wave analysis including (pulse transit time [PTT]).

RRK Method

Till recently, this method has been the mainstay of clinical BP measurement and is gradually replaced by other automated techniques. In this auscultatory method the audible sounds (Korotkoff sounds), distal to the occluded artery, during slow deflation of inflated rubber cuff are produced by vibration of the vessel wall, consequent to the rapid flow of blood passing through the collapsed artery. In this auscultatory method of indirect measurement of BP, the onset of audible sounds (Phase I) during deflation is equal to peak SBP and disappearance of sounds (Phase V) as corresponding to end-diastolic pressure.

In situations where Korotkoff sounds are heard, even after complete deflation – such as AR (Aortic Regurgitation), the fourth phase (Muffling of sounds) may be used as diastolic BP (DBP). In some patients – especially in older patients the Korotkoff sounds may be inaudible between SBP and DBP (independent of respiration and cardiac arrhythmias), as the cuff deflation is continued, this is called auscultatory gap. It is commonly seen in patients with stiff arteries and is most likely to occur in subjects with target organ damage.

External brachial pulse recording during standard BP cuff deflation reveals three components, labeled as K1, K2, and K3.

Table 1: Cuff size measurement of blood pressure

Lean arms	Circumference in cm	Dimensions in cm	
		BHS	AHA
Adults and children	22–26	-	12×22
Adult arms	27–-34	12×18	16×30
Large	35–44	12×26	16×36
Thigh	45–52	-	20×42

BHS: British Hypertension Society, AHA: American Heart Association

The K2 component is high frequency triphasic component that coincides with audible Korotkoff sounds. In conditions characterized by stiff arteries, the K2 component either is blunted or disappears, resulting in loss of Korotkoff sounds and thus auscultation gap.[2] Thus, it is desirable to measure SBP by palpatory method and inflate cuff to 30 mmHg more than SBP (obtained by palpation) during auscultation. The auscultatory method has been validated in animal experiments and human beings, with intravascular pressure recordings. The SBP by auscultatory method is often underestimated (by about 5–10 mmHg), and DBP is overestimated with nearly equal mean arterial pressure (MAP).

Mercury manometers used in traditional auscultatory methods are gradually replaced due to possible environmental toxicities of mercury – by aneroid manometers and hybrid sphygmomanometers. Hybrid manometers have been developed to overcome the banning of mercury in measuring instruments, by replacing mercury with electronic pressure gauge. In aneroid devices, the pressure is registered by the mechanical system of metal bellows that expand as the cuff pressure increase and register the pressure on circular scale. Being mechanical systems may lose stability over time and need to be calibrated periodically by mercury manometers.

A common source of error in measuring BP by this technique is using of inappropriate size of cuff that encircles the upper arm. Ideal cuff should have bladder length that is 80% of circumference and width of at least 40% arm distance with length-width ratio of 2:1.

The Recommended Size of Cuff for Various Arm Sizes Table-1, after Home BP Moitor Table-2 are as Follows[3]

BP measurements are commonly made in the sitting position with feet flatly touching floor and with back support and upper arm at the level of heart, with support (to eliminate possible isometric exercise in trying to hold at level). It is also measured in supine position and standing position if needed (in Elderly and on drug therapy) but has to make sure that measuring arm should be at the level of the heart. Any variability of arm position in relation to heart level is due to hydrostatic pressure and may result in 2 mmHg change for every inch above or below heart level (Higher when arm is below and lower if arm is Higher).

Table 2: Home blood pressure technique, timing, and schedule

Technique	Timing	Schedule
Comfortable	5 min after resting–after emptying the bladder	7-day monitoring schedule
Distraction-free environment	2 h after meal	Duplicate measurements – each time
Sitting position	1 h after coffee or tobacco usage	Morning and evening (4 measurements per day)
Back supported	30 min after exercise	Not fewer than 12 readings, i.e., at least 3 days data
Feet flat on the floor	Before taking medicines	(for diagnostic purposes)
Legs–uncrossed		Long-term–1–2 duplicate measurements per week
Arm supported		initially (Long-term monitoring)
Middle of the cuff at heart level		
Arm bare with the lower edge of the		
cuff 3 cm above the elbow		
No conversation and no movement		

Interpretation: Discard 1st-day readings and take average of remaining readings. Normal values – <135/85 mmHg (Same as daytime readings of ABP)

BP should be measured in both arms at first examination, and when there is consistent arm difference between the two, the arm with higher BP values should be used for follow-up. Before investigation for possible obstructive artery disease – simultaneous measurement in two arms is mandatory. Any difference of BP by >15 mmHg between the arms (inter arms difference) is sign of obstructive arterial disease and demands further evaluation.

The BP should also be measured in lower limbs generally at the level of ankle, as it does not require special inflatable rubber cuff (as the size of ankle and arm are approximately same girth). The ankle SBP is generally expressed as a ratio in comparison to brachial SBP – ankle-brachial index (ABI). Normally, ABI is 0.9–1.1 any deviation from this value indicates peripheral vascular disease – lower value <0.9 indicating occlusive vascular disease and higher values >1.3 indicating stiffer vessel wall both these conditions indicate worse long-term clinical outcome.

Apart from technical details of the measurement of BP cuff size, position of patient and arm, the observer is the important component of accurate BP measurement and must fulfill all the following criteria.

He should be properly trained in the technique of BP measurement by selecting the appropriate size of cuff, instrument, and positions arm appropriately. The mercury columns should be deflated at 2–3 mmHg/s and listen to Korotkoff sounds noting the level at which first sound appears (phase-I SBP) and last sound disappears (Phase-V–DBP). The columns should be read to nearest 2 mmHg. The observer should recognize subject factors – anxiety, Nicotine, coffee use, etc., that would adversely affect the BP measurement. It is important to note that observer and patients should not converse during measurement. The BP should be measured after rest period of 5 min and not immediately after arrival to the examining room. The mercury manometer should be at the eye level of observers, to prevent parallax error. Observer error is a major limitation of auscultatory methods, just as terminal digit preference. It is recommended to read BP to nearest 2 mmHg.

Because observer error is a major limitation of auscultatory method, automated measurement by oscillometric method has become popular and currently the standard of clinical care.

Oscillometric Method

In this method, Riva-Rocci arm cuff is used to measure the BP by analyzing pressure oscillation by device in the cuff. When the cuff is inflated above SBP, there are no pressure oscillations. The maximum oscillations during the deflation of cuff correspond to the mean arterial BP and have been validated by invasive methods.[4] From the mean arterial BP, the SBP and DBP are derived using a variety of algorithms. Currently, the oscillometric method is popular, as it is independent of observer errors and ease of multiple recordings. Further oscillometric techniques tend to overestimate low pressure and underestimate when pressure is high. Finally, movement of the arm during measurement can give false reading, mistaking movement as oscillation.

The predictive power of multiple BP recordings is much greater than single office recording. Presently, it is recommended to measure BP readings automatically in quiet room without any health-care providers in the room after the rest of 5 min (Automatic Office BP [AOBP]). The major advantage of automatic devices is avoidance of observer errors, multiple readings and the ease of use even by layperson with elementary training. This has resulted in increasing use of oscillometric devices in office, home, and ambulatory monitoring of BP measurement.

The disadvantage of oscillometric techniques includes inherent error in oscillometric techniques and lack of long-term outcome data based on oscillometric techniques. For appropriate evaluation of patient with hypertension (HTN) it should not only be measured in office but also out of office environment (000 BP) either at home or by continuous ambulatory BP (ABP) recording measurement. Home/self-monitoring has several advantages, as it identifies white coat HTN (isolated office HTN) and masked HTN (isolated home HTN with normal office BP). It also provides a convenient way of monitoring BP over long periods of time and may improve, drugs compliance, and HTN control. For accurate reporting, devices that have memory or printout of readings should be recommended. The measurement of BP in office, like measurement at home, also demands same guidelines to be implemented.

Home BP Recording

It is generally done by oscillometric technique and should adhere to the following guidelines. The ideal requirement for appropriate measurements is as follows.

Utility

- Diagnostic – diagnosis of HTN-white coat or masked
- Prognostic – better than on base percentage recording
- Home BP variability
- Therapeutic – Effectiveness of drug treatment
- Drug duration of action
- Home BP ratio – Morning/Evening is similar to trough to peak ratio by ABP.

Limitations

- Usage of poor-quality devices
- Need for elementary training
- Misrepresenting of data – patients
- Self-adjustment of drug therapy
- Anxiety – due to "high" or low BP values
- Inability to monitor nocturnal BP.

ABP Measurement

ABP is automated technique of BP recording over an extended period of time, typically for 24 h. The equipment consists of cuff, connected to recorder by a tubing, which in turn is attached to

belt tied at waist. BP is measured by oscillometric technique. The frequency of measurement can be programmed – every 15 min, 30 min, or hourly. During typical ABP monitoring BP is measured every 15–30 min during awake and hourly during sleep hours preferably on working days. The number of readings usually vary 50–100 are analyzed offline and provides report giving mean values by hour and period – day time and night and 24 h – SBP and DBP mean during day and night time-24 h values are used in decision-making.

The inflatable rubber cuff should be attached to non-dominant arm and series of calibration readings taken with mercury manometer to ensure that device is giving readings within 5 mmHg of mercury manometer. ABP should be appropriately used in identifying patients with white coat HTN. Non-dipper at night by ABP (<10% decrease) super dipper (>20% decrease) has adverse prognosis. ABP can also be used for correlating patients' symptoms with BP as in (postural hypotension) and to know adequacy 24 h coverage of antihypertensive effects by drugs.

Normal ABP values are as follows:

- Average 24 h–130/80 mmHg
- Day time – 135/85
- Night time – 120/75
- Normal fall (Dipper) in SBP and DBP during night sleep 10–20%.

ABP record is recognized as a gold standard for evaluation of elevated office BP by US preventive service task force and National Clinical Guideline Centre in United Kingdom. Guidelines recommend at least 20 or more-day time recordings and at least seven or more-night time recordings for appropriate interpretation of ABP. Recommendations vary from obtaining at least 70% of programmable readings to 20 awake/daytime and seven asleep or night time readings. IDACO (International Database ABP in relation to cardiovascular [CV] outcome) studies applied fixed clock time intervals excluding transition period in morning and evening when BP rapidly changes.

BP Measurements in Special Situations

Elderly

Measurement of BP in the elderly should not only be in sitting position but also in standing position, with the upper arm at heart level, as postural hypotension related to disease or drug therapy will determine the dose and type of anti-HTN drugs.

Pseudo HTN

It is defined as elevated BP by the indirect method of estimation with normal invasive intra-arterial pressure is gold standard for diagnosis of pseudo HTN. It is presumably due to stiff vessel wall of brachial artery that makes the indirect measurement of BP unreliable when compared to intra-arterial pressure. The time tested Osler's maneuver of identifying thickened vessel wall after complete occlusion of blood flow by inflating the BP cuff to suprasystemic level is good clinical indicator of vessel wall pathology at bedside. Quantification of vessel wall thickness was done in one study by estimating PWV which was markedly increased in patients with pseudo HTN.

Systematic study of the prevalence of pseudohypertension is very low (1.7%), in non-selected elderly population. There was no correlation observed between pulse wave velocity (PWV) and difference between direct and indirect pressures.[6] The Osler's maneuver was misleading being positive in patients with no pseudohypertension and negative in some patients with pseudohypertension.

Diagnosis of pseudohypertension is suspected, when BP recording is very high over a long period of the time with no target organ damage and attempting to treat suspected HTN with drug therapy results in symptoms of low BP – dizziness, confusion, etc.

Measurement of intravascular pressure is gold standard for diagnosis. Alternative methods of estimating BP at finger level by vascular clamp method are useful in diagnosis of pseudohypertension.

Obesity

Diagnosis of HTN in obese patients by indirect BP measurement should be done after making sure that it is not due to an error in cuff sizing-smaller cuff leading to overestimation of BP.

Pregnancy

Measurement of BP during pregnancy should be in sitting position but supine BP should be measured in left lateral position is reasonable alternative during labor. Korotkoff Phase- V Should be the DBP while using auscultatory sphygmomanometer.

Children

Interpretation of BP values should take into consideration age, gender, and height. A BP value that is consistently higher than 95th percentile of distribution should lead to one to diagnose HTN. The table that provides SBP, DBP level at 95th percentile according to age, gender, and height should be consulted before labeling patients as HTN. The role of ABP in children is less clear in diagnosis of HTN.

Cardiac Arrhythmias

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia, being present in 1–2% of general population, with increasing prevalence with age-approximately 5% of adults older than 65 years.

Assessment of BP in AF is challenging, due to significant variability in SBP, consequent to varying cardiac cycle lengths (varying stroke volume). The accuracy of the automated oscillometric technique is questionable and recommended repeated measurements using auscultatory method. Recently automated BP monitors with AF detection capability-

MICROLIFE – are available and are reliable in estimation of BP (in the setting of AF). National Institute for Health Care Excellence recommends MICROLIFE for BP Measurement in patients 65 years and older, in primary care, for detection and therapy of AF, leading to reduction of stroke in the community.

In patients with bradycardia, measurement of BP by auscultatory sphygmomanometry may be erroneous if the cuff deflation is fast and recommended slow deflation so as not missing the early onset and late offset of Korotkoff sounds.

Central Aortic Pressure

Some clinical trials and meta-analysis have shown that central aortic pressure predicts CV events better than brachial arterial BP. As of now, the incremental prognostic value of central aortic pressure remains unclear. Furthermore, the technique of derivation of central aortic pressure from brachial pressure is not standardized for routine clinical use; then, as of now central aortic pressure derivation is not recommended for clinical studies. The only exception may be isolated systolic HTN (ISH) in young, where the increased SBP at the brachial level may be due to high amplification of central pressure, while central aortic BP may be normal.[7]

Applanation Tonometry (Applanation-to Flatten, Tonometry-Measurement of Pressure)

Applanation tonometry is based on the work of Pressman and Newgard,[8] who showed that transducer strapped to artery transcutaneously can obtain arterial pulse wave, similar to intravascular pressure wave. This is based on Imbert–Fick Principle which states that thin-walled sphere inside pressure, is equal to force necessary to flatten surface, divided by area of flattening MAP obtained from pulse wave is used to derive SBP and DBP.

The superficial blood vessel in flattened by applying pressure over the artery against the underlying bone-classical radial artery. The arterial pressure in top of flattened artery equals the luminal pressure, allowing pressure waveform to be recorded. Comparative studies have shown that arterial pressure waveform recorded by transcutaneous tonometer corresponds to those recorded invasively with intra-arterial catheters. The major limitation of arterial tonometry is its inability to give absolute values of SBP and DBP as it has to calibrate tonometric pressure wave, with brachial artery pressure usually obtained by oscillometry. From these data obtained, central aortic pressure can also be determined either by direct method-analyzing carotid tonometric pressure wave or indirectly using radial artery tonometric pressure wave analysis. Central aortic BP has been shown to be better predictor of CV events in some of the clinical trials of HTN. The methodology of estimating central aortic pressure is not standardized, and its value over and above brachial arterial pressure is questioned.

Apart from measuring arterial BP, by pulse wave analysis, other parameters – augmentation index, BP amplification, and subendocardial viability ratio can be calculated. Commercially available, applanation tonometry includes – Pulse pen device – DiaTecna, Milan, Italy; Indirect-Sphygmocor (ATCOR Medical, Australia); OMRONHEM 9000A-OMRONHEM-Healthcare-Kyoto Japan.

One clinical study comparing arterial tonometry derived BP with invasive arterial pressure in post-operative patients[9] revealed poor agreement between two methods, well beyond the limits set by Association for Advancement of Medical Instruments. Thus, arterial tonometry may be useful in assessing the trend of BP during monitoring rather than absolute values.

Modification of transducer of tonometry by including another parameter – volume change in arterial lumen may yield additional physiologic data like compliance of vessel. Recent guidelines ESC and EHS advise recording of central aorta pressure – in patients with ISH and not in any other hypertensive conditions.

Volume Clamp Method (Arterial Unloading)

Volume clamp method is based on the work of Penaz, aCzech physiologist, who measured finger blood volume by photoplethysmography, which changes continuously throughout the cardiac cycle. The BP is measured at the finger, with transparent inflatable cuff, containing photodiode and photocell, which in turn is connected pressure controller. This technique measures the blood volume in finger by plethysmography.

The counter pressure that is required to keep finger blood volume constant is the arterial BP. By applying counter pressure from outside, the arterial wall is unloaded (i.e., not under stress of intraluminal pressure). The pressure controller adjusts the pressure (using servo mechanism) such that blood volume in finger is held constant. Thus, finger cuff pressure will represent arterial BP; it is calibrated to brachial arterial BP, measured by independent technique. (Usually by oscillometric method) and triggered automatically and periodically) (Once in 15–30 s). This method of non-invasive measurement of BP is commercially available for continuous beat to beat measurement of BP, in critical area of monitoring-during anesthesia, intraoperative, post-operative, and intensive care units.

Disadvantages

The pneumatic cuff on finger continuously causes discomfort and can compromise digital circulation. Peripheral vasomotor changes occurring spontaneously or in response to various drugs (Inotropes, vasopressors, vasodilators can cause error, and primarily affecting SBP). Improper application of finger cuff can also cause inaccurate pressure results. This method is also motion sensitive and cannot be used during normal physical activities, just as it cannot be used in patients which finger deformities either congenital or acquired like in rheumatoid disease.

Cuff less, Continuous BP Measurement

Since 1990 novel techniques-based on PWV principles have been developed. PWV is speed of movement of expansile

impulse of vessel wall (Not velocity of blood flow), which progressively increases from 4 M/s in central aorta to reach 8 M/s in iliac arteries. This PWV is proportional to magnitude of BP in addition to compliance of blood vessels.

PTT is the time delay for pressure wave to travel between two arterial sites and can be measured as the time interval between peak of "R" wave (of electrocardiogram [ECG]) and onset of blood flow. PTT is inversely related to the magnitude of mean arterial BP. Calibration of these PTT parameters is crucial component of accurate measurement of BP by this method. Recently, Food and Drug Administration (FDA) has cleared Visimobile – For continuous noninvasive cuffless BP measurement BP. Cuffless BP measurement device using PTT for beat to beat calculation of BP values has been validated over short period of time-Somnomedics (GmbH, Germany).

Recent study of cuffless, continuous noninvasive BP[11] measurement using PTT technology is compared to ABP oscillometric technique. (Ambulatory BP) monitoring using oscillometry technique) found a significant difference between the two systems-PTT system-showing consistently higher values ranging from 5 to 10 mmHg in both SBP and DBP. Thus, this system using PTT technique has to be refined for improving the accuracy before widespread use in clinical settings.

Measurement of BP using Smartphones

These devices – smartphones are used as processors by having BP App. The biological signals from ECG, Plethysmography or pressure transducers, are recorded by appropriate sensors and transmitted to the smartphone by blue tooth technology, or sensors are inbuilt in instrument. Analysis and calibration of signals are the crucial part of application.

The BP measurement from health App in one study[12] was highly inaccurate with 77.5% of individuals with HTN being shown in non-hypertensive range. As on today, in 2018, this technology is in its nascent stage and is not ready for prime time. The US-FDA, which regulates devices, has not approved any of the BP Apps. These instruments underestimated higher BP range and overestimated lower BP range giving false reassurance that their BP is under control.

Wearable Devices

Wearable technology is a broad term for electronics that are worn on body, either as a part of garment or as an accessory individual unit.

Wearable BP monitoring device is available that looks like a smartwatch and provides many of the measures-like walking speed and distance covered and heart rate in addition to BP measurement. This does not have an arm cuff but still has inflatable cuff built into wrist band and provides SBP and DBP.

Another wearable device technology-a bracelet, utilizes, combination of optical sensors, and smartphone app to measure and monitor BP.

These wearable BP measurement gadgets are available but are not validated for accuracy.

Transdermal Optical Imaging Technology

Facial video, using cameras, were analyzed for variations in skin color, caused by pulsatile blood volume changes in cutaneous arteries. These variations were converted to SBP and DBP using mathematical models. These values were comparable to BP recorded with arm cuff methods This study was conducted in East Asians in still subjects, using two light sources at fixed distances. In people with dark skin and variations in position of head, consequent to movement, it is difficult to extract skin color variation of skin principle of using skin color variation, for measurement of BP is a novel concept but has too many limitations, for routine clinical applications at the present time.

Assessment of BP

(Clinical methodology) Ambulatory Patients Clinical Methods

Four approaches can be used:

- AOBP
- Non-AOBP (Standard office measurements)
- ABP monitoring
- Home BP monitoring.

(Threshold for Diagnosis of HTN is Different for each of the above Methods)

- AOBP is the preferred method of performing in office measurement but is not practical in India
- Multiple BP recordings in non-AOBP is most frequently performed for evaluation of BP, but should always be combined with out of office measurements, especially in the absence of target organ damage or clinical CV disease
- In the absence of AOBP, the next preferable method of evaluation of BP is by ABP, usually recording for 24 h. Ideal if available, affordable and tolerable
- Home monitoring of BP has to be done as a part of out of office measurement in the absence of ABP monitoring
- Combination of office BP and out of office measurements is mandatory for the diagnosis of HTN.

Summary

Multiple methods of the measurement of BP by indirect methods are available.

- Standard inflatable rubber cuff using mercury manometer is outdated for clinical purpose but still has utility for calibration of other indirect methods
- Commonly used BP devices in clinical practice are by oscillometry, though less reliable in patients with cardiac arrhythmias
- Out of office (000-BP) BP measurement, either at home or by ABP record, in addition to office BP (AOBP), is the current standard for diagnosis of HTN and as substitute for multiple recordings in office
- Newer methods of measuring BP continuously on the beat to

beat are in evaluation using pulse wave analysis-like PTT and applanation tonometry
- They are being evaluated against the standard methods of measuring BP by oscillometry
- Measurement of BP by android smartphone is unreliable and currently not approved by any regulatory agencies or any professional organization.

References

1. Zhu P. Digital Maturity: Journey of a Thousand Miles from Functioning to Delight. Abu Dhabi: LuLu Company; 2018.
2. Blank SG, West JE, Müller FB, Pecker MS, Laragh JH, Pickering TG. Characterization of auscultatory gaps with wideband external pulse recording. Hypertension 1991;17:225-33.
3. Smith LI. New AHA recommendations for blood pressure measurement. Am Fam Physician 2005;72:1391-8.
4. Cao X, Song C, Guo L, Yang J, Deng S, Xu Y, *et al*. Quality control and validation of oscillometric blood pressure measurements taken during an epidemiological investigation. Medicine (Baltimore) 2015;94:e1475.
5. Nerenberg KA, Zarnke KB, Leung AA. Hypertension Canadian 2018 guidelines. Can J Cardiol 2018;34:506-25.
6. Kuwajima I, Hope, Suzuki Y, Matsushite. J Hypertens 1990;8:429-32.
7. Williams B, Mancia G, Spiering W, Rosei EA, Azizi M, Burnier M, *et al*. 2018 ESC/ESH guidelines for management of arterial hypertension. Eur Heart J. 2018;39:3021-104.
8. Pressman GL, Newgard PM. A transducer for the continuous external measurement of arterial blood pressure. IEEE Trans Biomed Eng 1963;10:73-81.
9. Meidert AS, Huber W, Müller JN, Schöfthaler M, Hapfelmeier A, Langwieser N, *et al*. Radial artery applanation tonometry for continuous non-invasive arterial pressure monitoring in intensive care unit patients: Comparison with invasively assessed radial arterial pressure. Br J Anaesth 2014;112:521-8.
10. Kim SH, Lilot M, Sidhu KS, Rinehart J, Yu Z, Canales C, *et al*. Accuracy and precision of continuous noninvasive arterial pressure monitoring compared with invasive arterial pressure: A systematic review and meta-analysis. Anesthesiology 2014;120:1080-97.
11. Krisai P, Vischer AS, Kilian L, Meienberg A, Mayr M, Burkard T. Accuracy of 24-hour ambulatory blood pressure monitoring by a novel cuffless device in clinical practice. Heart 2019;105:399-405.
12. Plante TB, Currea B, Zane T, Blumenthal RS, Miller ER 3rd, Appel LJ, *et al*. Validation of instant blood pressure smartphone app. JAMA 2016;176:700-2.

How to cite this article: Rao D. Blood Pressure Measurement in Clinical Practice Methods and Emerging Options. Hypertens 2019;5(3): 92-98.

Source of support: Nil, **Conflicts of interest:** None