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Cardiological Society of India

Yearbook of CARDIOLOGY 2025

Hypertension

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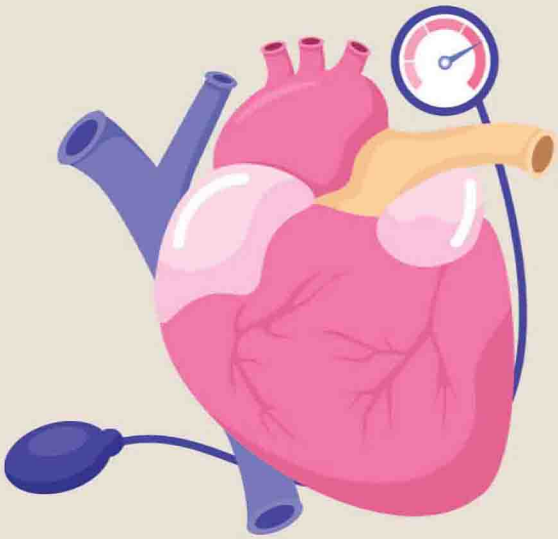

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SECTION 1

Blood Pressure Measurement

***Section Editor*: Aditya Kapoor**

ARTICLE 1

Ability of a 24-hour Ambulatory Cuffless Blood Pressure Monitoring Device to Track Blood Pressure Changes in Clinical Practice

Derendinger FC, Vischer AS, Krisai P, Socrates T, Schumacher C, Mayr M. Ability of a 24-Hour Ambulatory Cuffless Blood Pressure Monitoring Device to Track Blood Pressure Changes in Clinical Practice.
J Hypertens. 2024;42(4):662-71.

Abstract

Objective: Cuffless blood pressure measurement (BPM) devices are becoming more and more common. The capacity of these devices to monitor changes in BP levels over a 24-hour period in relation to an initial calibration blood pressure (CalibBP) remains unknown, despite encouraging results when comparing individual data. Our goal was to use pulse transit time to analyze this capability in a cuffless device.

Methods: For concurrent cuffless (Somnotouch-NIBP) and cuff-based (Spacelabs 90217A/IEM Mobil-O-graph) 24-hour BPM, we prospectively recruited 166 subjects. The initial cuff-based blood pressure (BP) was used as CalibBP for the cuffless device. We used the difference between the CalibBP and the mean 24-hour awake and sleep BP obtained by the two devices as a stand-in for changes in BP following the CalibBP. Furthermore, we examined the correlation between the CalibBP and cuff-based BPM devices and the cuff-based and cuffless BPM devices.

Conclusion: The mean (SD) difference between the CalibBP and the mean 24-hour BP measured by the cuffless or cuff-based BP monitor was 6.6 (6.8) versus 1.6 (5.8) mm Hg for the diastolic ($p < 0.0001$) and 7.4 (13.2) versus 1.8 (8.3) mm Hg for the systolic ($p < 0.0001$). The difference between the cuff-based and cuffless BPM devices, as well as the difference between the CalibBP and cuff-based BPM values, showed a nearly linear connection. In conclusion, our data show that the cuffless BPM device is less able to monitor changes in BP following CalibBP. Furthermore, BP level variations following the initial CalibBP were linked to cuffless device accuracy; the greater the BP level shift, the greater the discrepancy between the devices.

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COMMENTARY

Cuffless blood pressure measurement (BPM) refers to estimating a person's blood pressure without using an inflatable cuff around the arm (or wrist). Instead of physically compressing an artery to detect pressure, these devices use physiological signals—like pulse-wave timing, optical signals, or bioimpedance—to *estimate* BP continuously and noninvasively. It offers continuous, user-friendly monitoring but remains less accurate for dynamic BP changes due to its reliance on calibration and physiological variability. While promising for future home and remote monitoring, it is not yet a substitute for standard cuff-based BPM in clinical practice.

This 2024 *Journal of Hypertension* study investigated the clinical reliability of a 24-hour cuffless BP monitoring device, the Somnotouch-NIBP, which estimates BP using pulse transit time (PTT) rather than traditional cuff inflation. The primary goal was to assess the device's ability to track BP changes over a 24-hour period following an initial calibration with a standard cuff-based measurement.

A total of 166 participants were enrolled, each undergoing simultaneous monitoring with both the cuffless Somnotouch-NIBP and standard validated cuff-based devices (Spacelabs and Mobil-O-Graph). The study compared mean systolic and diastolic BP readings during 24-hour, awake, and asleep periods and analyzed the relationship between calibration BP (CalibBP) and subsequent BP changes.

Results revealed that the cuffless device consistently recorded higher BP values than the standard method and had limited ability to reflect actual BP fluctuations after calibration. Specifically, when BP changed significantly after the initial calibration, discrepancies between the two devices widened—demonstrating a near-linear relationship between the magnitude of BP change and measurement difference. This limitation suggests that the cuffless system often overestimates BP in cases of white-coat hypertension and underestimates it in masked hypertension.

While the cuffless device offers advantages such as continuous beat-to-beat monitoring, reduced discomfort, and additional physiological data (e.g., ECG and oxygen saturation), its tracking precision remains inadequate for clinical decision-making. The findings align with the recent European Society of Hypertension guidelines, which recommend caution in clinical use of cuffless BP technologies until further validation is achieved.

In conclusion, although promising for long-term, user-friendly monitoring, the Somnotouch-NIBP currently cannot replace standard cuff-based ambulatory BP measurement. Its lower accuracy in detecting dynamic BP changes limits its application for diagnosing or managing hypertension in clinical practice.

Take-Home Messages

- ***Cuffless BP devices (PTT-based) offer continuous, noninvasive monitoring, improving patient comfort and feasibility for long-term and home-based tracking.***
- ***Their accuracy depends on initial calibration BP (CalibBP), making them vulnerable to errors when BP changes significantly over time.***

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- ***Cuffless monitoring shows limited ability to track dynamic BP changes over 24 hours, compared to standard cuff-based ambulatory BP monitoring (ABPM). The greater the BP variation after calibration, the greater the measurement discrepancy, showing a near-linear relationship between BP change and inaccuracy.***
- ***Cuffless devices may overestimate BP in white-coat hypertension and underestimate BP in masked hypertension, limiting their diagnostic reliability.***
- ***Despite advantages (comfort, beat-to-beat data, additional physiological parameters), current devices are not sufficiently accurate for clinical decision-making.***
- ***Cuff-based ABPM remains the gold standard, and current guidelines recommend cautious use of cuffless technologies until further validation.***

ARTICLE 2

Comparison between Visit-to-visit Office and 24-hour Blood Pressure Variability in Treated Hypertensive Patients

Mancia G, Facchetti R, Quarti-Trevano F, Dell'Oro R, Cuspidi C, Grassi C. Comparison Between Visit-to-Visit Office and 24-Hour Blood Pressure Variability in Treated Hypertensive Patients.
J Hypertens. 2024;42(1):161-8.

Abstract

Goals: Blood pressure (BP) readings may vary from visit to visit in any treated hypertensive patient, and this variability (V) has a negative prognostic effect. On visit-to-visit 24-hour BPV, however, not much information is available.

Methods: We examined visit-to-visit office and 24-hour mean BPV in 1,114 hypertensives from the ELSA and PHYLLIS trials using the coefficient of variation (CV) of the mean systolic (S) and diastolic (D) blood pressure measured annually during a period of 3–4 years of therapy. Additionally, daylight and nighttime visit-to-visit BPV were compared.

Findings: Office SBP-CV was approximately 20% higher than 24-hour SBP-CV ($p < 0.0001$). SBP-CV was significantly higher at night than during the day (20%, $p < 0.0001$). The DBP results were comparable for both males and females, older and younger patients, patients on different antihypertensive medications, and patients with varying baseline or attained blood pressure values. Office SBP or DBP CV accounted for only 1–4% of 24-hour SBP or DBP-CV values, according to the poor correlation coefficients between office and 24-hour BP-CV in both the group as a whole and subgroups.

In summary, the mean blood pressure over a 24-hour period is more consistent than the mean blood pressure during a visit to the clinic. Although there is a strong relationship between visit-to-visit office and 24-hour BPV, the correlation coefficients are modest, rendering visit-to-visit office BP fluctuations weakly predictive of the concurrent 24-hour BP variations and, consequently, of on-treatment ambulatory BP stability.

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COMMENTARY

The study "Comparison between visit-to-visit office and 24-hour blood pressure variability in treated hypertensive patients" by Mancia et al. (2024) investigates how blood pressure variability (BPV) differs when measured through traditional office readings versus 24-hour ambulatory monitoring. Using data from 1,114 treated hypertensive patients in the ELSA and PHYLLIS trials, the researchers assessed the coefficient of variation (CV) of systolic and diastolic BP across multiple yearly visits over 3–4 years.

Results demonstrated that 24-hour systolic BPV was approximately 20% lower than office BPV ($p < 0.0001$), indicating that ambulatory BP measurements are more stable over time. Night-time BPV, however, was significantly higher than daytime variability. These trends were consistent across patient subgroups—regardless of sex, age, drug regimen, or baseline BP levels. Although there was a statistically significant correlation between office and 24-hour BPV, the correlation coefficients were weak ($r \approx 0.1$–0.2), suggesting that only 1–4% of ambulatory BPV could be predicted from office measurements.

The study concluded that visit-to-visit office BP measurements are poor predictors of 24-hour BP stability. Ambulatory blood pressure monitoring (ABPM) provides a more reliable assessment of BP control during treatment, especially considering its stronger prognostic relevance for cardiovascular risk. Notably, night-time BP control was less consistent and showed higher variability than daytime control, potentially contributing to residual cardiovascular risk despite treatment.

Importantly, no major antihypertensive drug class [beta-blockers, calcium channel blockers, angiotensin-converting enzyme (ACE) inhibitors, or diuretics] showed superior performance in reducing visit-to-visit BPV. The authors emphasize that reliance solely on office BP readings may underestimate true BP instability, reinforcing the clinical value of regular ABPM. Future research should explore the prognostic implications of visit-to-visit 24-hour BPV for cardiovascular outcomes.

Take-Home Messages

- ***24-hour ambulatory BPV is more stable and reliable than visit-to-visit office BPV, with office variability being approximately 20% higher. Office BP fluctuations are poor predictors of true BP control, as they explain only a small proportion (≈1–4%) of 24-hour BPV.***
- ***Correlation between office and ambulatory BPV is weak, limiting the clinical utility of office readings in assessing BP stability.***
- ***Night-time BPV is significantly higher than daytime variability, highlighting an important contributor to residual cardiovascular risk.***
- ***ABPM provides a more accurate reflection of real-life BP patterns, making it superior for treatment assessment.***
- ***No antihypertensive drug class shows clear superiority in reducing BPV, suggesting the need for individualized treatment strategies.***
- ***Clinical implication: Reliance solely on office BP may underestimate BP instability—regular ABPM should be considered for better risk stratification and management.***

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ARTICLE 3

Differences between Brachial and Aortic Blood Pressure in Adolescence and their Implications for the Diagnosis of Hypertension

Hughes AD, Smith GD, Howe LD, Lawlor D, Jones S, Park CM. Differences Between Brachial and Aortic Blood Pressure in Adolescence and Their Implications for the Diagnosis of Hypertension.
J Hypertens. 2024;42(8):1382-9.

Abstract

Goals: Blood pressure (BP), the primary cause of death worldwide, is becoming more common in children and teenagers. In adults, aortic BP is lower than brachial BP. Our goal was to determine the magnitude of this disparity and how it affected the diagnosis of hypertension in teenagers.

Methods: We used data from 3,850 participants from a UK cohort of Southwest England births in the early 1990s who visited their approximately 17-year follow-up and had reliable measurements of aortic BP and brachial BP at that clinic [mean (SD) age 17.8 (0.4) years, 66% female persons]. For both sexes, the data are displayed as mean differences (95% prediction intervals).

Findings: Aortic systolic blood pressure (SBP) was lower than brachial SBP [male, −22.3 (−31.2, −13.3) mm Hg; female, −17.8 (−25.5, −10.0) mm Hg]. There were not many differences between brachial and aortic diastolic blood pressure (DBP). Brachial BP measures were used to classify 101 males (6%) and 22 females (1%) as hypertensive. The predictive value of brachial BP for aortic hypertension was poor (positive-predictive value = 13.8%), and only 9 males (<1%) and 14 females (<1%) met the criteria for hypertension based on aortic BP. Compared to individuals with brachial hypertension, those with aortic hypertension had a greater left ventricular mass index.

Conclusion: Due to significant aorta-to-brachial pulse pressure amplification, brachial BP significantly overestimates aortic BP in teenagers. When screening adolescents, the use of brachial BP measurement may lead to an overdiagnosis of hypertension.

COMMENTARY

The study "Differences between brachial and aortic blood pressure (BP) in adolescence and their implications for diagnosis of hypertension" by Hughes et al. (2024) examines how BP readings taken from the arm (brachial BP) differ from central aortic BP in adolescents, and how this affects hypertension diagnosis. Using data from 3,850 participants (mean age 17.8 years; 66% female) in the Avon Longitudinal Study of Parents and Children (ALSPAC), the researchers compared brachial and aortic BP measurements and assessed their associations with cardiac and vascular indicators of organ damage.

Results showed that aortic systolic BP (SBP) was significantly lower than brachial SBP—by an average of 22 mm Hg in males and 18 mm Hg in females—due to pronounced pulse pressure amplification

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from the aorta to the arm. Diastolic BP (DBP) differences were minimal. Using standard diagnostic criteria, 6% of males and 1% of females were classified as hypertensive based on brachial BP; however, when using aortic BP, hypertension prevalence dropped below 1% for both sexes. The positive predictive value of brachial BP for detecting true (aortic) hypertension was low (13.8%), suggesting that brachial measurements substantially overestimate hypertension in adolescents.

Both aortic and brachial hypertension were linked with higher left ventricular mass index (LVMI), a marker of cardiac target organ damage, but associations were stronger for aortic BP. No significant relationship was found between either BP type and vascular indicators such as carotid intima–media thickness or pulse-wave velocity.

The study concludes that reliance on brachial BP can lead to overdiagnosis of hypertension during adolescence, primarily due to pulse pressure amplification. Aortic BP more accurately reflects cardiovascular load and early cardiac effects, suggesting that central BP assessment may be a better diagnostic tool for identifying true hypertension and cardiovascular risk in young people.

Take-Home Messages

- ***Brachial SBP significantly overestimates central (aortic) SBP in adolescents due to marked pulse pressure amplification (~18–22 mm Hg difference).***
- ***DBP shows minimal difference, making SBP the key source of discrepancy.***
- ***Reliance on brachial BP may lead to overdiagnosis of hypertension in adolescents, with prevalence dropping markedly when using aortic BP.***
- ***Brachial BP has poor predictive value for true (aortic) hypertension, with low positive predictive accuracy (~14%).***
- ***Aortic BP correlates more strongly with target organ damage (e.g., increased left ventricular mass index), making it a better indicator of true cardiovascular risk.***
- ***Pulse pressure amplification is more pronounced in younger individuals, explaining the greater discrepancy seen in adolescents compared to adults.***
- ***Clinical implication: Central (aortic) BP assessment may provide a more accurate diagnosis and risk stratification, but brachial BP remains the current standard for screening.***

ARTICLE 4

High versus Low Measurement Frequency during 24-hour Ambulatory Blood Pressure Monitoring: A Randomized Crossover Study

Thomsen MB, Nyvad J, Christensen KL, Reinhard M, Buus NH. High Versus Low Measurement Frequency During 24-Hour Ambulatory Blood Pressure Monitoring: A Randomized Crossover Study.
J Hum Hypertens. 2024;38(2):146-54.

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Abstract

The amount of cuff inflations may have an impact on how stressful and uncomfortable ambulatory blood pressure monitoring (ABPM) is. We contrasted a high-frequency (HF-ABPM) regimen carried out in accordance with current standards, which uses two cuff inflations at night and three cuff inflations per hour during the day, with a low-frequency (LF-ABPM) regimen that uses one cuff inflation per hour. Patients in a crossover study received ABPMs at both frequencies in a randomized order over a few days. Following each ABPM, patients reported sleep disruptions and pain (on a visual analogue scale of 0–10). The difference in mean 24-hour systolic blood pressure (SBP) between HF-ABPM and LF-ABPM was the main outcome measure. Data from 131 individuals (age 58 ± 14 years, 47% female, 24% normotensives, 53% mildly hypertensives, and 22% moderate-to-severe hypertensives) who completed both ABPMs were included in the study. A total of 171 participants were randomized. For HF-ABPM and LF-ABPM, the mean SBP was 137.5 mm Hg [95% confidence interval (CI) 134.8; 140.2) and 138.2 mm Hg (95% CI 135.2; 141.1), respectively. −15.3 and + 14.0 mm Hg were the 95% limits of agreement. Between HF-ABPM and LF-ABPM, the mean 24-hour SBP difference was −0.7 mm Hg (95% CI − 2.0; 0.6). The LF-ABPM and HF-ABPM coefficients of variation were comparable. HF-ABPM and LF-ABPM pain ratings (median with interquartile range) were 1.5 (0.6; 3.0) and 1.3 (0.6; 2.9) during the day and 1.3 (0.4; 3.4) and 0.9 (0.4; 2.0) at night ($p < 0.05$ for both differences). We find that there are no clinically significant changes in blood pressure between the LF-ABPM and HF-ABPM results, which are in good agreement. Additionally, procedure-related discomfort is somewhat reduced by LF-ABPM.

COMMENTARY

This randomized crossover study investigated whether reducing the frequency of measurements during 24-hour ambulatory blood pressure monitoring (ABPM) affects blood pressure (BP) accuracy and patient comfort. The standard high-frequency protocol (HF-ABPM) involves three measurements per hour during the day and two per hour at night, while the low-frequency protocol (LF-ABPM) uses just one measurement per hour throughout.

A total of 171 patients were randomized, with 131 completing both ABPM protocols. The primary outcome was the difference in mean 24-hour systolic BP (SBP) between HF-ABPM and LF-ABPM. Results showed minimal difference: Mean SBP was 137.5 mm Hg for HF-ABPM and 138.2 mm Hg for LF-ABPM, with a mean difference of –0.7 mm Hg [95% confidence interval (CI) –2.0 to 0.6]. Diastolic BP (DBP) differences were similarly small. Coefficients of variation for SBP and DBP were nearly identical across both methods, indicating consistent BP variability assessment.

Patient-reported pain and discomfort were slightly lower with LF-ABPM. Median pain scores were modestly reduced during both day and night with LF-ABPM, and more patients reported no symptoms at the cuff site. Sleep quality and duration were unaffected by measurement frequency.

Subgroup analyses revealed no significant BP differences based on hypertension severity, prior ABPM exposure, or measurement order. Notably, nighttime SBP showed

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a slight negative correlation with increasing BP levels under HF-ABPM, but this was not clinically significant.

The study concludes that LF-ABPM provides BP readings comparable to HF-ABPM, with the added benefit of reduced discomfort. These findings challenge current guidelines recommending higher measurement frequencies and suggest that hourly measurements may suffice for accurate BP monitoring without compromising patient experience.

Take-Home Messages

High versus low frequency ABPM

- ***LF-ABPM provides BP values comparable to standard HF-ABPM, with no clinically significant difference in 24-hour systolic or diastolic BP. This indicates that reduced measurement frequency does not compromise overall BP assessment.***
- ***BP variability (coefficient of variation) remains similar across both methods, supporting reliability of low-frequency monitoring.***
- ***Patient discomfort and pain are slightly lower with LF-ABPM, especially during nighttime measurements. Although sleep quality is not significantly affected by measurement frequency, fewer cuff inflations may improve patient experience.***
- ***No significant differences are observed across subgroups (age, sex, hypertension severity), reinforcing generalizability.***
- ***Clinical implication: LF-ABPM may be a patient-friendly alternative without loss of accuracy, potentially challenging current guideline-recommended higher measurement frequencies.***

ARTICLE 5

Innovations in Blood Pressure Measurement and Reporting Technology: International Society of Hypertension Position Paper Endorsed by the World Hypertension League, European Society of Hypertension, Asian Pacific Society of Hypertension, and Latin American Society of Hypertension

Kario K, Williams B, Tomitani N, McManus RJ, Schutte AE, Avolio A, et al. Innovations in Blood Pressure Measurement and Reporting Technology: International Society of Hypertension Position Paper Endorsed by the World Hypertension League, European Society of Hypertension, Asian Pacific Society of Hypertension, and Latin American Society of Hypertension.
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Abstract

The lifetime risk of cardiovascular disease and preclinical organ damage is significantly influenced by blood pressure (BP). Conventional clinic-based BP readings do not record BP during regular

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daily activities because they are usually taken infrequently and under standardized/resting settings. As a result, current hypertension guidelines stress how crucial it is to include out-of-office BP monitoring in methods for diagnosing and treating hypertension. Conventional home and ambulatory BP monitors, on the other hand, employ the upper-arm cuff oscillometric approach and only offer sporadic BP readings in certain circumstances or in static conditions. Technologies for remote monitoring, reporting, and storage of BP data; technologies for BP data interpretation and patient interaction intended to enhance hypertension management; and technologies for BP estimation based on processing of sensor signals supported by artificial intelligence tools are examples of new innovations ("digital therapeutics"). The quantity and volume of data pertaining to new gadgets and technologies are growing quickly and will keep doing so. This position paper from the International Society of Hypertension (ISH) discusses the use of digital therapeutics, the reliability and usefulness of new BP monitoring devices, the evidence pertaining to new BP measurement techniques and related indices, the standards for the validation of new devices and technologies, and the relationship between these metrics and clinical outcomes. It also draws attention to the obstacles and gaps in the available data that must be filled before these new technologies can be regarded as a reliable and easy-to-use source of novel BP data to guide clinical hypertension management plans.

COMMENTARY

This International Society of Hypertension (ISH) position paper, endorsed by global hypertension organizations, explores emerging technologies in blood pressure (BP) measurement and their implications for clinical practice. Traditional BP monitoring methods—primarily upper-arm cuff-based devices—are limited by their intermittent nature, discomfort, and inability to capture dynamic BP fluctuations during daily life. The paper emphasizes the growing importance of out-of-office BP monitoring, such as ambulatory blood pressure monitoring (ABPM) and home blood pressure monitoring (HBPM) while highlighting the limitations of conventional devices.

Recent innovations aim to overcome these challenges through wearable, cuffless, and continuous BP monitoring technologies. These include wrist-worn devices, smart rings, and smartphone-based systems that utilize photoplethysmography (PPG), pulse transit time (PTT), and pulse arrival time (PAT) to estimate BP. While promising, these methods often require calibration with traditional cuff-based readings and face issues with accuracy, movement artifacts, and user variability.

The paper categorizes novel devices into cuff-based and cuffless technologies, detailing their mechanisms, validation status, and clinical utility. It underscores the need for rigorous validation standards tailored to these new devices, as existing protocols are designed for cuff-based systems. Continuous monitoring technologies, though valuable in critical care and sleep disorder contexts, still face usability and calibration hurdles for routine use.

Additionally, the paper discusses digital therapeutics—integrated systems combining BP monitoring with data transmission, artificial intelligence (AI)-driven analysis, and personalized feedback—to enhance hypertension management. Multisensor devices that track environmental and physiological parameters are also emerging.

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In conclusion, while innovative BP technologies offer transformative potential for personalized and accessible hypertension care, widespread adoption requires overcoming validation, accuracy, and usability challenges. The ISH advocates for continued research, standardization, and integration of these tools into clinical workflows to improve global hypertension control.

Take-Home Messages

Innovations in BP measurement and reporting

- ***Emerging technologies (wearables, cuffless devices, smartphone-based systems) enable continuous and user-friendly BP monitoring, improving accessibility and patient engagement.***
- ***Out-of-office BP monitoring (ABPM/HBPM) is essential, as clinic BP alone fails to capture real-life BP variability and may misclassify patients.***
- ***Most cuffless technologies rely on indirect signals (PPG, PTT, PAT) and require calibration, limiting accuracy—especially during dynamic BP changes.***
- ***Digital therapeutics (AI-based analysis + remote monitoring + feedback systems) can potentially transform into personalized, data-driven management.***
- ***Accuracy, motion artifacts, calibration dependency, and usability remain key limitations, restricting routine clinical adoption at present. Moreover, the current validation standards are inadequate for new technologies, highlighting the need for updated, device-specific validation protocols.***
- ***Clinical implication: While promising personalized care, innovative BP technologies cannot yet replace validated cuff-based methods and require further evidence and standardization.***

ARTICLE 6

Legacy Benefits of Blood Pressure Treatment on Cardiovascular Events are Primarily Mediated by Improved Blood Pressure Variability: The ASCOT Trial

Gupta A, Whiteley WN, Godec T, Rostamian S, Ariti C, Mackay J, et al. Legacy Benefits of Blood Pressure Treatment on Cardiovascular Events are Primarily Mediated by Improved Blood Pressure Variability: The ASCOT Trial.
Eur Heart J. 2024;45(13):1159-69.

Abstract

Context and objectives: Systolic blood pressure variability (SBPV) from visit to visit is a significant predictor of cardiovascular (CV) outcomes. Uncertainty surrounds the long-term effects of a period of blood pressure (BP) control using differential BPV. In order to ascertain the CV impact of mean systolic blood pressure (SBP) control and BPV during the trial, as well as among those assigned to amlodipine- and atenolol-based treatment, morbidity and mortality follow-up of UK participants in the Anglo-Scandinavian Cardiac Outcomes Trial-Blood Pressure-Lowering Arm has been extended for up to 21 years.

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Methods: Using linked hospital and mortality records, 8,580 hypertensive participants (4,305 assigned to amlodipine ± perindopril-based treatment and 4,275 to atenolol ± diuretic-based treatment during the in-trial period) (median 5.5 years) were tracked for up to 21 years (median 17.4 years). A self-administered questionnaire and a clinic visit were used to follow up with a subgroup of participants (n = 2,156) 6 years after the trial's end. More than 100,000 BP readings were used to calculate the in-trial mean SBP and the standard deviation of visit-to-visit SBP as a measure of BPV. The risk [hazard ratios (HRs)] associated with (1) mean with SBP and BPV during the in-trial period, for the CV endpoints occurring after the trial's conclusion, and (2) randomly assigned treatment to events after randomization, for the first occurrence of pre-specified CV outcomes, were estimated using Cox proportional hazard models.

Results: Using BP data from the in-trial period, systolic BPV independent of mean SBP was a strong predictor of CV events [HR per 5 mm Hg 1.22 (95% CI 1.18 – 1.26), $p < 0.001$] and predicted events even in participants with well-controlled BP. However, mean SBP was a predictor of CV outcomes in the post-trial period [HR per 10 mm Hg, 1.14 (95% CI 1.10 – 1.17), $p < 0.001$]. The risk of stroke [HR 0.82 (95% CI 0.72 – 0.93), $p = 0.003$], total CV events [HR 0.93 (95% CI 0.88 – 0.98), $p = 0.008$], total coronary events [HR 0.92 (95% CI 0.86 – 0.99), $p = 0.024$], and atrial fibrillation [HR 0.91 (95% CI 0.83 – 0.99), $p = 0.030$] was significantly lower for those receiving amlodipine-based in-trial treatment compared to those receiving atenolol-based treatment. There was also less evidence of a difference in CV mortality [HR 0.91 (95% CI 0.82 – 1.01), $p = 0.073$]. The incidence of fatal coronary heart disease, heart failure, and all-cause mortality did not differ significantly from that of nonfatal myocardial infarction.

Conclusion: Even in people with regulated SBP, systolic BPV is a powerful predictor of CV prognosis. An impact on systolic BP throughout the trial period seems to be the main mediator of the long-term advantages of amlodipine-based treatment over atenolol-based treatment in lowering CV events.

COMMENTARY

The ASCOT (Anglo-Scandinavian Cardiac Outcomes Trial) investigated the long-term effects of blood pressure variability (BPV) on cardiovascular (CV) outcomes among hypertensive patients. In this 21-year follow-up of 8,580 UK participants, researchers compared an amlodipine ± perindopril regimen with an atenolol ± diuretic regimen to determine whether the benefits of antihypertensive therapy persisted beyond the trial period and whether BPV influenced CV risk.

During the in-trial phase (median = 5.5 years), over 100,000 BP measurements were analyzed to calculate both mean systolic BP and visit-to-visit BPV. Long-term follow-up (median = 17.4 years) showed that, although mean systolic BP predicted CV outcomes [hazard ratio (HR) 1.14/10 mm Hg increase], systolic BPV was a stronger independent predictor (HR 1.22/5 mm Hg increase). Elevated BPV remained associated with greater CV risk, even in patients with well-controlled BP (<140 mm Hg).

Participants initially treated with amlodipine-based therapy experienced significantly lower risks of stroke (HR 0.82), total CV events (HR 0.93), coronary events (HR 0.92),

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and atrial fibrillation (HR 0.91) compared to those on atenolol-based therapy, with weaker evidence for reduced CV mortality.

The study concludes that systolic BPV is a powerful determinant of long-term CV outcomes and that the enduring benefits of amlodipine-based treatment are largely mediated through its stabilizing effect on BPV. These findings suggest BPV should be recognized as a therapeutic target in hypertension management and a key predictor of CV risk.

Take-Home Messages

BP variability and legacy effects (ASCOT)

- ***Legacy benefits of antihypertensive treatment are largely mediated through sustained reduction in BP variability, not just BP lowering.***
- ***Visit-to-visit systolic BPV is a strong independent predictor of CV events. Although mean SBP remains important, BPV provides additional prognostic information beyond average BP levels.***
- ***Higher BPV is associated with an increased long-term risk of stroke, coronary events, and atrial fibrillation, even in patients with well-controlled BP.***
- ***Amlodipine-based therapy reduces BP variability more effectively than atenolol-based therapy, contributing to better long-term CV outcomes.***
- ***Clinical implication: BPV should be considered a therapeutic target, alongside achieving target BP levels. Stable BP control (with lesser fluctuation) is as important as BP reduction, and drug selection may influence variability and long-term outcomes.***

ARTICLE 7

Novel Pulse Waveform Index by Ambulatory Blood Pressure Monitoring and Cardiac Function: A Pilot Study

Narita K, Yuan Z, Yasui N, Hoshide S, Kario K. Novel Pulse Waveform Index by Ambulatory Blood Pressure Monitoring and Cardiac Function: A Pilot Study.
JACC: Advances. 2024;3(1):100737.

Abstract

Context: For the purpose of monitoring patients with heart failure (HF), a basic ambulatory cardiac function test may be useful.

Goals: Using data from our created multisensor-ambulatory blood pressure monitoring (ABPM) system, the "Sf/Am" ratio was used to analyze pulse waveforms in order to discover whether it is related to echocardiographic left ventricular ejection fraction (LVEF).

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Techniques: Twenty HF patients with HF-reduced LVEF or HF-preserved LVEF (median age 66 years, male 65%) had multisensor ABPM twice at baseline and during a 6–12-month follow-up following patient-tailored treatment. We evaluated the variations in LVEF and the pulse waveform index Sf/Am between the baseline and follow-up. The area of the square forward wave's ejection portion (Sf) and the measured wave's amplitude (Am) makes up the Sf/Am. Based on a ≥10% rise in LVEF, we separated the patients into two groups: Recovered (n = 11) and not recovered (n = 9).

Outcomes: While neither group's ambulatory blood pressure levels or variabilities changed, the recovered group's Sf/Am considerably increased (baseline 21.4 ± 4.5; follow-up, 25.6 ± 3.7, p = 0.004). There was no change between the baseline and follow-up for the group that was not recovered. The LVEF ratio was substantially correlated with the follow-up/baseline Sf/Am ratio (r = 0.469, p = 0.037). Overall measures showed a strong correlation between the Sf/Am and the LVEF (n = 40, r = 0.491, p = 0.001).

Conclusion: These findings showed a relationship between LVEF and a new noninvasive pulse waveform index, the Sf/Am, as determined by multisensor ABPM. When assessing heart function, the Sf/Am may be helpful.

COMMENTARY

The study "Novel Pulse Waveform Index by Ambulatory Blood Pressure Monitoring and Cardiac Function: A Pilot Study" by Narita et al. (2024, JACC: Advances) investigated whether a new, noninvasive pulse waveform index—the Sf/Am ratio—measured using a multisensor ambulatory blood pressure monitoring (ABPM) device, could estimate cardiac function, particularly left ventricular ejection fraction (LVEF), in patients with heart failure (HF).

The study included 20 HF patients (median age 66 years; 65% male) with either reduced or preserved ejection fraction. Each underwent multisensor ABPM and echocardiography at baseline and again after 6–12 months of individualized treatment. The Sf/Am ratio represents the area of the ejection portion of the forward pulse wave (Sf) divided by the amplitude of the measured wave (Am), aiming to isolate cardiac systolic performance from arterial and cuff compliance effects.

Results showed that while ambulatory BP levels and variability remained stable, the Sf/Am ratio increased significantly in the group whose LVEF improved by ≥10% (from 21.4 ± 4.5 to 25.6 ± 3.7, p = 0.004). A strong correlation was observed between changes in Sf/Am and LVEF (r = 0.469, p = 0.037), confirming that the index tracked functional recovery.

The findings demonstrate that Sf/Am correlates with LVEF, suggesting its utility as a noninvasive surrogate marker for cardiac function in ambulatory settings. The authors propose that with further validation in larger cohorts, this method could enable routine, cuff-based monitoring of heart function, enhancing HF management outside clinical environments.

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Take-Home Messages

Novel pulse waveform index (Sf/Am) and cardiac function

- *Sf/Am (pulse waveform index from multisensor ABPM) shows a significant correlation with LVEF, suggesting its potential as a noninvasive marker of cardiac function.*
- *Changes in Sf/Am reflect improvement in cardiac function, with significant increases seen in patients who demonstrate ≥10% recovery in LVEF. It is of predictive value even when BP levels and BP variability remain unchanged, indicating added value beyond traditional BP metrics.*
- *It has a potential role in HF monitoring, allowing ambulatory, repeatable, and noninvasive assessment of cardiac function.*
- *Multisensor ABPM systems can expand beyond BP measurement to provide cardiac insights, supporting integrated cardiovascular monitoring.*
- *Clinical implication: Promising tool for remote HF monitoring but requires validation in larger studies before routine clinical adoption.*

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