

Home Blood Pressure in Target Range as an Additional Therapeutic Goal in Hypertensive Patients. Telemonitoring-based Analysis.

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Research Article

Keywords: hypertension, telehealth, mobile health, cardiovascular risk, blood pressure, home blood pressure monitoring, kappa coefficient, measurement

Posted Date: July 21st, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1880725/v1>

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Version of Record: A version of this preprint was published at Connected Health on September 9th, 2022. See the published version at <https://doi.org/10.20517/ch.2022.12>.

Abstract

Aim

Guidelines recommend treating hypertension (HTN) keeping office blood pressure (BP) within the therapeutic range (TR) rather than aiming to achieve only cut-off value. Time of office BP values in TR is an independent predictor of cardiovascular events. However, data on home BP in TR are lacking. Telehealth simplify collection and structure home BP. We aim to find reliable proportion of home systolic (S) BP in TR (sBPiTR) and to evaluate its impact on overall BP control.

Methods

We used the data of HTN patients who participated in BP telemonitoring and counseling for 3 months. We divided sBPiTR (110–130 mmHg, all SBP readings except the very or every 1st day) by quartiles (< 25; 25 to 49; 50 to 74; >74). A weighted Cohen's kappa coefficient was an estimate of inter-rater reliability between sBPiTR and office SBP or home SBP in TR at 3 months. We used binomial logistic regression to evaluate the predictive value of sBPiTR on target office/home SBP achievement.

Results

A total of 123 patients were included (median age 54 years; 102 males) with a median office SBP of 140 mmHg. By 3 months it decreased to 130 mmHg ($p < 0.001$), and 60.2% patients achieved a target of 120–139 mmHg. More patients were in the upper sBPiTR quartiles (70% versus 30%). There was a slight agreement between office SBP in TR and sBPiTR $\geq 50\%$ ($k = 0.19$, $p < 0.035$). The reliability increased when countered against home SBP in TR ($k = 0.32–0.65$], $p < 0.0001$). Patients with sBPiTR $\geq 50\%$ were more likely to fall within office SBP TR (OR 2.41, 95% CI [1.06 to 5.51] and home SBP TR (OR 5.2 95% CI [2.06–13.12] after adjustment for baseline covariates.

Conclusion

The threshold of 50% of home SBP measurements within 110–130 mmHg has a slight agreement with office BP control and a fair agreement with home BP control. This variable may serve a predictor for achievement of target SBP both for in- and out-of office. Larger studies are needed to confirm these preliminary results.

Introduction

Over the past few decades, the concept of 'target' blood pressure (BP) has been revised several times, gradually decreasing from 160/115 mmHg down to 130/80 mm Hg, and even lower [1, 2].

In 2018, the European Society of Cardiology and the European Society of Hypertension (ESC/ESH) Guidelines for the management of hypertension (HTN) were published [3] followed by Russian Ministry of Health Guidelines in 2020 [4]. Experts still recommend measuring BP mostly in office to diagnose HTN and to use out-of-office BP monitoring techniques if 'these measurements are logistically and economically feasible'. The definition of HTN *per se* remained unchanged regarding office and ambulatory BP cut-offs. Unlike the previous 2013 edition [5], current Guidelines introduced a certain 'target range' (TR) of office BP values. This fundamental change poses several uncertainties at once.

As for the first one, there are still no corresponding target ranges for out-of-office BP, neither for ambulatory, nor for home (HBP). This issue is reported in the section 'gaps in the evidence' [3]. In the recent 2021 ESH position paper by the Working Group on Blood Pressure Monitoring and Cardiovascular Variability it was suggested that HBP values $\leq 130/80$ mmHg should be achieved [6]. This statement, however, was made with certain reservations due to the absence of specific supporting evidence. Interestingly, in the 'main changes' section of the document there is another statement claiming 'systolic home BP between 125 and 135 mmHg [should be a target] for most people' [6]. As for ambulatory BP monitoring only 2017 ACC/AHA Guidelines provided the corresponding ambulatory TR [7]. Both European and American experts agree on that the precise relationships between office, ambulatory and home BP are unsettled.

It is axiomatic that BP is not a single snapshot, but rather a dynamic measure with instant-to-seasonal variations. Office and diurnal BP variability is a well-known risk factor in hypertensive patients [8] and it is also true for home BP fluctuations [9, 10]. So, it seems reasonable to investigate BP ranges and not specific targets. A time or proportion of BP readings in target range (TTR) may be also an attractive therapeutic goal. Studies on office BP TTR emerged in the last 5 years and different scientific groups have found its association with major adverse cardiovascular events and mortality [11, 12]. As for ambulatory BP-derived measures (dipping status, BP load, area under BP curve, time above BP threshold) there is no clear consensus how to integrate them into clinical practice, as prognostic and diagnostic relevance of the most of them are a matter of debate [13]. Here comes **the second unknown**: to our knowledge, there are no studies aiming at home or ambulatory TTR.

Home BP monitoring (HBPM) is more attractive in terms of investigating TTR, as it is simple, feasible, cost effective, and user-friendly technique [14]. Its predictive accuracy is much alike 24-hour BP and superior to office BP. It is also has high reproducibility even in the short-term, because of a higher number of readings [6]. Its well-known difficulties (misreporting, handwritten logbooks, etc.) might be overcome by mobile health and other digital interventions. Several recently published meta-analyses confirm the superiority of HBPM over conventional office strategy especially when combined with BP telemonitoring (BPTM), additional support and patient education [15–17]. Therefore 'upgraded' HBPM is advantageous in obtaining reliable self-measured BP values for the custom timeframe to calculate and investigate TTR.

For this study we propose a therapeutic range between 110 and 130 mmHg for home systolic (S) BP to be a reasonable target for treatment and control of HTN. We also hypothesized that patients with higher

proportion of home SBP within the therapeutic range will have their office and home BP controlled independently of other confounding factors.

Methods

This was an open prospective one-group single-center 12-month study in patients with HTN, who attended HTN Center of Excellence in the city of St. Petersburg, Russian Federation. Of those who met inclusion/exclusion criteria were consecutively enrolled in a study with BPTM.

Inclusion criteria: uncontrolled HTN (office SBP level ≥ 140 mmHg or self-reported home SBP ≥ 135 mm Hg and ongoing treatment with at least one antihypertensive drug in the last month). Exclusion criteria were as follows: age above 80 years, symptomatic cardiovascular or other major comorbidities requiring close medical monitoring (<3-month periods), pregnancy, significant cognitive impairment, and active or acute mental problem. All the patients were to have a smartphone/tablet with instant high-speed Internet access (Wi-Fi or cellular 3 or 4 G).

The study design as follows: for the first 3 months patients are being actively monitored and counseled. The rest 9 months of the study represent passive follow-up which implies no mandatory office visits, and patients might continue BPTM at their sole intention. The final visit should have been conducted at 12-month point. For this analysis we used the data of the first 3-month active period.

All patients signed the informed consent document at the baseline visit. The study was carried according to the ICH GCP standards and the Helsinki Declaration of the World Medical Association. The study protocol was approved by the local ethics committee.

Office blood pressure

Office BP measurements were performed at baseline and at 3-month visits according to the ESC/ESH Guidelines [3]. Each time, BP was measured with automatic oscillometric device Omron M3 Expert (HEM 7132-ALRU, Kyoto, Japan) after 3-5 minutes of quiet rest in sitting position with the back and (dominant) arm supported. An appropriate bladder cuff was used, encircling at least 80% of the arm. Three serial BP readings were taken 1–2 minutes apart, and the average of the last two readings was displayed. We used two variations of SBP control in the office: a cut-off of <140 mmHg or TR within 120-139 mmHg.

Blood pressure telemonitoring and online counseling

A free simple website and a mobile application was used for patient–physician communication as well as storage and exchange of medical information. Detailed information on the hybrid telehealth solution can be found elsewhere [18]. In brief, patients used the mobile application, while web-based software was installed on office computers at the clinical site. Each patient was managed by the same physician throughout the follow-up period. At baseline, patients were registered in the program and their accounts were linked to doctors' ones. The interface allowed the patient to manually input the HBP data. A text chat

window was available for remote consultations (an unlimited number with a 24- to 72-hour timeframe for a physician to reply).

Home blood pressure monitoring

Initially it was recommended to record BP by a validated device in the morning and evening, 3 times in a row with 1-minute intervals, before meals and drug intake, for 3 to 7 days. Patients were advised to manually enter the last two BP readings into the electronic HBP diary. HBPM tutorials and the list of validated devices (STRIDE-BP [19]) were available for patients in the dedicated 'Support' section of the BPTM app. The supervising physician was advised to check HBP readings after the first week and then to adjust HBPM accordingly (using the text chat). Results of HBPM guided antihypertensive treatment titration. We used two variations of SBP control at home: a cut-off of <135 mmHg or TR within 110-130 mmHg.

Proportion of home systolic blood pressure readings in target range

Here we introduce the measure called proportion of home SBP readings in target range (sBPiTR). For this analysis we express this variable as the percent of home SBPs which fall within 110 and 130 mmHg in a certain time window (**Equation 1**)

$$sBPiTR = \left(\frac{\Sigma \text{ of SBP in TR}}{\Sigma \text{ of all SBP measurements}} \right) \times 100\% \quad (1)$$

Due to an observational nature of the study and our previous experience with BPTM, home monitoring might be chaotic. So, we did not expect patients would monitor BP on the daily basis but rather skip some days (or even weeks) taking breaks.

Hence, we applied 2 scenario towards calculation of sBPiTR: (1) to analyze all available BP measurements in the electronic diary except **the very first day** or (2) to analyze BP readings discarding **every first day** if HBPM was interrupted ≥ 7 days.

We then divided sBPiTR (0-3 months) into 4 groups (quartiles): high rate of home SBP control (75-100%), more than half of SBP readings in TR (50–74%), less than half of SBP readings in TR (25–49%), and low rate of home SBP control (0-24%).

Statistical analyses

Descriptive statistics included median and interquartile range, IQR for continuous variables (the data were non-normally distributed). We applied a frequency analysis (the χ^2 test) to assess the contingency between counts and proportions. We applied MacNemar's test for the paired nominal variables. Continuous variables were compared by Mann-Whitney U test, and Wilcoxon rank-sum test was used for paired parameters. Weighted Cohen's kappa coefficient was used as a measure of inter-rater reliability between office/home SBP (nominal variable) and different sBPiTR quartiles. Kappa coefficients were

interpreted according to McHugh [20]. Spearman's Rho (r_s) coefficient was used to assess the association between the variables.

Multivariate logistic regression analysis was used to assess the associations between controlled HTN (per office (1) or home (2) SBP) as dependent categorical variables (in TR/not in TR) and sBPiTR (main independent categorical variable), with the adjustment for age, sex, number of antihypertensive drugs, baseline office SBP (included as covariates). Only the best-case sBPiTR scenario was taken as a potential predictor and the results are presented as the odds ratio (OR) and 95% confidence interval (95% CI).

Two-sided p values <0.05 were considered significant.

Statistical analyses were carried out by two authors (MI, ME) using SPSS version 23 (IBM SPSS, Chicago, IL, United States), Python Software Foundation (Python Language Reference, version 2.7; available at <http://www.python.org>) and jamovi. (the jamovi project, version 1.6 for MacOS) retrieved from <https://www.jamovi.org>.

Results

Baseline characteristics

The current study included 123 patients. The baseline characteristics are presented in Table 1.

Table 1
Baseline characteristics of study participants

Variable	Median (IQR)
Age, y	54 (17)
Sex, males	102 (83%)
BMI, kg/m ²	28.4 (5.2)
Obesity	43 (35%)
Office SBP, mmHg	140 (23)
Office DBP, mmHg	83 (18)
Heart rate, bpm	70 (14)
Type 2 diabetes mellitus	10 (8%)
High -to-very high cardiovascular risk (SCORE \geq 5%)	102 (83%)
*Total cholesterol, mmol/L	5.23 (1.49)
*Serum glucose, mmol/L	5.76 (0.9)
*Serum creatinine, μ mol/L	82.1 (22.0)
Number of medications	2 (1 to 4)

Footnotes. BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index. In categorical variables n+% are presented. For number of antihypertensive drugs median and minimum to maximum are presented. *Missing data for total cholesterol, serum glucose and serum creatinine in 17, 8 and 13 patients, respectively.

These were predominantly middle-aged, mildly hypertensive Caucasian males of high or very-high cardiovascular risk. One third of them were overweight or obese, and less than 10% were diagnosed with type 2 diabetes mellitus. They were prescribed a median of 2 drugs to treat HTN. Most of them were taking RAAS inhibitors and diuretics in fixed combinations.

Overall results of a three-month surveillance

After the three months of close surveillance there was noted a significant reduction of a median office BP: to 132 mmHg (IQR 16 mmHg) and to 80 mmHg (IQR 13 mmHg), $p < 0.001$ for both. By the end of an active time window 74 of 123 patients had had their office SBP in TR ($p < 0.001$) and in 93 of them office SBP was lower than 140 mmHg ($p < 0.001$). There was no change in heart rate (70 beats per minute [IQR 12], $p = 0.08$). Of 123 patients 59 (48%) had stopped HBPM after about 1 month, but after additional phone calls or text notifications most of them resumed it. The mean number of text consultations within the 3-month period was 37 ± 18 per patient. The number of antihypertensive drugs has not changed over

time (median of 2 medications, $p = 0.1$). Most frequently patients were advised to change their medications to more potent ones or due to side effects (48.6%) or no actions were taken (22.9%) and patients were given only lifestyle advice. One adverse event was captured for the whole 3 months in this cohort. It was drug-induced orthostatic hypotension with syncope in male who took his medications before the strenuous physical activity (resolved without sequelae).

Home systolic blood pressure in target range

The median number of HBP measurements was 85 per patient (from 3 to 398). There were significantly more patients whose home SBP was in TR at 3 months (90 vs 30; $p < 0.001$). When the discrete home SBP target (< 135 mmHg) was applied, we noticed that 110 patients achieved it ($p < 0.001$). There were 16.3%, 13.8%, 30.1% and 39.8% patients in lowest to highest sBPiTR quartiles, respectively ($\chi^2 = 22$; $p < 0.001$). There were significantly more patients with sBPiTR $\geq 50\%$ than those with $< 50\%$ (87 vs 36 [1 scenario] and 86 vs 37 [2 scenario], $p < 0.001$ for both) but much fewer in the upper quartile (49 vs 74 in both scenario, $p = 0.03$) (Fig. 1). There was no differences between quartiles or between $\geq 50\%$ and $\geq 75\%$ groups regarding office SBP and Δ office SBP. The only statistically significant difference was noted between $\geq 50\%$ and $< 50\%$ (both scenario) in regards to home SBP at 3 months: mean difference $- 4.00$, 95% CI $[-9.0$ to $-1.0]$, $p = 0.03$.

Our analysis revealed a slight inter-rater reliability of sBPiTR compared with office BP in TR (second scenario only) but not for discrete office SBP cut-off (< 140 mmHg). There was a fair (second scenario) to substantial (first scenario) agreement between sBPiTR $\geq 50\%$ and home SBP in TR and a fair agreement between sBPiTR $\geq 50\%$ and home SBP < 135 mmHg. A fair agreements were found between sBPiTR $\geq 75\%$ (both scenario) and home SBP in TR (Table 2).

Table 2
Inter-rater reliability between sBPiTR and conventional therapeutic targets

Variable	κ Cohen's	Spearman r_s
sBPiTR. First scenario		
sBPiTR ($\geq 50\%$ vs $< 50\%$) X office BP < 140 mmHg	0.03 [#]	0.03 [#]
sBPiTR ($\geq 50\%$ vs $< 50\%$) X home SBP < 135 mmHg	0.36**	0.45**
sBPiTR ($\geq 50\%$ vs $< 50\%$) X office SBP in TR	0.09 [#]	0.09 [#]
sBPiTR ($\geq 50\%$ vs $< 50\%$) X home SBP in TR	0.65**	0.65**
sBPiTR ($\geq 75\%$ vs $< 75\%$) X office BP < 140 mmHg	-0.07 [#]	-0.1 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X home SBP < 135 mmHg	0.09 [#]	0.2 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X office SBP in TR	0.08 [#]	0.09 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X home SBP in TR	0.21**	0.27**
sBPiTR. Second scenario		
sBPiTR ($\geq 50\%$ vs $< 50\%$) X office BP < 140 mmHg	0.09 [#]	0.1 [#]
sBPiTR ($\geq 50\%$ vs $< 50\%$) X home SBP < 135 mmHg	0.24**	0.29**
sBPiTR ($\geq 50\%$ vs $< 50\%$) X office SBP in TR	0.19*	0.19*
sBPiTR ($\geq 50\%$ vs $< 50\%$) X home SBP in TR	0.32**	0.32**
sBPiTR ($\geq 75\%$ vs $< 75\%$) X office BP < 140 mmHg	0.07 [#]	0.1 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X home SBP < 135 mmHg	0.09 [#]	0.18 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X office SBP in TR	0.11 [#]	0.12 [#]
sBPiTR ($\geq 75\%$ vs $< 75\%$) X home SBP in TR	0.21**	0.27**

Footnotes. ** $P < 0.01$, * $P < 0.05$, # $P \geq 0.05$. sBPiTR: proportion of [home] systolic blood pressure readings in target range; SBP: systolic blood pressure; TR: target range (for office SBP: 120–139 mmHg; for home SBP: 110–130 mmHg). First scenario: excluding the very first day of home blood pressure monitoring. Second scenario: excluding every first day of home blood pressure monitoring if it interrupts for ≥ 7 days.

Multivariate logistic regression analysis (adjusted for age, sex, number of drugs, baseline office SBP) revealed that compared with the group whose sBPiTR was $< 50\%$ (the reference group), patients from the group with $\geq 50\%$ sBPiTR were more likely to have office BP in TR (OR 2.41 [95% CI, 1.06–5.51]). This was true as well for home SBP in TR (OR 5.2 [95% CI, 2.06–13.12]) and for home SBP < 135 mmHg (OR 7.58 [95% CI, 1.87–30.81]) but not for office SBP < 140 mmHg (OR 1.56 [95% CI, 0.65–3.76]). The upper

quartile of sBPiTR (compared to all other three) was associated only with home SBP in TR (OR 4.86 [95% CI, 1.74–13.59]).

Discussion

Our small study reiterated that BPTM gives an opportunity to collect large amounts of home BP values. Relying on the support of telehealth, we proposed sBPiTR as the new potential therapeutic target for patients with HTN. We have revealed that a threshold of 50% of home SBP measurements within 110–130 mmHg has a slight agreement with office BP control and at least fair agreement with home BP control. The latter becomes even more evident especially when HBPM protocol is followed strictly with discarding every first day.

The term BP variability has been known for almost 30 years. About 20 years ago Rothwell et al. suggested long term BP variability predicts stroke and coronary events in high risk patients [21], which then was confirmed in a meta-analysis of 33 studies by Stevens et al. in 2016 [22]. But the authors of the latter study reasonably stated that BP variability is not simply calculated at hand, and it is unclear if certain measures should be preferred over another (standard deviation, coefficient of variation, variation independent of mean, etc.). These necessitated the search for other and easy to use measures of BP fluctuations, such as BP load [23], cumulative BP [24] and finally, TTR.

Several scientific groups in the last 5 years were focused on TTR because this parameter represents BP variability over the time course. This concept is 'novel' and nascent but only in the field of HTN as TTR has been integrated successfully in other fields of cardiovascular and preventive medicine, like vitamin K therapy or diabetes treatment [25, 26]. Cohort studies with the data on hundreds of thousands of participants have showed that BP TTR is closely associated with all-cause and cardiovascular mortality as well as morbidity [11, 27]. Interestingly, in the recent secondary analysis of SPRINT study TTR was found to be an independent predictor of major adverse cardiovascular events even after adjustment for BP variability and a mean BP [12]. The raised interest to this new variable is intuitive because TTR reflects a more holistic view of an individual patient's BP control. At least two trials used TTR as an endpoint [28] or as a guide to make treatment decisions (HyperLink trial) [29].

The main body of evidence is based primarily on in-office BP values in TR. In contrast, the uniqueness of HBP is in the large amounts of data which could be easily collected within a short period of time (weeks to months). So, there is no need to perform complex linear interpolation calculations to find TTR [30]. This makes HBPM favorably different from other measurement techniques. The main uncertainty lies in the HBP TR *per se* because the Guidelines and experts do not point a definitive answer on this issue. Bearing in mind that there is strong evidence on J-curve phenomenon [31] for the office BP, and a belief that there is a 10 mmHg difference between home and office BP [6], for the present study we applied a relatively fluent TR 110–130 mmHg.

Home BP is very valuable in clinical practice. However, a remarkable and counterintuitive phenomenon has been recently discovered. Of all eligible for out-of-office BP monitoring, only 3–4% are advised to

perform HBPM and 15–16% of patients do it irrespective of the doctor's advice [32]. How many of these patients perform HBPM correctly? The accuracy and reliability of HBPM requires not only the use of a validated device, but following standardized procedures, good patient education and training [10]. In this regard BPTM is helpful for establishing HBPM regime, thus improving treatment adherence and doctor-patient relations [33]. The proper HBPM may reduce the need for office visits, as forced the recent COVID-19 pandemic [34]. Therefore, our proposed target (sBPiTR) becomes even more crucial as self-monitored BP in the long-term run.

The limitations of our study should be mentioned. These are relatively small number of patients observed, the absence of a comparator group and an observational nature of study. All of these contribute to selection, ascertainment, and information bias. On the other hand, the study design does not mandatory need a comparison group. Also, an increase in the number of patients with no to very few home BP measurements will most certainly fail to lead to an equal increase in the data reliability (i.e., compliance bias). In this regard we did our best to keep patients under follow-up and actively consulted them so that HBPM continued properly. Regarding the relatively short study duration it should be firstly mentioned that (a) several ABPM indicators like BP load or area under BP curve [35] are calculated for 24 hours only and (b) in recent studies only few baseline home readings were used to enhance predictive ability of BP profile (without continued HBPM) [36]. Secondly, we preferred 3 months as time-window because of its principal importance for management of uncontrolled HTN [3, 7], during which Guidelines recommend to achieve the TR.

In conclusion we should summarize that proportion of home sBPiTR may serve a reasonable treatment target as it positively reflects HTN control and may act as a predictor for achievement of target SBP both in- and out-of office.

Larger studies are needed to confirm these preliminary results. We are extremely interested to pursue our efforts in this direction. Further work will aim at increasing the number of patients in the ramping BPTM program to confirm its feasibility and perceived usefulness. We also aim to facilitate more structured HBPM schedule and to proceed to automatic BP data uploading which is in line with the Internet-of-Medical-Things paradigm [37] and is showed to be more reliable than manually imputed values [38]. We plan to expand the follow-up for patients, the frequency of office visits and compare the TTR with sBPiTR. Finally, ABPM data should be integrated and sBPiTR should be tested against 'hard' endpoints like organ damage.

Declarations

Acknowledgments

The authors are grateful to Dr. Natiia Orbeladze, Dr. Natalia Avdonina, Dr. Asiiat Alieva and Dr. Alexey Yakovlev for their cooperation in patient enrollment. The authors also wish to thank Dr. Igor Emelyanov for his useful comments.

Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation: Mikhail Ionov, Elena Usova, Michil Egorov

Performed data acquisition, as well as provided administrative, technical, and material support: Nadezhda Zvartau, Alexandra Konradi

All authors contributed to interpretation of the results, and meaningful contribution to writing and accepting the final manuscript.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, Mikhail Ionov, upon reasonable request.

Financial support and sponsorship

This work was financially supported by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 075-15-2020-901).

Conflicts of interest

All authors declared that there are no conflicts of interest related to this manuscript.

Ethical approval and consent to participate

All patients signed the informed consent document at the baseline visit. The study was carried according to the ICH GCP standards and the Helsinki Declaration of the World Medical Association. The protocol was approved by the local ethics committee.

Consent for publication

Not applicable

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References

1. Kalehoff JP, Oparil S. The Story of the Silent Killer: A History of Hypertension: Its Discovery, Diagnosis, Treatment, and Debates. *Curr Hypertens Rep* 2020;22:72. <https://doi.org/10.1007/s11906-020-01077-7>.

2. Blood Pressure Lowering Treatment Trialists' Collaboration. Age-stratified and blood-pressure-stratified effects of blood-pressure-lowering pharmacotherapy for the prevention of cardiovascular disease and death: an individual participant-level data meta-analysis. *Lancet Lond Engl* 2021;398:1053–64. [https://doi.org/10.1016/S0140-6736\(21\)01921-8](https://doi.org/10.1016/S0140-6736(21)01921-8).
3. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension. *Eur Heart J* 2018;39:3021–104. <https://doi.org/10.1093/eurheartj/ehy339>.
4. Kobalava Z.D., Konradi A.O., Nedogoda S.V., Shlyakhto E.V., Arutyunov G.P., et al. Arterial hypertension in adults. Clinical guidelines 2020. *Russian Journal of Cardiology*. 2020;25(3):3786. (In Russ.). <https://doi.org/10.15829/1560-4071-2020-3-3786>.
5. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, et al. 2013 ESH/ESC guidelines for the management of arterial hypertension: the Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *Eur Heart J* 2013;34:2159–219. <https://doi.org/10.1093/eurheartj/eh151>.
6. Parati G, Stergiou GS, Bilo G, Kollias A, Pengo M, et al. Home blood pressure monitoring: methodology, clinical relevance and practical application: a 2021 position paper by the Working Group on Blood Pressure Monitoring and Cardiovascular Variability of the European Society of Hypertension. *J Hypertens* 2021;39:1742–67. <https://doi.org/10.1097/HJH.0000000000002922>.
7. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertens Dallas Tex* 1979 2017. <https://doi.org/10.1161/HYP.0000000000000066>.
8. Kario K. Blood pressure variability in hypertension: A possible cardiovascular risk factor. *Am J Hypertens* 2004;17:1075–6. <https://doi.org/10.1016/j.amjhyper.2004.06.021>.
9. Schutte AE, Kollias A, Stergiou GS. Blood pressure and its variability: classic and novel measurement techniques. *Nat Rev Cardiol* 2022. <https://doi.org/10.1038/s41569-022-00690-0>.
10. Kario K. State-of-the-Art review: Home blood pressure monitoring: current status and new developments. *Am J Hypertens* 2021:hpab017. <https://doi.org/10.1093/ajh/hpab017>.
11. Doulas M, Tsioufis C, Fletcher R, Amdur R, Faselis C, Papademetriou V. Time in Therapeutic Range, as a Determinant of All-Cause Mortality in Patients With Hypertension. *J Am Heart Assoc Cardiovasc Cerebrovasc Dis* 2017;6:e007131. <https://doi.org/10.1161/JAHA.117.007131>.
12. Fatani N, Dixon DL, Van Tassell B, Fanikos J, Buckley LF. Systolic Blood Pressure Time in Target Range and Cardiovascular Outcomes in Patients with Hypertension. *J Am Coll Cardiol* 2021;77:1290–9. <https://doi.org/10.1016/j.jacc.2021.01.014>.
13. O'Brien E, Parati G, Stergiou G, Asmar R, Beilin L, et al. European Society of Hypertension position paper on ambulatory blood pressure monitoring. *J Hypertens* 2013;31:1731–68.

<https://doi.org/10.1097/HJH.0b013e328363e964>.

14. Andraos J, Munjy L, Kelly MS. Home blood pressure monitoring to improve hypertension control: a narrative review of international guideline recommendations. *Blood Press* 2021;30:220–9. <https://doi.org/10.1080/08037051.2021.1911622>.
15. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, et al. Self-monitoring of blood pressure in hypertension: A systematic review and individual patient data meta-analysis. *PLoS Med* 2017;14:e1002389. <https://doi.org/10.1371/journal.pmed.1002389>.
16. Park S-H, Shin J-H, Park J, Choi W-S. An Updated Meta-Analysis of Remote Blood Pressure Monitoring in Urban-Dwelling Patients with Hypertension. *Int J Environ Res Public Health* 2021;18:10583. <https://doi.org/10.3390/ijerph182010583>.
17. Caverro-Redondo I, Saz-Lara A, Sequí-Dominguez I, Gómez-Guijarro MD, Ruiz-Grao MC, et al. Comparative effect of eHealth interventions on hypertension management-related outcomes: A network meta-analysis. *Int J Nurs Stud* 2021;124:104085. <https://doi.org/10.1016/j.ijnurstu.2021.104085>.
18. Ionov MV, Zhukova OV, Yudina YS, Avdonina NG, Emelyanov IV, Kurapeev DI, et al. Value-based approach to blood pressure telemonitoring and remote counseling in hypertensive patients. *Blood Press* 2021:20–30. <https://doi.org/10.1080/08037051.2020.1813015>.
19. STRIDE BP Scientific Advisory Board. VALIDATED DEVICES FOR HOME BLOOD PRESSURE MONITORING 2019. Available from: <https://stridebp.org/bp-monitors/37-pdfs/734-home?format=pdf&tmpl=component&box=home> [Last accessed on 03 Jul 2022].
20. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Medica* 2012;22:276–82. <https://doi.org/10.11613/BM.2012.031>
21. Rothwell PM, Howard SC, Dolan E, O'Brien E, Dobson JE, et al. Prognostic significance of visit-to-visit variability, maximum systolic blood pressure, and episodic hypertension. *Lancet Lond Engl* 2010;375:895–905. [https://doi.org/10.1016/S0140-6736\(10\)60308-X](https://doi.org/10.1016/S0140-6736(10)60308-X).
22. Stevens SL, Wood S, Koshiaris C, Law K, Glasziou P, et al. Blood pressure variability and cardiovascular disease: systematic review and meta-analysis. *The BMJ* 2016;354:i4098. <https://doi.org/10.1136/bmj.i4098>.
23. Zachariah PK, Sheps SG, Ilstrup DM, Long CR, Bailey KR, et al. Blood Pressure Load—a Better Determinant of Hypertension. *Mayo Clin Proc* 1988;63:1085–91. [https://doi.org/10.1016/S0025-6196\(12\)65503-7](https://doi.org/10.1016/S0025-6196(12)65503-7).
24. Reges O, Ning H, Wilkins JT, Wu CO, Tian X, et al. Association of Cumulative Systolic Blood Pressure With Long-Term Risk of Cardiovascular Disease and Healthy Longevity: Findings From the Lifetime Risk Pooling Project Cohorts. *Hypertens Dallas Tex 1979* 2021;77:347–56. <https://doi.org/10.1161/HYPERTENSIONAHA.120.15650>.
25. Schmitt L, Speckman J, Ansell J. Quality assessment of anticoagulation dose management: comparative evaluation of measures of time-in-therapeutic range. *J Thromb Thrombolysis* 2003;15:213–6. <https://doi.org/10.1023/B:THRO.0000011377.78585.63>.

26. Advani A. Positioning time in range in diabetes management. *Diabetologia* 2020;63:242–52. <https://doi.org/10.1007/s00125-019-05027-0>.
27. Chung S-C, Pujades-Rodriguez M, Duyx B, Denaxas SC, Pasea L, et al. Time spent at blood pressure target and the risk of death and cardiovascular diseases. *PLOS ONE* 2018;13:e0202359. <https://doi.org/10.1371/journal.pone.0202359>.
28. Dixon DL, Baker WL, Buckley LF, Salgado TM, Van Tassell BW, Carter BL. Effect of a Physician/Pharmacist Collaborative Care Model on Time in Target Range for Systolic Blood Pressure: Post Hoc Analysis of the CAPTION Trial. *Hypertens Dallas Tex 1979* 2021;78:966–72. <https://doi.org/10.1161/HYPERTENSIONAHA.121.17873>.
29. Margolis KL, Asche SE, Bergdall AR, Dehmer SP, Groen SE, et al. Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control: a cluster randomized clinical trial. *JAMA* 2013;310:46–56. <https://doi.org/10.1001/jama.2013.6549>.
30. Rosendaal FR, Cannegieter SC, van der Meer FJ, Briët E. A method to determine the optimal intensity of oral anticoagulant therapy. *Thromb Haemost* 1993;69:236–9. PMID: 8470047.
31. Messerli FH, Bangalore S, Messerli AW, Räber L. The muddy waters of the J-curve and coronary revascularization. *Eur Heart J* 2020;41:1684–6. <https://doi.org/10.1093/eurheartj/ehaa054>.
32. Bryant KB, Green MB, Shimbo D, Schwartz JE, Kronish IM, et al. Home Blood Pressure Monitoring for Hypertension Diagnosis by Current Recommendations: A Long Way to Go. *Hypertens Dallas Tex 1979* 2022;79:e15–7. <https://doi.org/10.1161/HYPERTENSIONAHA.121.18463>.
33. Omboni S, McManus RJ, Bosworth HB, Chappell LC, Green BB, et al. Evidence and Recommendations on the Use of Telemedicine for the Management of Arterial Hypertension: An International Expert Position Paper. *Hypertens Dallas Tex 1979* 2020;76:1368–83. <https://doi.org/10.1161/HYPERTENSIONAHA.120.15873>.
34. Omboni S, Padwal RS, Alessa T, Benczúr B, Green BB, et al. The worldwide impact of telemedicine during COVID-19: current evidence and recommendations for the future. *Connect Health* 2022;1:7–35. <https://doi.org/10.20517/ch.2021.03>.
35. Kengne A-P, Czernichow S, Huxley R, Grobbee D, Woodward M, et al. Blood Pressure Variables and Cardiovascular Risk. *Hypertension* 2009;54:399–404. <https://doi.org/10.1161/HYPERTENSIONAHA.109.133041>.
36. Mancia G, Facchetti R, Seravalle G, Cuspidi C, Corrao G, Grassi G. Adding Home and/or Ambulatory Blood Pressure to Office Blood Pressure for Cardiovascular Risk Prediction. *Hypertension* 2021;77:640–9. <https://doi.org/10.1161/HYPERTENSIONAHA.120.16303>.
37. Omboni S. Connected Health in Hypertension Management. *Front Cardiovasc Med* 2019;6:76. <https://doi.org/10.3389/fcvm.2019.00076>.
38. Parker RA, Paterson M, Padfield P, Pinnock H, Hanley J, et al. Are self-reported telemonitored blood pressure readings affected by end-digit preference: a prospective cohort study in Scotland. *BMJ Open* 2018;8:e019431. <https://doi.org/10.1136/bmjopen-2017-019431>

Figures

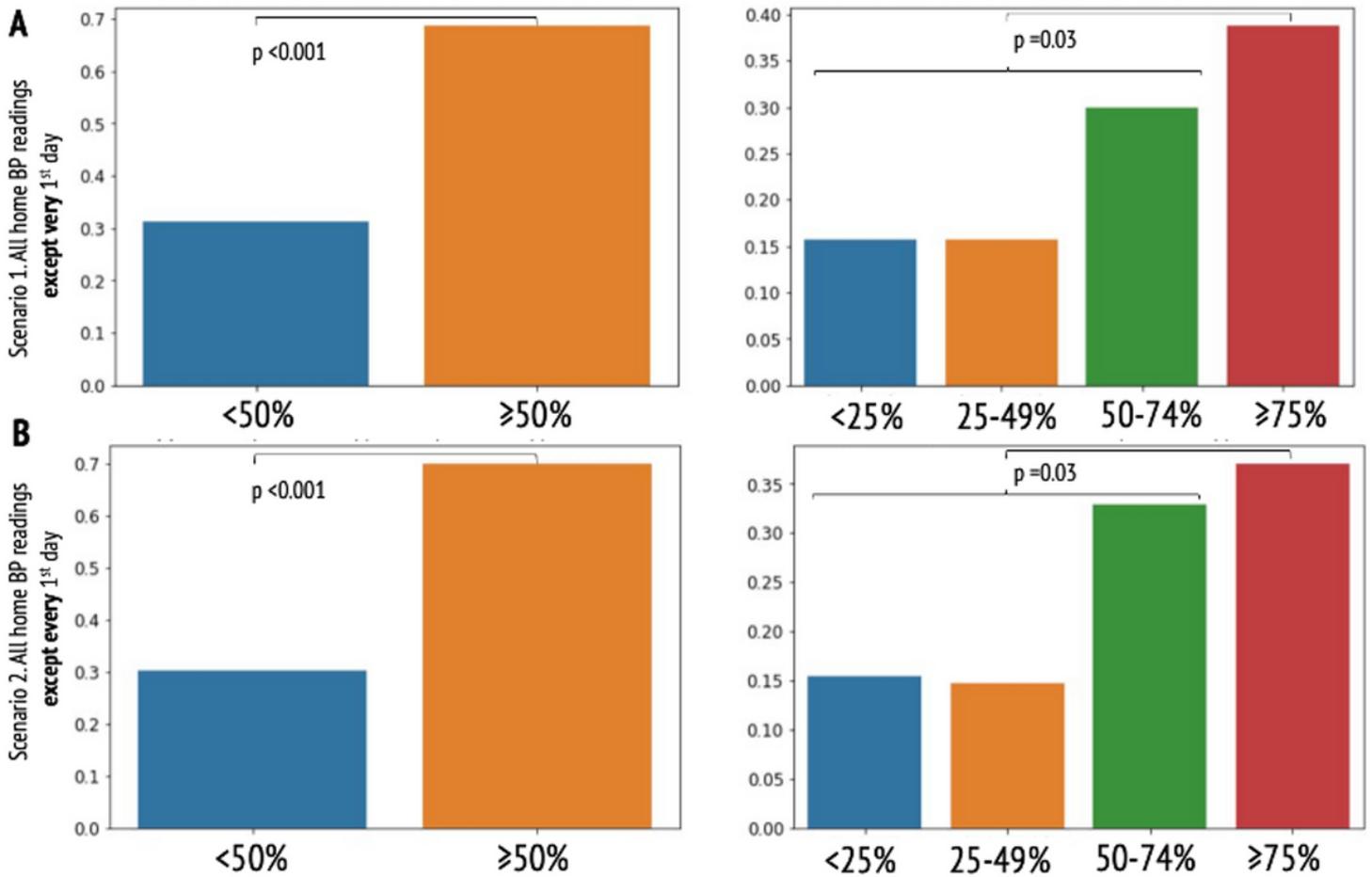


Figure 1

Proportions of patients with home systolic blood pressure in target range. A, excluding the very first day of home blood pressure monitoring (scenario 1). B, excluding every first day of home blood pressure monitoring if it interrupts for ≥ 7 days.