Things change: The early identification of patients with an unfavourable prognosis

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Chapter 4

The early identification of patients at risk of persistent uncontrolled hypertension, using self-monitored blood pressure.

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ABSTRACT

Background

Early identification of patients with an increased risk of persistent uncontrolled hypertension could provide opportunities for timely adjustment of treatment. To that end, we aimed to develop an easy to use prediction model to identify patients at risk of persistent uncontrolled hypertension.

Methods

We used data of 56 adult with uncontrolled hypertension from a 12-month primary care RCT with three-monthly assessments and self-monitored blood pressure measurements. With logistic regression we modelled the association between level of persistent uncontrolled hypertension risk, patient characteristics, and early treatment response. Persistent uncontrolled hypertension was defined as self-monitored blood pressure of > 135 mmHg at 12 months.

Results

Patients had a mean age of 61.9 (SD 8.3) and 54.4% was female. The mean systolic self-monitored blood pressure was 144.8 (SD 12.4) at baseline. Taking data on early treatment response into account, self-monitored blood pressure after approximately two months, the risk prediction improved (AUROC 0.91) compared to a model containing only baseline self-monitored blood pressure (AUROC = 0.82). The risk prediction includes two easy to obtain predictors, namely; the initial self-monitored blood pressure and the first follow-up self-monitored blood pressure. Other (patient characteristic) predictors did not contribute to the prediction.

Conclusion

We developed an easy to use risk prediction score to identify patients with persistent uncontrolled hypertension after one year of high blood pressure treatment, based on baseline and two month self-monitored blood pressure. It can be used as an online self-management support in order to improve real-time blood pressure.

INTRODUCTION

Worldwide, over one billion people have hypertension.[1] Hypertension is one of the most prominent risk factors of cardiovascular morbidity and mortality.[2] Hypertension is a silent (chronic) condition, therefore, many people will not experience any symptoms. However, raised blood pressure could lead to health issues, including heart attack and stroke. Lowering blood pressure (BP) by lifestyle and drug treatment strategies can substantially reduce premature morbidity and mortality. However, for the majority of patients having hypertension, control of blood pressure remains sub-optimal.[3]

Treatment of hypertension is still mainly based on clinical blood pressure measurements. However, self-monitored blood pressure has several advantages such as a higher frequency of blood pressure measurements, elimination of the white coat effect, low costs and easy application.[4-6] Furthermore, several studies have also shown self-monitored blood pressure is superior to clinical measurements in predicting important end points, including all-cause mortality, progression of chronic kidney disease, and functional decline in the elderly.[7]

To date, most hypertension prognostic models include only one initial self-monitored blood pressure measurement, besides other predictive factors including smoking status, treatment adherence, age, level of education, sex, ethnicity and body mass index (BMI).[8] The performance of a prognostic model might substantially improve by including the early treatment response, as we have recently demonstrated in asthma.[9] More importantly, such a prognostic model including identification of patients with an unfavourable early treatment response potentially allows early identification of those patients with an increased risk of persistent uncontrolled hypertension, thereby providing opportunities for timely adjustment of treatment. Thus far, only limited data is available on repeated blood pressure measurements in a prognostic model and home measurements were not incorporated, even despite the common mentioned advantage of (continuously) self-monitored blood pressure.[8,10,11] We hypothesized that adding an assessment of early treatment response after three months aids in the prediction of persistent uncontrolled hypertension.

Overall, the aim of this study was to develop an easy to use prediction model, in patients currently diagnosed with hypertension, based on patient characteristics and early treatment response assessed by self-monitored blood pressure measurements.

METHODS

Study design

We analysed potential predictive variables of hypertension using primary care data from the TeleHype-study: a trial of TELEmonitoring and self-management support of patients with uncontrolled HYPErtension. The dataset was obtained from a pragmatic randomized control trial (RCT) comparing solely usual care to telemonitoring of blood pressure and self-management support via an internet-based service, in addition to usual care. We only analysed data of the telemonitoring strategy with self-monitored blood pressure measurements, as data of the usual care strategy did not contain sufficient information on early treatment response. Clinicians provided treatment according to usual care, based on (inter)national evidence-based treatment guidelines, supported by an online self-management tool. Patients were asked to monitor blood pressure as often as they wanted, patients were encouraged to do this especially in a 7-day intensified monitoring period. During the 7-day intensified monitoring period patients were asked to monitor blood pressure twice in the morning and twice in the evening over three out of seven consecutive days; according to the European Society of Hypertension (ESH) and European Society of Cardiology (ESC) guidelines.[12] A detailed description of study procedures and participants will be published elsewhere (trial registry: ISRCTN10969896).

Study population

In this cohort patients were aged 18-75 years, with a diagnosis of hypertension in general practice; a systolic office blood pressure > 140 mmHg, or if diabetes or chronic kidney disease were present > 130 mmHg. Follow-up was 12 months and patients filled out online questionnaires at approximately three-monthly intervals. We limited our selection to patients with completed self-monitored blood pressure measurements at twelve months.

Potential predictor variables

Demographic and clinical variables that potentially predict future risk were obtained at baseline including age, sex and current smoking status. At baseline, medication adherence was assessed with the Medication Adherence Report Scale (MARS),[13] indirect utilities from the general public were obtained by the EuroQol 5 dimensions (EQ-5D).[14,15] Self-management characteristics are measured using the Partners In Health scale (PIH-NL).[16] At baseline and per three-monthly interval mean self-monitored blood pressure was measured, and health-related quality of life was assessed with the Short Form (SF)-12.[17] The results obtained three months after the baseline visit were used as

measures of early treatment response.

Outcome

Our primary outcome of interest was the presence of self-monitored hypertension after twelve months of treatment. We classified patients as having persistent uncontrolled hypertension based on their mean self-monitored blood pressure of > 135 mmHg at twelve months of follow-up. Mean self-monitored blood pressure was calculated based on twelve self-monitored blood pressure measurements within seven consecutive days, patients were asked to measure their blood pressure four times per day, twice in the morning and twice in the evening. In keeping with international guidelines, the first four measurements were eliminated (the first day of measurements), and the mean self-monitored blood pressure was calculated based on the remaining eight self-monitored blood pressure measurements.[18-21]

Model development

With logistic regression we studied the relation between uncontrolled self-monitored blood pressure (>135 mmHg) at twelve months and baseline characteristics plus the information on early treatment response. Baseline variables that were univariably associated with future risk (p-value < 0.10) were initially selected for multivariable logistic regression and backward selection was performed (p-value < 0.10). Second, we studied the additional contribution of information on early treatment response by adding variables, assessed at three months follow-up, to the first multivariable logistic regression model. Performance of all multivariable models was assessed with the area under the receiver operating curve (AUROC), which we internally validated with 2,000 bootstraps. Based on the regression coefficients of our final model a risk prediction score was developed as extensively described by Sullivan et al. (2004), in order to facilitate clinical application of the model (*online supplement, table S1*).[22] Cut-offs were based on sensitivity and specificity, and clinical perspective, in relation to the outcome of persistent uncontrolled hypertension.

RESULTS

Patient information

We included 56 patients with a diagnosis of hypertension (table 1). Patients had a mean age of 61.9 (SD 8.3) and 54.4% was female. The mean systolic self-monitored blood pressure was 144.8 (SD 12.4) at baseline (first 7-day intensified monitoring period), and blood pressure significantly improved at the second 7-day intensified monitoring

period (mean systolic self-monitored blood pressure 138.8; SD 13.6), on average 2.6 months after baseline.

TABLE 1. *Baseline characteristics (n = 56). For continuous variables; values are stated as the mean (standard deviation). For categorical variables; values are numbers (percentages).*

Continuous variables	
Age years	63.9 (8.4)
Systolic blood pressure (mmHg)	144.8 (12.4)
Diastolic blood pressure (mmHg)	87.0 (9.8)
EQ-5D	0.9 (0.1)
EQ-5D Visual Analogue Scale	76.7 (15.5)
Medication Adherence Report Scale	3.4 (0.5)
SF-12 Physical Health Score	-61.5 (8.1)
SF-12 Mental Health Score	-71.8 (10.7)
PIH-NL Knowledge	26.2 (4.6)
PIH-NL Coping	19.7 (3.5)
PIH-NL Management in symptoms	20.2 (3.3)
PIH-NL Adherence to treatment	14.2 (2.3)
PIH-NL Total	80.3 (11.6)
Categorical variables	
Female sex	30 (53.6)
Current smokers	4 (7.1)

SF-12 = Short Form , EQ-5D = EuroQol 5 dimensions, PIH = Partners In Health

TABLE 2. *Univariable odds ratios (95% confidence interval) and corresponding p-values in the derivation dataset.**

Continuous variables	**Odds ratio (CI95%)**	**p-value**
Age years	1.01 (0.95-1.08)	0.74
Systolic blood pressure (mmHg)	1.08 (1.02-1.16)	0.01
Diastolic blood pressure (mmHg)	0.05 (0.00-93.46)	0.43
EQ-5D	0.98 (0.95-1.02)	0.28
EQ-5D Visual Analogue Scale	0.58 (0.22-1.57)	0.29
Medication Adherence Report Scale	1.08 (1.02-1.16)	0.01
SF-12 Physical Health Score	1.01 (0.94-1.07)	0.88
SF-12 Mental Health Score	1.00 (0.96-1.05)	0.90
PIH-NL Knowledge	0.93 (0.83-1.05)	0.24
PIH-NL Coping	1.02 (0.88-1.19)	0.80
PIH-NL Management in symptoms	0.98 (0.83-1.15)	0.82
PIH-NL Adherence to treatment	0.83 (0.65-1.07)	0.15
PIH-NL Total	0.98 (0.94-1.03)	0.45
Categorical variables		
Female sex	1.12 (0.39-3.21)	0.83
Current smokers	1.30 (0.17-9.97)	0.80

SF-12 = Short Form , EQ-5D = EuroQol 5 dimensions, PIH = Partners In Health

Predictors of uncontrolled self-monitored blood pressure

With univariable logistic regression, uncontrolled self-monitored blood pressure (> 135 mmHg) at twelve months was significantly predicted by systolic and diastolic self-monitored blood pressure at baseline, with respectively an OR of 1.14 (CI95% 1.06-1.24) and an OR of 1.08 (CI95% 1.02-1.16) per mmHg (table 2). Other baseline variables were not univariable associated with persistent uncontrolled hypertension.

Using multivariable logistic regression analysis with the univariably associated baseline variables only systolic self-monitored blood pressure remained in the model after backward selection, therefore resulting in a univariable prediction model, corresponding to an internally validated AUROC of 0.82 (0.71-0.93). Multivariable logistic regression analysis with both systolic self-monitored blood pressure measurements, initial systolic blood pressure and systolic blood pressure after approximately two months, resulted in an internally validated AUROC of 0.91 (0.84-0.98); both measurements remained in the model (OR of 1.09 (1.00-1.19) and an OR of 1.18 (1.05-1.33)). The AUROC of the model with early treatment response differs significantly from the model without early treatment response ($p < 0.05$) (figure 1).

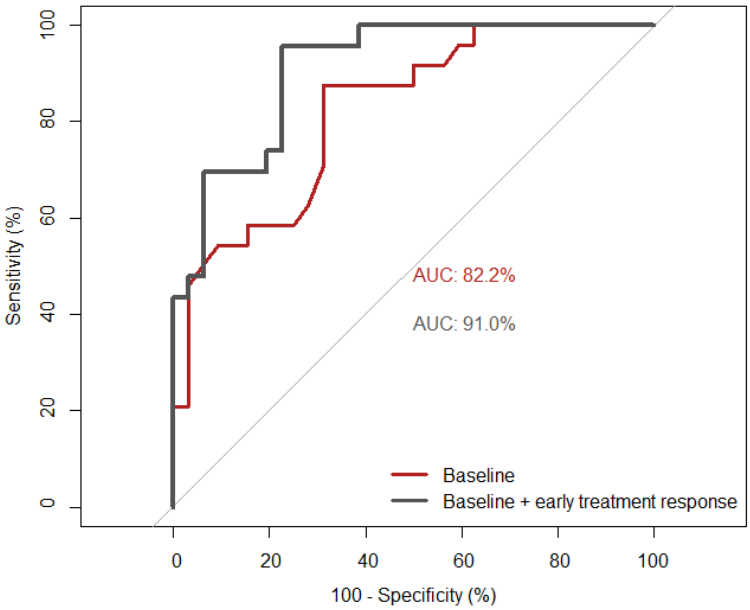

FIGURE 1. *ROC-curves for models with and without early treatment response. The AUROC of the model with early treatment response differs significantly from the model without early treatment response (p = 0.03).*

Figure 2 presents the risk prediction scores corresponding to the final model. From our final prediction model, we derived an easy to calculate score which ranged from -1 to 12. For 57% of patients with a risk score of 5-12 points, the positive predictive value of prolonged treatment course was 65%, compared to 5% (1-negative predictive value) for patients with a score of 0-4 points. At this cut-off level sensitivity was 0.96 and specificity 0.64. For a risk score of 5-12 points either baseline systolic self-monitored blood pressure was ≥ 150 mmHg or after approximately two months of treatment systolic self-monitored blood pressure was ≥ 130 mmHg. See also table 5.

		CURRENT VISIT					
		< 120	120-129	130-139	140-149	150-159	160+
PREVIOUS VISIT (2-3 month before)	< 120	-1	0	2	4	6	8
	120-129	-1	0	2	4	6	8
	130-139	0	1	3	5	7	9
	140-149	1	2	4	6	8	10
	150-159	2	3	5	7	9	11
	160+	3	4	6	8	10	12

FIGURE 2. *The risk prediction score in clinical practice: simplified. The risk prediction score is assessed within two moments of time. Higher scores indicate a higher risk of persistent hypertension (ranging from -1 to 12). For patients with a risk score of 5-12 points, the positive predictive value of persistent hypertension was 65%, compared to 5% (1-negative predictive value) for patients with a score of 0-4 points. At this cut-off level sensitivity was 0.96 and specificity 0.64.*

TABLE 3. *Multivariable odds ratios (95% confidence interval) and corresponding p-values; at baseline (AUROC of 0.82 (CI95% 0.71-0.93)) and after two months of treatment at follow-up (AUROC of 0.91 (CI95% 0.84-0.98).*

	OR (CI 95%)	p-value	OR (CI 95%)	p-value
Systolic blood pressure (mmHg) at baseline	1.14 (1.06-1.24)	0.001	1.09 (1.00-1.19)	0.06
Systolic blood pressure (mmHg) at two months			1.18 (1.05-1.33)	< 0.01
AUROC	**0.82 (0.71-0.93)**		**0.91 (0.84-0.98)**	

TABLE 4. *Construction of the persistent hypertension risk prediction score. The risk prediction score is assessed within two moments of time; first part at baseline (here defined as the previous visit) and after approximately two-three months, here defined as the current visit.*

Factor	Points
Current visit	
Self-monitored systolic blood pressure	
< 120	-1
120-129	0
130-139	2
140-149	4
150-159	6
≥ 160	8
Previous visit	
Self-monitored systolic blood pressure	
< 120	0
120-129	0
130-139	1
140-149	2
150-159	3
≥ 160	4
Total score (range)	**-1 ; 12**

TABLE 5. *The distribution of patients for the risk prediction score of persistent hypertension; assessed after approximately two months of treatment. Higher scores indicate a higher risk of persistent hypertension; high risk scores ranging from 5 to 12.**

Risk prediction score	N patients without persistent hypertension	N patients with persistent hypertension	Total
-1	0	0	0
0	2	0	2
1	2	0	2
2	5	0	5
3	6	0	6
4	6	1	7
5	2	3	5
6	5	5	10
7	1	2	3
8	1	4	5
9	0	2	2
10	1	4	5
11	0	0	0
12	0	2	2

N = 56. * For 57% (N = 32) of patients with the highest scores (5-12), the positive predictive value for persistent hypertension was 65% (sensitivity 0.96, specificity 0.64).

DISCUSSION

In this study we have developed a prediction model that can be used to accurately predict persistent uncontrolled hypertension in primary care. Initial higher self-monitored blood pressure can be used as an estimate, resulting in an AUC of 0.82. The performance of the risk prediction model is improved by adding an assessment of early treatment response (AUC 0.91). Higher self-monitored blood pressure at approximately two months, indicating an unfavourable initial response to treatment is the strongest predictor of persistent uncontrolled hypertension after one year of treatment.

Comparisons with literature

Our study confirms and adds to previous studies. In contrast to other studies, we used self-monitored blood pressure as an outcome. Self-monitored blood pressure, with or without telemonitoring, when used by general practitioners to titrate antihypertensive medication, has been shown to lower systolic blood pressure.[23] With an increased number of general practitioners and many patients using self-monitoring, it could become the cornerstone of hypertension management in primary care, elimination of the white coat effect, low costs and easy application.[4] Increased successful reduction of hypertension in primary care, will benefit the risk of cardiovascular morbidity and mortality.[24]

Our final risk prediction model included two assessments of systolic self-monitored blood pressure as predictors of persistent uncontrolled hypertension, other predictors were outperformed and therefore not included in the final risk prediction model. First, self-monitored systolic blood pressure is the strongest predictor. This adds to other studies, where systolic and/or diastolic blood pressure were included in hypertension risk prediction models.[25-28] Especially our study adds to the previous study of Hozawa et al. (2000) which showed the prognosis of hypertension would be improved by treatment focused on systolic rather than on diastolic self-monitored blood pressure measurements.[29] Second, early treatment response was included in our risk prediction model by the inclusion of multiple assessments of self-monitored blood pressure. Despite the advantages and availability of self-monitored blood pressure measurements over time, early treatment response is not a common measure in risk prediction models. Most risk prediction models include only one assessment of blood pressure.[25-28] However, early treatment response adds an insight that can be acted upon; guiding decisions in the treatment plan. For example, when early treatment response is minimal after approximately two months of treatment, and self-monitored blood pressure is still marked as hypertension, it is quite likely that the patient will still have raised blood pressure after one year of treatment. In contrast to previous

studies we showed that as soon as two months after initiated treatment these patients can be identified, where other studies showed this effect after six months.[23,30] Third, our study showed that initial blood pressure and early treatment response are by far the most important predictors of persistent uncontrolled hypertension, whereas the contribution of additional predictors was limited.[8] Within this study we could not make any statement about family history or physical inactivity because both were not available. However, other variables did not end up in the risk prediction of persistent uncontrolled hypertension and our predictive performance is already very high.

Strengths and weaknesses

Extensive self-monitoring of blood pressure is a strength of our study. Patients monitored blood pressure two times in the morning and two times in the evening, within seven consecutive days and we took the mean, which accounts for variability and measurement errors in blood pressure. Another strength is the implementation of the use of early treatment response as a predictor for future raised blood pressure in routine care. Easy to assess, in contrast to for example risk prediction models including genetic factors.[31] A limitation of our study is the small sample size of this study. Despite this, the effects are internally validated and high (AUC 0.91). Another limitation could be the telemonitoring which was additive to the self-monitored blood pressure, therefore patients awareness of hypertension may be increased, as well as drug compliance.[32] At the same time, telemonitoring could be a strength of our study; the predictive performance of the risk prediction model is high, and the accessibility of telemonitoring and self-monitored blood pressure is easy.[23,33-36]

Clinical implications

The developed risk prediction score provides the clinician, and patients, with a clear estimate of persistent uncontrolled hypertension. Since only self-monitored systolic blood pressure measurements are required, this aids the implementation of this model in clinical practice and empowers the patient, at home. With the inclusion of early treatment response in the model, a review of effectiveness of treatment is included and to our best knowledge not commonly used in clinical practice as a predictor. It is especially meaningful to consider patients without or with minimal decrease of systolic blood pressure (high risk patients) for evaluation and monitoring of rational medication switches, therapy compliance, reduce salt-intake or interventions to reduce adverse life circumstances.

Conclusion

We showed the additional value of systolic blood pressure as early treatment

response in risk prediction of persistent uncontrolled hypertension; increased systolic blood pressure approximately two months after initiation of treatment improves predictive performance compared to initial characteristics only. Successful reduction of hypertension in primary care, especially focussing on patients with minimal or no decrease of systolic blood pressure, may benefit the risk of cardiovascular morbidity and mortality.

REFERENCES

1. Mills KT, Bundy JD, Kelly TN, Reed E, Kearney PM, Reynolds K, et al. Global Disparities of Hypertension Prevalence and Control: A Systematic Analysis of Population-based Studies from 90 Countries. Circulation. 2016; 134(6): 441-450.
2. GBD 2013. Risk Factors Collaborators Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risk factors or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2015; 386: 2287-2323.
3. Ikeda N, Sapienza D, Guerrero R, Aekplakorn W, Naghavi M, Mokdad AH, et al. Control of hypertension with medication: a comparative analysis of national surveys in 20 countries. Bull World Health Organ. 2014; 92(1): 10-19C.
4. Verberk WJ, Kroon AA, Lenders JW, Kessels AG, van Montfrans GA, Smit AJ, et al. Self-measurement of blood pressure at home reduces the need for antihypertensive drugs: a randomized, controlled trial. Hypertension. 2007; 50(6): 1019-1025.
5. Pickering TG, Miller NH, Ogedegbe G, Krakoff LR, Artinian NT, Goff D. Call to action on use and reimbursement for home blood pressure monitoring: a joint scientific statement from the American Heart Association, American Society Of Hypertension, and Preventive Cardiovascular Nurses Association. Hypertension. 2008; 52: 10-29.
6. Stergiou GS, Argyraki KK, Moyssakis I, Mastorantonakis SE, Achimastos AD, Karamanos VG, et al. Home blood pressure is as reliable as ambulatory blood pressure in predicting target-organ damage in hypertension. Am J Hypertens. 2007; 20: 616-621.
7. Sheikh S, Sinha AD, Agarwal R. Home blood pressure monitoring: how good a predictor of long-term risk? Curr Hypertens Rep. 2011; 13(3): 192-9.
8. Echouffo-Tcheugui JB, Batty GD, Kivimäki M & Kengne AP. Risk Models to predict hypertension: a systematic review. PLoS ONE. 2013; 8(7).
9. Boer S, Sont JK, Loijmans RJB, Snoeck-Stroband JB, Ter Riet G, Schermer TRJ, et al. Development and validation of personalized prediction to estimate future risk of severe exacerbations and uncontrolled asthma in patients with asthma, using clinical parameters and early treatment response. J Allergy Clin Immunol Pract. 2019; 7(1) : 175-182.
10. Niiranen TJ, Hänninen MR, Johansson J, Reunanen A, Jula AM. Home-measured blood pressure is a stronger predictor of cardiovascular risk than office blood pressure: the Finn-Home study. Hypertension. 2010; 55(6): 1346-51.
11. Kivimäki M, Tabak AG, Batty GD, Ferrie JE, Nabi H, Marmot MG, et al. Incremental predictive value of adding past blood pressure measurements to the Framingham Hypertension Risk Equation. Hypertension. 2010; 55: 1058-1062.
12. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Böhm M et al. ESH/ESC guidelines for the management of arterial hypertension. Eur Heart J. 2013; 34: 2159-2219.
13. Horne R. Measuring adherence: the case for self-report. Int J Behav Med. 2004; 11: 75.
14. Dolan P. Modeling valuations for EuroQol health states. Med Care. 1997; 35: 1095-1108.

15. Szende A, Svensson K, Stahl E, Meszaros A, Berta GY. Psychometric and utility-based measures of health status of asthmatic patients with different disease control level. Pharmacoeconomics. 2004; 22(8): 537-547.
16. Petkov J, Harvey P, Battersby M. The internal consistency of construct validity of the partners in health scale: validation of a patiënt rated chronic condition self-management measure. Qual Life Res. 2010; 29(7): 1079-85.
17. Ware J, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. Med Care. 1996; 34: 220-233.
18. García-Vera MP, Sanz J. How many self-measured blood pressure readings are needed to estimate hypertensive patients "true" blood pressure? J Behav Med. 1999; 22(1): 93-113.
19. Verberk WJ, Kroon AA, Jongen-Vancraybex HA, de Leeuw PW. The applicability of home blood pressure measurment in clinical practice: a review of literature. Vasc Health Risk Manag. 2007; 3(6): 959-966.
20. Parati G, Stergiou GS, Asmar R, Bilo G, de Leeuw P, Imai Y, et al. European Society of Hypertension guidelines for blood pressure monitoring at home: a summary report of the Second International Consensus Conference on Home Blood Pressure Monitoring. J Hypertens. 2008; 26(8): 1505-1526.
21. Almeida AE, Stein R, Gus M, Nascimento JA, Belli KC, Arévalo JR, et al. Relevance to home blood pressure monitoring protocol of blood pressure measurements taken before first-morning micturition and in the afternoon. Arg Bras Cardiol. 2014; 103(4): 338-347.
22. Sullivan LM, Massaro JM, D'Agostino RB. Presentation of multivariate data for clinical use: The Framingham Study risk score functions. Stat Med. 2004; 23(10): 1631-1660.
23. McManus RJ, Mant J, Franssen M, Nickless A, Schwartz C, Hodgkinson J, et al. Efficacy of self-monitored blood pressure, with or without telemonitoring, for titration of antihypertensive medication (TASMINH4): an unmasked randomized controlled trial. Lancet. 2018; 391: 949-59.
24. Ohkubo T, Imai Y, Tsuji I, Nagai K, Kato J, Kikuchi N, et al. Home blood pressure measurement has a stronger predictive power for mortality than does screening blood pressure measurement: a population-based observation in Ohasama, Japan. J Hypertens. 1998; 16: 971-975.
25. Parikh NI, Pencina MJ, Wang TJ, Benjamin EJ, Lanier KJ, Levy D, et al. A risk score for predicting near-term incidence of hypertension: the Framingham Heart Study. Ann Intern Med. 2008; 148: 102-110.
26. Paynter NP, Cook NR, Everett BM, Sesso HD, Buring JE, Ridker PM. Prediction of incident hypertension risk in women with currently normal blood pressure. Am J Med. 2009; 122: 464–471.
27. Kshirsagar AV, Chiu YL, Bomback AS, August PA, Viera AJ, Colindres RE, et al. A hypertension risk score for middle-aged and older adults. J Clin Hypertens. 2010; 12: 800-808.
28. Bozorgmanesh M, Hadaegh F, Mehrabi Y, Azizi F. A point-score system superior to blood pressure measures alone for predicting incident hypertension: Tehran Lipid and Glucose Study. J Hypertens. 2011; 29: 1486-1493.
29. Hozawa A, Ohkubo T, Nagai K, Kikuya M, Matsubara M, Tsuji I, et al. Prognosis of isolated systolic and isolated diastolic hypertension as assessed by self-measurement of blood pressure at home: the Ohasama study. Arch Intern Med. 2000; 160: 3301-3306.
30. Shah BR, Thomas KL, Elliot-Bynum S, Thomas K, Damon K, LaPointe AN, et al. Check it, change it: a community-based intervention to improve blood pressure control. Circ Cardiovasc Qual Outcomes. 2013; 6(6): 741-748.
31. Sun D, Liu J, Xiao L, Liu Y, Wang Z, Li C, et al. Recent development of risk-prediction models for incident

hypertension: An updated systematic review. PLos One. 2017; 12(10).

32. Edmonds D, Foerster E, Groth H, Greminger P, Siegenthaler W, Vetter W. Does self-measurement of blood pressure improve patient compliance in hypertension? J Hypertens. 1985; 3: 31-34.
33. Glynn LG, Murphy AW, Smith SM, Schroeder K, Fahey T. Interventions used to improve control of blood pressure in patients with hypertension. Cochrane Database Syst Rev. 2010; 3.
34. 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(9).
35. Mallick S, Kanthety R, Rahman M. Home blood pressure monitoring in clinical practice: a review. Am J Med. 2009; 122(9): 803-10.
36. Arrieta A, Woods JR, Qiao N, Jay SJ. Cost-benefit analysis of home blood pressure monitoring in hypertension diagnosis and treatment: an insurer perspective. Hypertension. 2014; 64(4): 891-896.

ONLINE SUPPLEMENT APPENDIX 1

TABLE S1. *Based on the regression coefficients of our final model the risk prediction score was developed.*[23]

Variable	Beta	Categories	Reference (W)	Beta * ($W-W_{REF}$)	Points†	Rounded points
Self-monitored systolic blood pressure, baseline	0.083	< 120	120	-0.374	-0.450	0
		120-129	**124.5**$_{REF}$	0.000	0.000	0
		130-139	134.5	0.830	1.000	1
		140-149	144.5	1.660	2.000	2
		150-159	154.5	2.490	3.000	3
		> 160	166	3.445	4.150	4
Self-monitored systolic blood pressure, follow-up	0.169	< 120	120	-0.761	-0.961	-1
		120-129	**124.5**$_{REF}$	0.000	0.000	0
		130-139	134.5	1.690	2.036	2
		140-149	144.5	3.380	4.072	4
		150-159	154.5	5.070	6.108	6
		> 160	166	7.014	8.450	8
Intercept	-35.727					

† Constant B = 0.830

Variable. The remaining variables of the risk prediction model.

Beta. The regression coefficients corresponding to the variables.

Categories. Variables are categorized into meaningful categories.

Reference (W). The reference value for each category was determined; the midpoint of each category. Furthermore, we determined the base category for each variable, for the referent ($_{REF}$) profile.

Beta * ($W-W_{REF}$). We determined how far each category is from the base category in regression units; multiplying the beta by the difference between reference value for the specific category and the reference value for the base category.

Points. In order to compute the risk prediction points, we had to set a constant B for the point system, or the number of regression units that will correspond to one point. We set the constant as the smallest beta (self-monitored systolic blood pressure, baseline) and multiplied it by ten; we multiplied the constant by ten in order to keep the total risk prediction score in a feasible range without loss of accuracy. Points were computed by (*Beta * ($W-W_{REF}$)) / constant B*.

Rounded. Risk prediction points were rounded to the nearest integer.