Observational Study

Medicine®

OPEN

Hypertension defined by the 2017 ACC/AHA guideline is more accurate than 2018 ESC/ESH for detecting early vascular aging in young adults

Mariana P. de Souza, MD[a], Paulo Cesar Lopes, MD[a], Gabriel Bazo, MSc[b], Paulo Ricardo H. Rocha, PhD[b], Daniela Aparecida Lorencini, MSc[a], Heloisa Bettiol, MD, PhD[b], Marco Antonio Barbieri, MD, PhD[b], Eduardo B. Coelho, MD, PhD[a,*]

Abstract

Determine the most accurate diagnostic criteria of arterial hypertension (AH) for detecting early vascular aging (EVA) defined by pulse wave velocity (PWV) higher than ≥9.2 m/s.

Cross-sectional study of a birth cohort started in 1978/79. The following data were collected between April 6, 2016 and August 31, 2017 from 1775 participants: demographic, anthropometric, office blood pressure (BP) measurement, biochemical risk factors, and PWV. A subsample of 454 participants underwent 24-hour ambulatory BP monitoring. The frequencies of AH, and BP phenotypes were calculated according to both guidelines. BP phenotypes (white-coat hypertension, masked hypertension (MHT), sustained hypertension (SH) and normotension) were correlated with risk factors and subclinical target organ damage after adjustment for confounders by multiple linear regression. Receiver operating characteristic curves were constructed to determine the best BP threshold for detecting EVA.

A higher frequency of AH (45.1 vs 18.5%), as well as of SH (40.7 vs 14.8%) and MHT (28.9 vs 25.8%) was identified using the 2017 ACC/AHA criteria comparing with 2018 ESC/ESH. EVA was associated with the higher-risk BP phenotypes (SH and MHT, $P < .0001$) in both criteria. There was a higher accuracy in diagnosing EVA, with the 2017 ACC/AHA criteria. Analysis of the receiver operating characteristic curves showed office BP cutoff value (128/83 mm Hg) for EVA closer to the 2017 ACC/AHA threshold.

The 2017 AHA/ACC guideline for the diagnosis of AH, and corresponding ambulatory BP monitoring values, is more accurate for discriminating young adults with EVA. Clinical application of PWV may help identify patients that could benefit from BP levels <130/80 mm Hg.

Abbreviations: ABPM = ambulatory blood pressure monitoring, ACC/AHA = American College of Cardiology and American Heart Association, AH = arterial hypertension, BMI = body mass index, BP = blood pressure, DBP = diastolic blood pressure, ESC/ESH = European Society of Cardiology and European Society of Hypertension, EVA = early vascular aging, HbA1c = glycated hemoglobin, MHT = masked hypertension, PWV = pulse wave velocity, ROC = receiver operating characteristic, SBP = systolic blood pressure, SH = sustained hypertension, TOD = target organ damage, WCH = white-coat hypertension.

Keywords: adults, hypertension, pulse wave velocity

1. Introduction

The increase in cardiovascular mortality associated with blood pressure (BP) >115/75 mm Hg[1,2] and the benefit of BP lowering to levels <130/80 mm Hg, have motivated the redefinition of the arterial hypertension (AH) diagnostic criteria by the American College of Cardiology and American Heart Association (ACC/AHA) in 2017, adopting a BP level ≥130/80 mm Hg.[3] Data from the National Health and Nutrition Examination Survey (NHANES – USA)[4] showed 24% prevalence of AH in young adults (20–44 years) using the ACC/AHA definition compared to 10.5% when applying the European Society of Cardiology and European Society of Hypertension in 2018 (2018 ESC/ESH)[5] threshold of 140/90 mm Hg. This difference in prevalence would correspond to 13.9 million young adults with a BP between 130 to 139 and/or 80 to 89 mm Hg; of these, up to 300,000 would require drug treatment, that is, patients with a 10-year cardiovascular risk >10% or with cardiovascular disease, renal disease or diabetes mellitus. In part, this number only reflects that the probability of cardiovascular events measured by risk scores is low in young adults. However, the risk-based strategy may hide a significant number of patients with subclinical target organ damage (TOD) such as early vascular aging (EVA), which may

Editor: Mihnea-Alexandru Găman.

The authors have no conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] Departamento de Clínica Médica, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, Brazil, [b] Departamento de Puericultura e Pediatria, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, Brazil.

[*] Correspondence: Eduardo B. Coelho, Divisão de Nefrologia, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, Av. Bandeirantes 3900 6 andar sala 636, Brazil (e-mail: ebcoelho@fmrp.usp.br).

How to cite this article: de Souza MP, Lopes PC, Bazo G, Rocha PR, Lorencini DA, Bettiol H, Barbieri MA, Coelho EB. Hypertension defined by the 2017 ACC/AHA guideline is more accurate than 2018 ESC/ESH for detecting early vascular aging in young adults. Medicine 2022;101:6(e28841).

Received: 26 March 2021 / Received in final form: 15 November 2021 / Accepted: 23 January 2022

http://dx.doi.org/10.1097/MD.0000000000028841

benefit of early pharmacology intervention. The latter is characterized by arterial stiffening and is generally defined as an average carotid–femoral pulse wave velocity (PWV) 2 standard deviations above the expected for a healthy population.[6] PWV is an independent predictor of cardiovascular mortality, with higher predictive values in younger subjects.[7]

The choice of the BP measurement method continues to be a relevant variable for the diagnosis of AH in young adults. The current guidelines recommend 24-hour ambulatory blood pressure monitoring (ABPM) for individuals with an office BP between 120 to 129 and/or 75 to 79 mm Hg (2017 ACC/AHA)[3] or between 130 to 139 and/or 80 to 89 mm Hg (2018 ESC/ESH)[5] and for those with detectable TOD. Correlating 24-hour ABPM results and BP office measurements allows to classify patients into different BP phenotypes: normotension, sustained hypertension (SH), masked hypertension (MHT), and white-coat hypertension (WCH), which have different prognoses and are more accurate than the isolated office measurement.[8–10]

The PWV applied to the diagnosis of EVA is not routinely used as a parameter for the therapeutic decisions in AH. The 2018 ESC/ESH guidelines recommend the use of PWV as a marker of TOD, but applies fixed values >10 m/s without correction for age or sex, which impairs its applicability in young adults. Thus, our main objective was to determine the most accurate BP threshold for detecting the presence of EVA in young adults. Additionally, we estimated the effect of the 2 hypertension guidelines definition on the distribution of BP phenotypes and their association with arterial stiffness, renal function and albuminuria as markers of subclinical TOD.

2. Methods

2.1. Study population, measurement of demographic variables and biochemical tests

A cross-sectional study was done using data from the fifth follow-up of a birth cohort started in 1978/79 in the city of Ribeirão Preto, São Paulo, Brazil, conducted between April 2016 and August 2017. The initial cohort included 6973 live births that occurred between June 1, 1978 and May 31, 1979 of mothers living in the city. The last assessment took place in 2016/17 with 1775 individuals aged 38/39 years. To locate the participants, a telephonic contact was done, and an invitation letter was sent based on birth addresses and contact data previously collected in the last visit of the cohort. In addition, we also searched potential participants on the Electronic Health Record of public and private health system and spread the invitation call to the follow up visit on the internet social media apps, local newspapers, and television channels. All the participants that answered our call and belonged to original birth cohort were included.

The details of this cohort, including previous follow-ups, are described elsewhere.[11,12] A total of 1775 participants were interviewed and evaluated at the Clinical Research Unit of the University Hospital of the Ribeirão Preto Medical School, University of São Paulo, by a trained team. Standardized questionnaires regarding lifestyle habits, socioeconomic situation, health behavior, and physical activity level were applied. All participants signed a free informed consent form. The study was approved by the Research Ethics Committee of the University Hospital of The Ribeirão Preto Medical School, University of São Paulo (protocol 1.282.710).

BP, waist circumference (cm), weight (kg), and height (m) were measured. The body mass index (BMI) was calculated by dividing weight by the square of height (kg/m^2).[13] A waist circumference >102 cm in men and >88 cm in women was used for risk stratification. Physical activity was categorized as low, moderate or high using the short form of the International Physical Activity Questionnaire.[14]

Blood and urine samples were collected, processed and stored in a freezer at −80°C until the time of biochemical analyses. Serum concentrations of creatinine, total cholesterol, high-density lipoprotein, triglycerides, and glucose were quantified in an automated biochemistry analyzer (Weiner, Rosario, Argentina). Albuminuria, was defined as albumin levels ≥30 mg/g creatinine. The glomerular filtration rate was estimated from creatinine and cystatin C using the CKD-EPI 2009 equation.[15] Glycated hemoglobin (HbA1c) was determined by HPLC (Bio-Rad D-10, Hercules, CA). The cardiovascular risk was estimated by the Atherosclerotic cardiovascular disease equation[16] considering an age of 40 years for all participants. Skin color was self-reported and classified as white, black, or brown. The presence of diabetes was defined as fasting glucose ≥126 mg/dL, HbA1c ≥6.5% or use of medications to control blood glucose levels.

2.2. Measurement of blood pressure and pulse wave velocity

The office BP was measured by the oscillometric device (Omron HEM742INT, São Paulo, Brazil). With the subject sitting, the measurement was obtained on both arms after 5 minutes of rest and the measurement with the highest value was considered. Two additional measurements were obtained and the mean was recorded as the office BP.

Twenty-four-hour ABPM (DynaMapa, Cardios, São Paulo, Brazil) was performed in a randomly selected subsample. Sex and skin color previously recorded in the cohort's database were used as stratification criteria. The size of this subsample was calculated based on the hypothesis that the 2017 ACC/AHA diagnostic criteria of AH would be more accurate than 2018 ESC/ESH for detecting EVA. We estimated a prevalence of EVA of 8% in our cohort and an increase in sensitivity of at least 20% for the diagnosis of EVA when the 2017 ACC/AHA diagnostic criteria were used, assuming an alpha value of 0.05 and power of 0.80 (Gpower 3.1 sample size calculator, Dusseldorf University, Germany). Using these parameters, 369 participants would be necessary to study. Since the prevalence of EVA was unknown in our population, 540 participants were randomly selected for ABPM, considering the need to exclude participants undergoing pharmacological treatment and ABPM with less than 70% of valid measurements. Six tests were excluded because of poor technical quality (<70% of valid measurements) and 80 other tests because the participants received drug treatment for AH. Thus, 454 ABPM tests were selected for the study. The characteristics of the sample compared to the remaining participants in the cohort are shown in the supplemental material (n = 1094; Table A1, Supplemental Digital Content, http://links.lww.com/MD2/A887). The BP monitor was programmed to record BP measurements every 15 min during wakefulness (7 AM to 11 PM) and every 30 minutes during sleep (11 PM to 7 AM). The sleep and wake times were indicated by the patients and considered as nighttime in the interpretation of the tests.

The BP phenotypes were obtained by comparing the office BP data with the mean 24-hour, daytime and nighttime ABPM data for the 2 different hypertension guidelines. For 2018 ESC/ESH, participants with an office BP ≥140 or ≥90 mm Hg, corresponding

to 24-hour, daytime and nighttime ABPM values of ≥130/80, ≥135/85 and, ≥120/70 mm Hg, respectively, were classified as hypertensive. Considering the 2017 ACC/AHA criteria, an office BP ≥130 or ≥80 mm Hg was defined as AH, with corresponding 24-hour, daytime and nighttime ABPM values ≥125/75, ≥130/80, and ≥110/65 mm Hg, respectively. Normotension was defined when both measurements were normal; WCH when only the office BP measurement was considered altered; MHT when only the ABMP value was altered, and SH when the office BP and ABPM measurements were altered according to the criteria described above. In the present study, any altered value (mean 24-hour, daytime or nighttime BP) was considered abnormal ABPM.

The PWV was measured by tonometry (Sphygmocor-EM3, AtCor Medical, Sydney, New South Wales, Australia) on the same day and in the same place as the office BP measurement. The distance between the 2 pulse recording sites (right carotid artery and right femoral artery) and the sternal notch was measured with a tape measure. Electrodes for recording the electrocardiographic signal were placed on the right and left wrists and on the left ankle. The pulse waveform was then recorded in the carotid and femoral arteries by placing the tonometer over each artery and recording the time delay between the 2 signals (dt). The PWV was calculated using the algorithm 0.8 dL/dt and was estimated as m/s.[17] A PWV reference value ≥9.2 m/s (≥2standard deviation, for age)[6] was used to identify individuals with EVA.

2.3. Statistical analysis

The results are reported as mean and the respective measure of variation (standard deviation or 95% confidence interval). Categorical variables are described as percentage and were compared by the chi-squared test. Multivariate analysis of variance was used for comparison between guideline groups. The phenotypes were compared using Analysis of variance, followed by Bonferroni multiple comparisons. The univariate linear regression analysis was performed to verify the association ($P < .10$) between phenotypes and PWV. Multivariate linear regression model was built with simultaneous entry of the variables which included all showing $P < .10$ on univariate analysis and some of interest, based on previously report association with BP phenotypes. The model was adjusted for the covariates sex, BMI, waist circumference, total cholesterol, low-density lipoprotein-C, and HbA1c.

To compare the most accurate AH criteria for EVA diagnosis, a confusion matrix was used. Receiver operating characteristic (ROC) curves were obtained by stratifying office systolic blood pressure (SBP) and diastolic blood pressure (DBP) or values obtained by ABPM (mean 24-hour, daytime and nighttime) from the 1st percentile, with a progressive increase of 1% until the 99th percentile as threshold settings. Confusion matrices were constructed for each threshold value, and sensitivity and specificity were calculated. The ROC curve was constructed by plotting sensitivity vs (1-specificity), and Youden *J* index[18] and its respective 95% CI were calculated to determine the office SBP and DBP or ABPM cutoff values for the diagnosis of EVA. The data were analyzed with the STATA 14 software (Stata Corporation, College Station, Texas).

3. Results

Table A1, Supplemental Digital Content, http://links.lww.com/MD2/A887 describes the clinical and demographic characteristics of all participants (n = 1775), and those who undergo (n = 454) and did not undergo ABPM (n = 1094), excluding participants using antihypertensive drugs in both groups (n = 227). Comparison of participants showed slight alterations in high-density lipoprotein (lower by 1.7 mg/dL), SBP and DBP (increase of about 2 mm Hg), and PWV (higher by about 0.3 m/s) in ABPM group. Also, the frequency of EVA tended to be higher in ABPM group compared to the remaining sample (5.7 vs 3.1%, $P = .05$).

The prevalence of AH was 18.5% using the 2018 ESC/ESH office BP threshold. This increased to 45.1% when the 2017 ACC/AHA criteria were adopted. Table 1 describes the

Table 1

Characteristics of the blood pressure phenotypes in the groups formed according to the diagnostic criteria for ABPM and casual blood pressure measurement of 2018 ESC/ESH and 2017 ACC/AHA. Values are expressed as mean (±SD) or %.

	2017 AHA/ACC					2018 ESC/ESH				
	N 118 (26%)	SH 185 (40.7%)	MHT 131 (28.9%)	WCH 20 (4.4%)	*P*-value**	N 253 (55.7%)	SH 67 (14.8%)	MHT 117 (25.8%)	WCH 17 (3.7%)	*P*-value**
BMI (kg/m^2)	26.4 (.4)	29.9 (.4)*	27.6 (.4)	32.9 (1.8)*	.001	27.6 (.3)	30.2 (.6)*	28.7 (.4)	33.1 (2.3)*	**.001**
HbA1c (%)	5.2 (.03)	5.4 (.05)	5.3 (.03)	5.7 (.4)*	.039	5.3 (.04)	5.4 (.05)	5.3 (.07)	5.3 (.07)	.833
Homocysteine (μmol/L)	9.8 (.7)	10.2 (.35)	9.2 (.25)	9.8 (.6)	.458	9.6 (.35)	10.7 (.6)	9.4 (.27)	11.8 (2.5)	.128
eGFR (mL/min/1.73m^2)	93.5 (1.6)	92.4 (1.2)	91.2 (1.4)	95.3 (3.9)	.645	91.6 (1)	94.3 (2.1)	93.0 (1.5)	93.1 (4.9)	.671
PWV (m/s)	6.4 (.1)	7.3 (.1)*	7.0 (.1)*	7.4 (.4)*	.001	6.7 (.1)	7.7 (.2)*	7.2 (.1)*	7.4 (.2)	**.001**
EVA (%)	0	9.5	3.8	15	–	3.2	17.5	4.3	6.2	**–**
SBP (mm Hg)	111 (.7)	135 (.9)*	116 (.7)*	128 (2.1)*	.001	116 (.6)	145 (1.5)*	123 (.9)*	141 (1.7)*	**.001**
DBP (mm Hg)	69.3 (.5)	87.9 (.6)*	72.9 (.4)*	83.5 (1)*	.001	73 (.4)	95 (1.1)*	80 (.5)*	86 (1.8)*	**.001**
Albuminuria (mg/g creatinine)	21.5 (2.0)	23.3 (1.8)	19.3 (1.7)	31.8 (17.0)	.425	20.7 (1.8)	27.3 (3.9)	21.5 (2)	25.5 (5.5)	.541
Cholesterol (mg/dL)	167.5 (2.9)	192.6 (3.0)*	181 (3.3)*	191.2 (7.0)	.001	176.5 (2.2)	198.0 (5.5)*	186.0 (3.8)	190.8 (7.9)	**.004**
LDL (mg/dL)	98.2 (2.5)	110.9 (2.5)*	105.1 (2.9)	108.3 (5.4)	.008	102.9 (1.8)	112.0 (4.5)	106.4 (3.3)	117.8 (7.5)	.075
HDL (mg/dL)	46.0 (1)	43.9 (.8)	45.9 (1.1)	43.7 (2.1)	.312	45.6 (.7)	44.6 (1.4)	44.4 (1.1)	42.4 (2.5)	.585
ASCVD risk (%)	1.0 (.1)	2.2 (.1)*	1.4 (.1)	1.5 (.2)	.001	1.2 (.08)	2.5 (.2)*	1.8 (.15)*	2.5 (.4)	**.001**

ACC/AHA = American College of Cardiology and American Heart Association, ABPM = ambulatory blood pressure monitoring, BMI = body mass index, DBP = diastolic blood pressure, eGFR = glomerular filtration rate, ESC/ESH = European Society of Cardiology and European Society of Hypertension, EVA = early vascular aging, HbA1c = glycated hemoglobin, HDL = high-density lipoprotein, LDL = low-density lipoprotein, MHT = masked hypertension, PWV = pulse wave velocity, SBP = systolic blood pressure, SD = standard deviation, SH = sustained hypertension, WCH = white-coat hypertension.

* $P < .05$ compared to the normotensive group (N).

** *P* for differences between phenotypes using the same classification criteria.

Table 2

Unadjusted and adjusted linear regression analysis of the association between pulse wave velocity and hypertension phenotypes according to the 2017 ACC/AHA and 2018 ESC/ESH criteria.

		Unadjusted				Adjusted		
PWV	Coef	95% CI	*P*-value	r^2	Coef*	95% CI	*P*-value	r^2
2017 AHA/ACC				0.067				0.186
N	0				0			
SH	0.94	(0.60, 1.27)	.001		0.6	(0.23, 0.96)	.001	
MHT	0.55	(0.19, 0.91)	.003		0.45	(0.08, 0.80)	.014	
WCH	0.98	(0.29, 1.66)	.005		0.19	(−0.50, 0.89)	.588	
JNC7				0.054				0.184
N	0				0			
SH	0.95	(0.54, 1.34)	.001		0.62	(0.19, 1.04)	.004	
MHT	0.45	(0 .13, 0.76)	.006		0.36	(0.03, 0.67)	.029	
WCH	0.65	(−0.08, 1.38)	.083		0.37	(−0.34, 1.08)	.309	

ACC/AHA = American College of Cardiology and American Heart Association, CI = confidence interval, ESC/ESH = European Society of Cardiology and European Society of Hypertension, LDL = low-density lipoprotein, MHT = masked hypertension, N = normotension, PWV = pulse wave velocity, SH = sustained hypertension, WCH = white-coat hypertension.

* Adjusted for body mass index, glycated hemoglobin, cholesterol, LDL, waist circumference, and sex.

hypertension phenotypes according to AH guidelines. An increase in the prevalence of participants with SH from 14.8% to 40.7% was observed when the 2017 ACC/AHA criteria were adopted. There was still an expressive number of the MHT phenotype in both guidelines. When the 2017 ACC/AHA criteria were adopted, all participants classified as MHT by 2018 ESC/ESH were now classified as SH and 131 subjects previously classified as normotensive by 2018 ESC/ESH were reclassified as MHT.

Hypertensive subjects had higher levels of total cholesterol and fractions, BMI, waist circumference, and PWV than normotensive subjects in both guidelines. Participants classified as SH, MHT, and WCH exhibited higher PWV than those classified as normotensive in both diagnostic scenarios (2017 ACC/AHA: 7.4/6.8/7.4 vs 6.4; 2018 ESC/ESH: 7.7/7.2/7.4 vs 6.7, respectively). However, adjusted multiple linear regression analysis indicated an increase of PWV only in the SH (β = 0.60, 95%CI 0.23–0.96, *P* = .001) and MHT (β = 0.45, 95%CI 0.08–0.80, *P* = .014) groups (Table 2). Twenty-six cases of EVA (5.7%) were identified in ABPM group. The 2017 ACC/AHA AH definition was found to be more accurate than 2018 ESC/ESH for the diagnosis of EVA (22.3 vs 16.5; Table 3). In addition, the ROC curves (Fig. 1) and the office BP cutoff value for the diagnosis of EVA were close to the 2017 ACC/AHA AH BP threshold, with an office BP cutoff value of 128 × 83 mm Hg (95%CI 127–130 × 82–84 mm Hg). The SBP cut-off values of the ROC curves for 24-hour, daytime and nighttime ABMP were lower than those recommended by both guidelines. Youden *J* index and respective 95% CI were 119 (117–121), 121 (119–122) and 106 (104–108) mm Hg for mean 24-hour, daytime and nighttime SBP, respectively, and 79 (78–80), 87 (85–88), and 64 (63–65) mm Hg for DBP.

4. Discussion

A high prevalence of stage I AH in young adults has been reported, based on the 2017 ACC/AHA guideline, in other studies with only office BP measurements,[4,19–23] with values similar to those observed in the present study. In our sample, the presence of AH was accompanied by overweight, an increased waist circumference, and low physical activity level.

The classification into phenotypes revealed a high frequency of MHT and SH, accounting together for 69.5% of the sample studied. The presence of MHT was associated with higher PWV values when compared to normotensive subjects according both guidelines. The sample of participants undergoing ABMP exhibited slightly increased SBP and DBP and consequently PWV. Thus, the prevalence of AH and MHT in the cohort might be lower than in the sample of ABPM group. However, other studies reported a prevalence of MHT similar to that observed in this study for the age group of 30 to 50 years.[24–27]

Multivariate analysis showed that SH and MHT were independent variables in the determination of PWV. BP is the main factor that influences PWV,[28] but hemodynamic factors linked to glucose metabolism and chronic subclinical inflammation can also increase it PWV.[29,30] This may explain the association between PWV and WCH, which was associated with dyslipidemia and elevated HbA1c when compared to normotensive subjects. Patients with MHT are at higher cardiovascular risk than normotensive subjects, reaching the values observed in patients with SH,[31–34] and, in a recent study, showing stronger association with all-cause mortality.[9] Also in that study, nighttime BP elevation was an independent marker of cardiovascular diseases. MHT shows a high prevalence (1/3 of the office normotensive population), being associated with an increase of PWV, poor renal (albuminuria/cystatin C)[8] and cardiovascular

Table 3

Values of the confusion matrix for the 2017 ACC/AHA and 2018 ESC/ESH hypertension diagnostic criteria.

	Sensitivity	Specificity	Accuracy	PPV	NPV	LR
2017 ACC/AHA	0.07	0.98	22.3	0.88	0.32	3.2
2018 ESC/ESH	0.09	0.96	16.5	0.64	0.61	2.6

ACC/AHA = American College of Cardiology and American Heart Association, ESC/ESH = European Society of Cardiology and European Society of Hypertension, LR = likelihood ratio, NPV = negative predictive value, PPV = positive predictive value.

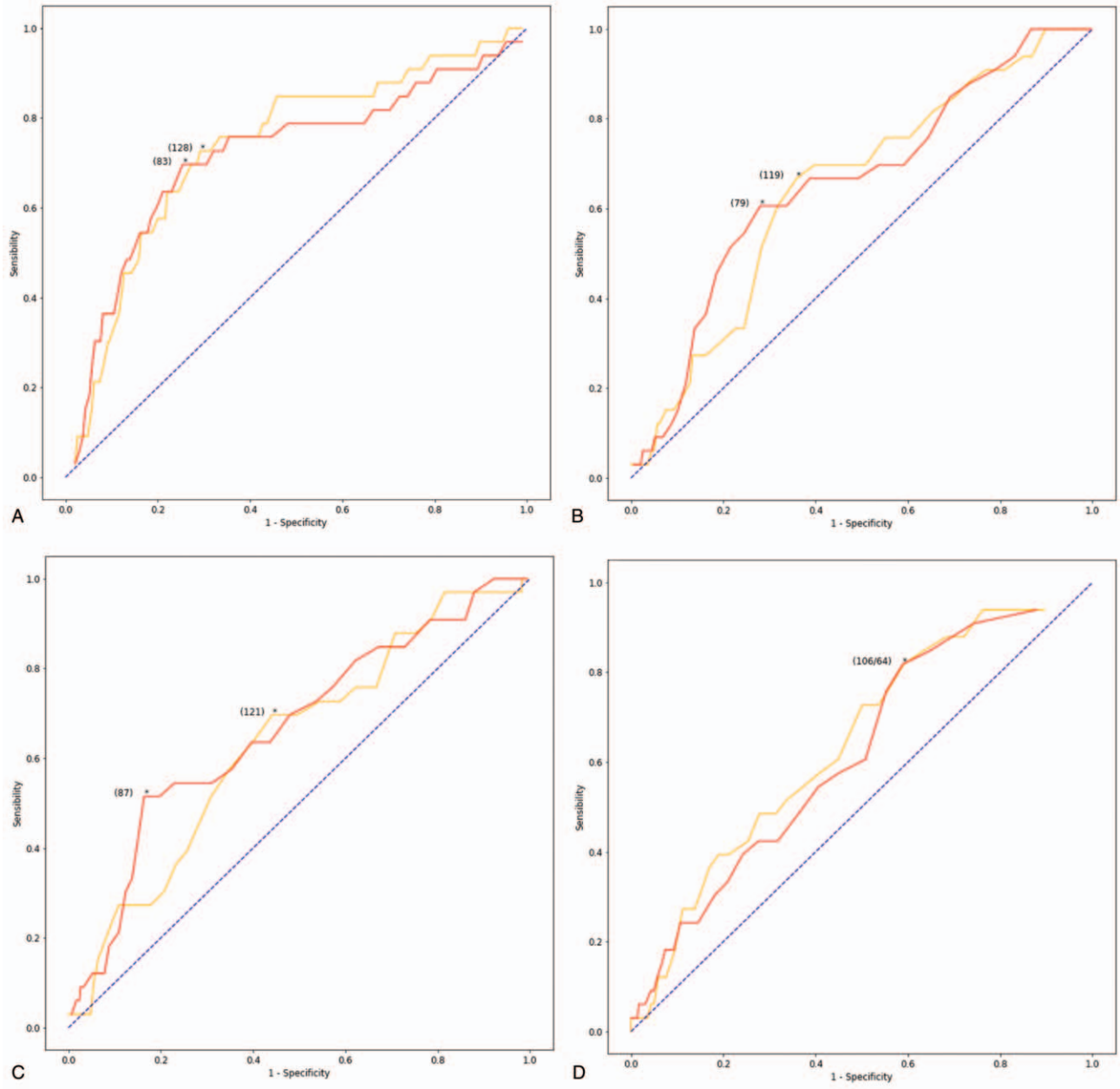

Figure 1. Receiver operating characteristic (ROC) curves for the diagnosis of early vascular aging. Systolic blood pressure (SBP) is plotted in orange lines and diastolic blood pressure (DBP) in red lines. Panel A: office blood pressure; B: mean 24-h ambulatory blood pressure monitoring (ABPM) blood pressure levels; C: daytime ABPM blood pressure levels; D: sleep-time ABPM blood pressure levels.

outcomes. Thus, our data reinforces the strategy of performing 24-hour ABPM in this population, highlighting the importance of nighttime BP levels, in addition to the previous recommendations of the 2017 ACC/AHA guidelines. Guidelines recommended the adoption of pharmacological treatment for subjects with BP levels 130 × 80 mm Hg if cardiovascular risk 10%.[32,35] However, most young adults lies on lower risk categories (<10%), with drug treatment only being recommended if their BP were 140 ×90mm Hg or in the presence of TOD.

Analysis of PWV showed that 5.7% of the sample (n = 26) had EVA, which is lower than that reported in other studies involving young patients, including the OPTIMO study[36] conducted in 12 Latin American countries, that showed a prevalence of 9.8%, an Austrian study[37] that reported a prevalence of 20.9%, and a Portuguese study that found a prevalence of EVA of 26.1%.[38] However, only the Austrian study performed ABPM. Thus, the incorrect classification of "normotension" using only the office BP measurement and MHT's association with elevated PWV may explain in part the differences observed among studies. In our sample, we observed an association of the SH and MHT phenotypes with PWV, but not renal damage. This fact suggests that vascular damage secondary to AH occurs earlier than renal damage. The Bogalusa heart study measured PWV on 2 different occasions in the same subject which and showed that, in some

participants, its increase can even precede the increase of BP,[39] reinforcing the idea to use the measurement of PWV as a strategy to identify young adults with early TOD.

The present study shows a correlation between PWV and BP. Although this study is cross-sectional, and does not allow the estimation of a temporal relationship between the 2 variables, data from longitudinal epidemiological studies show a direct relationship between AH and greater vascular stiffness measured by PWV after a few decades.[40–44] Also, an incidence of 32% of AH was detected in an evaluation performed 7 years after the diagnosis of vascular stiffness measured by carotid-femoral PWV.[45] Furthermore, it is plausible, from a pathophysiological point of view, that there is a causal relationship between BP elevation and target-organ damage over time and vice-versa.

This study has important limitations. First, for logistic and budget reasons, echocardiography was not used to detect left ventricular hypertrophy, an important subclinical TOD. Likewise, ABPM was performed in a subsample of the cohort. Since we lack Brazilian data, we used the means and standard deviations of a European cohort with a similar age as a reference value for PWV. Being a cross-sectional study, the associations observed may show bias inherent to the methodology and residual confounding can still be present, related to variables not considered by the authors. However, the association between vascular damage and the presence of high BP levels has biological plausibility supported by clinical and experimental studies. The Atherosclerotic cardiovascular disease formula has limitations for the study population, miscegenated and with age between 37 and 38 years, which could lead to incorrect values of cardiovascular risk and its use could also potentially privilege the ACC/AHA guidelines, considering 2018 ESC/ESH guidelines use the SCORE system coupled with risk modifiers to classify risk. Finally, the office BP measurement was performed on only one occasion, which may have biased the results obtained. Despite this, the measurement BP method adopted in our study followed the guidelines of the main AH guidelines and a significant sample of participants used ABPM.

Nevertheless, this study has several strengths. First, the sample size is representative of a city with about 700,000 inhabitants and its main focus is young adults for whom data are scarce. ABPM was performed, which enables to identify BP phenotypes and to obtain a large number of BP measurements, increasing their accuracy. Finally, the number of participants studied permitted the construction of ROC curves to estimate the best SBP and DBP values for detecting EVA in young adults.

In conclusion, the adoption of the 2017 ACC/AHA hypertension guideline was more accurate for the diagnosis of EVA in young adults, identifying a population of patients who could benefit from lowering BP to levels $<130 \times 80$ mm Hg.

Author contributions

Conceptualization: Mariana P. de Souza, Paulo Cesar Lopes, Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Data curation: Mariana P. de Souza, Paulo Cesar Lopes, Heloisa Bettiol, Marco Antonio Barbieri.
Formal analysis: Mariana P. de Souza, Paulo Cesar Lopes, Gabriel Bazo, Paulo Ricardo H. Rocha, Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Funding acquisition: Heloisa Bettiol, Marco Antonio Barbieri.
Investigation: Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Methodology: Mariana P. de Souza, Paulo Cesar Lopes, Gabriel Bazo, Paulo Ricardo H. Rocha, Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Project administration: Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Resources: Marco Antonio Barbieri, Eduardo B. Coelho.
Software: Eduardo B. Coelho.
Supervision: Heloisa Bettiol, Marco Antonio Barbieri, Eduardo B. Coelho.
Visualization: Eduardo B. Coelho.
Writing – original draft: Mariana P. de Souza, Paulo Cesar Lopes, Gabriel Bazo, Paulo Ricardo H. Rocha, Eduardo B. Coelho.
Writing – review & editing: Mariana P. de Souza, Daniela Aparecida Lorencini, Eduardo B. Coelho.

References

[1] Lewington S, Clarke R, Qizilbash N, Peto R, Collins R. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet 2002;360:1903–13.
[2] Rapsomaniki E, Timmis A, George J, et al. Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1·25 million people. Lancet 2014;383:1899–911.
[3] Whelton PK, Carey RM, Aronow WS, 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. Hypertension 2018;71:1269–324.
[4] Muntner P, Carey RM, Gidding S, et al. Potential US population impact of the 2017 ACC/AHA high blood pressure guideline. Circulation 2018;137:109–18.
[5] Mancia G, De Backer G, Dominiczak A, et al. ESC/ESH guidelines for the management of arterial hypertension: the task force for the management of arterial hypertension of the European Society of Cardiology and the European Society of Hypertension: the task force for the management of arterial hypertension of the European Society of Cardiology and the European Society of Hypertension. J Hypertens 2018;36:1953–2041.
[6] Reference Values for Arterial Stiffness' CollaborationDeterminants of pulse wave velocity in healthy people and in the presence of cardiovascular risk factors: 'establishing normal and reference values'. Eur Heart J 2010;31:2338–50.
[7] Ben-Shlomo Y, Spears M, Boustred C, et al. Aortic pulse wave velocity improves cardiovascular event prediction: an individual participant meta-analysis of prospective observational data from 17,635 subjects. J Am Coll Cardiol 2014;63:636–46.
[8] Tientcheu D, Ayers C, Das SR, et al. Target organ complications and cardiovascular events associated with masked hypertension and white-coat hypertension: analysis from the Dallas heart Study. J Am Coll Cardiol 2015;66:2159–69.
[9] Banegas JR, Ruilope LM, De La Sierra A, et al. Relationship between clinic and ambulatory blood-pressure measurements and mortality. N Engl J Med 2018;378:1509–20.
[10] Palla M, Saber H, Konda S, Briasoulis A. Masked hypertension and cardiovascular outcomes: an updated systematic review and meta-analysis. Integr Blood Press Control 2018;11:11–24.
[11] Barbieri MA, Bettiol H, Silva AAM, et al. Health in early adulthood: the contribution of the 1978/79 Ribeirão Preto birth cohort. Braz J Med Biol Res 2006;39:1041–55.
[12] Cardoso VC, Simões VMF, Barbieri MA, et al. Profile of three Brazilian birth cohort studies in Ribeirão Preto, SP and São. Braz Med Biol Res 2007;40:1165–76.
[13] Expert panel on detection evaluation and treatment of high blood cholesterol in adults. Executive summary of the third report (NCEP) – adult treatment panel III. JAMA 2001;285:2486–97.
[14] Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35:1381–95.
[15] Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med 2009;150:604–12.

[16] Lloyd-Jones DM, Braun LT, Ndumele CE, et al. Use of risk assessment tools to guide decision-making in the primary prevention of atherosclerotic cardiovascular disease: a special report from the American Heart Association and American College of Cardiology. J Am Coll Cardiol 2019;73:3153–67.
[17] Van Bortel LM, Laurent S, Boutouyrie P, et al. Expert consensus document on the measurement of aortic stiffness in daily practice using carotid-femoral pulse wave velocity. J Hypertens 2012;30:445–8.
[18] Youden WJ. Index for rating diagnostic tests. Cancer 1950;3:32–5.
[19] Hernández-Vásquez AA, Rojas-Roque C, Santero M, Ruiz-Maza JC, Casas-Bendezú M, Miranda JJ. Changes in the prevalence of hypertension in Peru using the new guideline of the American college of cardiology. Rev Med Chil 2019;147:545–56.
[20] Kibria GMAl, Swasey K, Kc A, Mirbolouk M, et al. Estimated change in prevalence of hypertension in Nepal following application of the 2017 ACC/AHA guideline. JAMA Netw Open 2018;1:e180606.
[21] Son JS, Choi S, Kim K, et al. Association of blood pressure classification in Korean young adults according to the 2017 American College of Cardiology/American Heart Association Guidelines with subsequent cardiovascular disease events. JAMA 2018;320:1783–92.
[22] Qi Y, Han X, Zhao D, et al. Long-term cardiovascular risk associated with stage 1 hypertension defined by the 2017 ACC/AHA hypertension guideline. J Am Coll Cardiol 2018;72:1201–10.
[23] Venkateshmurthy NS, Geldsetzer P, Jaacks LM, Prabhakaran D. Implications of the New American College of Cardiology guidelines for hypertension prevalence in India. JAMA Intern Med 2018;178:1416–8.
[24] Poudel B, Booth JN, Sakhuja S, et al. Prevalence of ambulatory blood pressure phenotypes using the 2017 American College of Cardiology/American Heart Association blood pressure guideline thresholds: data from the coronary artery risk development in young adults study. J Hypertens 2019;37:1401–10.
[25] Peacock J, Diaz KM, Viera AJ, Schwartz JE, Shimbo D. Unmasking masked hypertension: prevalence, clinical implications, diagnosis, correlates and future directions. J Hum Hypertens 2014;28:521–8.
[26] Diaz KM, Veerabhadrappa P, Brown MD, Whited MC, Dubbert PM, Hickson DA. Prevalence, determinants, and clinical significance of masked hypertension in a population-based sample of African Americans: the Jackson heart study. Am J Hypertens 2015;28:900–8.
[27] Tientcheu D, Ayers C, Das SR, et al. Target organ complications and cardiovascular events associated with masked hypertension and white-coat hypertension: analysis from the Dallas heart study. J Am Coll Cardiol 2015;66:2159–69.
[28] Nilsson PM. Early vascular aging in hypertension. Front Cardiovasc Med 2020;7:6.
[29] Gottsäter M, Östling G, Persson M, Engström G, Melander O, Nilsson PM. Non-hemodynamic predictors of arterial stiffness after 17 years of follow-up: the Malmö diet and cancer study. J Hypertens 2015;33:957–65.
[30] Guzik TJ, Touyz RM. Oxidative stress, inflammation, and vascular aging in hypertension. Hypertension 2017;70:660–7.
[31] Ohkubo T, Kikuya M, Metoki H, et al. Prognosis of "masked" hypertension and "white-coat" hypertension detected by 24-h ambulatory blood pressure monitoring 10-year follow-up from the Ohasama study. J Am Coll Cardiol 2005;46:508–15.
[32] Fagard RH, Cornelissen VA. Incidence of cardiovascular events in white-coat, masked and sustained hypertension versus true normotension: a meta-analysis. J Hypertens 2007;25:2193–8.
[33] Pierdomenico SD, Cuccurullo F. Prognostic value of white-coat and masked hypertension diagnosed by ambulatory monitoring in initially untreated subjects: an updated meta analysis. Am J Hypertens 2011;24:52–8.
[34] Asayama K, Thijs L, Li Y, et al. Setting thresholds to varying blood pressure monitoring intervals differentially affects risk estimates associated with white-coat and masked hypertension in the population. Hypertension 2014;64:935–42.
[35] Thomopoulos C, Parati G, Zanchetti A. Effects of blood pressure lowering on outcome incidence in hypertension: 7. Effects of more vs. less intensive blood pressure lowering and different achieved blood pressure levels –updated overview and meta-analyses of randomized trials. J Hypertens 2016;34:613–22.
[36] Botto F, Obregon S, Rubinstein F, Scuteri A, Nilsson PM, Kotliar C. Frequency of early vascular aging and associated risk factors among an adult population in Latin America: the OPTIMO study. J Hum Hypertens 2018;32:219–27.
[37] Danninger K, Hafez A, Binder RK, et al. High prevalence of hypertension and early vascular aging: a screening program in pharmacies in Upper Austria. J Hum Hypertens 2020;34:326–34.
[38] Cunha PG, Cotter J, Oliveira P, et al. Pulse wave velocity distribution in a cohort study: from arterial stiffness to early vascular aging. J Hypertens 2015;33:1438–45.
[39] Bhuiyan AR, Srinivasan SR, Chen W, Paul TK, Berenson GS. Correlates of vascular structure and function measures in asymptomatic young adults: the Bogalusa heart study. Atherosclerosis 2006;189:1–7.
[40] McEniery CM, Spratt M, Munnery M, et al. An analysis of prospective risk factors for aortic stiffness in men: 20-year follow-up from the Caerphilly prospective study. Hypertension 2010;56:36–43.
[41] Metcalf PA, Meyer ML, Tanaka H, et al. Longitudinal associations of blood pressure with aortic stiffness and pulsatility: the atherosclerosis risk in communities study. J Hypertens 2021;39:987–93.
[42] Aatola H, Hutri-Kähönen N, Juonala M, et al. Lifetime risk factors and arterial pulse wave velocity in adulthood: the cardiovascular risk in young Finns study. Hypertension 2010;55:806–11.
[43] AlGhatrif M, Strait JB, Morrell CH, et al. Longitudinal trajectories of arterial stiffness and the role of blood pressure: the Baltimore longitudinal study of aging. Hypertension 2013;62:934–41.
[44] Li S, Chen W, Srinivasan SR, Berenson GS. Childhood blood pressure as a predictor of arterial stiffness in young adults: the Bogalusa heart study. Hypertension 2004;43:541–6.
[45] Kaess BM, Rong J, Larson MG, et al. Aortic stiffness, blood pressure progression, and incident hypertension. JAMA 2012;308:875–81.