Outcome-Driven Thresholds for Ambulatory Blood Pressure Based on the New American College of Cardiology/American Heart Association Classification of Hypertension

Yi-Bang Cheng, Lutgarde Thijs, Zhen-Yu Zhang, Masahiro Kikuya, Wen-Yi Yang, Jesus D. Melgarejo, José Boggia, Fang-Fei Wei, Tine W. Hansen, Cai-Guo Yu, Kei Asayama, Takayoshi Ohkubo, Eamon Dolan, Katarzyna Stolarz-Skrzypek, Sofia Malyutina, Edoardo Casiglia, Lars Lind, Jan Filipovský, Gladys E. Maestre, Yutaka Imai, Kalina Kawecka-Jaszcz, Edgardo Sandoya, Krzysztof Narkiewicz, Yan Li, Eoin O'Brien, Ji-Guang Wang, Jan A. Staessen, on behalf of the IDACO Investigators

Abstract—The new American College of Cardiology/American Heart Association guideline reclassified office blood pressure and proposed thresholds for ambulatory blood pressure (ABP). We derived outcome-driven ABP thresholds corresponding with the new office blood pressure categories. We performed 24-hour ABP monitoring in 11 152 participants (48.9% women; mean age, 53.0 years) representative of 13 populations. We determined ABP thresholds resulting in multivariable-adjusted 10-year risks similar to those associated with elevated office blood pressure (120/80 mm Hg) and stages 1 and 2 of office hypertension (130/80 and 140/90 mm Hg). Over 13.9 years (median), 2728 (rate per 1000 person-years, 17.9) people died, 1033 (6.8) from cardiovascular disease; furthermore, 1988 (13.8), 893 (6.0), and 795 (5.4) cardiovascular and coronary events and strokes occurred. Using a composite cardiovascular end point, systolic/diastolic outcome-driven thresholds indicating elevated 24-hour, daytime, and nighttime ABP were 117.9/75.2, 121.4/79.6, and 105.3/66.2 mm Hg. For stages 1 and 2 ambulatory hypertension, thresholds were 123.3/75.2 and 128.7/80.7 mm Hg for 24-hour ABP, 128.5/79.6 and 135.6/87.1 mm Hg for daytime ABP, and 111.7/66.2 and 118.1/72.5 mm Hg for nighttime ABP. ABP thresholds derived from other end points were similar. After rounding, approximate thresholds for elevated 24-hour, daytime, and nighttime ABP were 120/75, 120/80, and 105/65 mm Hg, and for stages 1 and 2, ambulatory hypertension 125/75 and 130/80 mm Hg, 130/80 and 135/85 mm Hg, and 110/65 and 120/70 mm Hg. Outcome-driven ABP thresholds corresponding to elevated blood pressure and stages 1 and 2 of hypertension are similar to those proposed by the current American College of Cardiology/American Heart Association guideline. **(*Hypertension*. 2019;74:776-783. DOI: 10.1161/HYPERTENSIONAHA.119.13512.)** • **Online Data Supplement**

Key Words: blood pressure monitoring, ambulatory ■ hypertension ■ United States

Recording the ambulatory blood pressure (ABP) allows risk stratification over and beyond the office blood pressure (OBP) and is cost-effective in managing hypertension.[1–3] The recently published American College of Cardiology (ACC)/American Heart Association (AHA) guideline for the management of hypertension, therefore, recommended the application of ABP monitoring for diagnosing hypertension and adjusting antihypertensive drug treatment.[4] Based on the new classification of OBP, the ACC/AHA guideline suggested as ABP thresholds corresponding with office stage-1

Received June 6, 2019; first decision June 16, 2019; revision accepted July 2, 2019.

From the Center for Epidemiological Studies and Clinical Trials and Center for Vascular Evaluation, Shanghai Institute of Hypertension, Shanghai Key Laboratory of Hypertension, Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, China (Y.-B.C., Y.L., J.-G.W.); Research Unit Hypertension and Cardiovascular Epidemiology, KU Leuven Department of Cardiovascular Sciences, University of Leuven, Belgium (L.T., Z.-Y.Z., W.-Y.Y., F.-F.W., C.-G.Y., J.A.S.); Department of Hygiene and Public Health, Teikyo University School of Medicine, Tokyo, Japan (M.K., K.A., T.O.); Department of Planning for Drug Development and Clinical Evaluation, Tohoku Institute for Management of Blood Pressure, Sendai, Japan (K.A., T.O., Y.I.); Laboratorio de Neurociencias and Instituto de Enfermedades Cardiovasculares, Universidad del Zulia, Maracaibo, Venezuela (J.D.M., G.E.M.); Centro de Nefrología and Departamento de Fisiopatología, Hospital de Clínicas, Universidad de la República, Montevideo, Uruguay (J.B.); Steno Diabetes Center, Copenhagen, Gentofte, and Center for Health, Capital Region of Denmark, Denmark (T.W.H.); Stroke and Hypertension Unit, Blanchardstown, Dublin, Ireland (E.D.); First Department of Cardiology, Interventional Electrocardiology and Hypertension, Jagiellonian University Medical College, Krakow, Poland (K.S.-S., K.K.-J); Institute of Internal and Preventive Medicine, Institute of Cytology and Genetics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russian Federation (S.M.); Department of Medicine, University of Padua, Italy (E.C.); Section of Geriatrics, Department of Public Health and Caring Sciences, Uppsala University, Sweden (L.L.); Faculty of Medicine, Charles University, Pilsen, Czech Republic (J.F.); Department of Neurosciences and Department of Human Genetics, University of Texas Rio Grande Valley School of Medicine, Brownsville (G.E.M.); Asociación Española Primera de Socorros Mutuos, Montevideo, Uruguay (E.S.); Department of Hypertension and Diabetology, Hypertension Unit, Medical University of Gdańsk, Poland (K.N.); Conway Institute of Biomolecular and Biomedical Research, University College Dublin, Ireland (E.O.); and Cardiovascular Research Institute Maastricht, Maastricht University, the Netherlands (J.A.S.).

This paper was sent to Daniel W. Jones, Guest Editor, for review by expert referees, editorial decision, and final disposition.

The online-only Data Supplement is available with this article at https://www.ahajournals.org/doi/suppl/10.1161/HYPERTENSIONAHA.119.13512.

Correspondence to Jan A. Staessen, KU Leuven Department of Cardiovascular Sciences, Studies Coordinating Centre, Research Unit Hypertension and Cardiovascular Epidemiology, University of Leuven, Campus Sint Rafaël, Kapucijnenvoer 35, Box 7001, BE-3000 Leuven, Belgium. Email jan.staessen@med.kuleuven.be

hypertension, systolic/diastolic blood pressure (BP) levels of 125/75, 130/80, and 110/65 mm Hg for the 24-hour, daytime, and nighttime BP, respectively. Similarly, the guideline also proposed ABP thresholds corresponding with office of elevated BP (120/80 mm Hg) and stage-2 and severe hypertension (140/90 and 160/100 mm Hg, respectively).[4] The objective of the current analysis was to determine outcome-driven diagnostic BP thresholds for ambulatory recordings, corresponding with the new cutoff levels proposed by ACC/AHA for OBP. To this effect, we analyzed the International Database on Ambulatory Blood Pressure in Relation to Cardiovascular Outcome (IDACO), which at the time of writing of this article included 13 654 people recruited from 13 populations.[5]

Methods

The data that support the findings of this study are available from the corresponding author on reasonable request.

Study Population

Previous publications describe the IDACO database in detail.[5] Population studies qualified for inclusion, if information on the OBP and the ABP and cardiovascular risk factors was available at baseline and if follow-up included both fatal and nonfatal outcomes. All studies received ethical approval and adhered to the principles of the Declaration of Helsinki.[6] Participants gave written informed consent. Of the 13 654 people included in the database, we excluded 2502 because they were teenagers <18 years of age without events (n=317), because their OBP had not been measured (n=223), because their use of antihypertensive drugs had not been recorded (n=28), or because they had an ABP recording with <10 daytime and 5 nighttime readings (n=1934). Thus, the number of participants analyzed was 11 152. Table S1 available in the online-only Data Supplement provides detailed information on where and how participants were enrolled.

BP Measurement

Experienced observers measured the OBP with standard mercury sphygmomanometers or with validated auscultatory (USM-700F[7]) or oscillometric (OMRON HEM-705CP[8] or Dinamap 8100[9]) devices, using the appropriate cuff size, after the participants had rested for at least 2 minutes in the sitting or supine position. OBP was the average of 2 consecutive readings.[10] We programmed validated portable monitors to obtain ABP readings at 30-minute intervals throughout the whole day, or at intervals ranging from 15 to 30 minutes during daytime and from 20 to 60 minutes at night. Methods used for OBP and ABP measurement are described for each cohort in Tables S2 and S3, respectively. Daytime ranged from 10 AM to 8 PM in Europeans and South Americans and from 8 AM to 6 PM in Asians. The corresponding nighttime intervals ranged from midnight to 6 AM and from 10 PM to 4 AM, respectively. Using short, fixed clock-time intervals eliminates the transition periods in the morning and evening when BP changes rapidly and produces daytime and nighttime BP levels, which are within 1 mm Hg of the levels during wakefulness and sleep, respectively.[11] Participants were categorized according to their OBP and 24-hour ABP. Normotension and elevated BP on OBP measurement were systolic levels of <120 mm Hg and 120 to 129 mm Hg and a diastolic level of <80 mm Hg. Stage-1 and stage-2 hypertension and severe hypertension were systolic or diastolic levels of 130 to 139/80 to 89 mm Hg, 140 to 159/90 to 99 mm Hg, and ≥160/≥100 mm Hg, respectively. Considering the 24-hour ABP, normotension and elevated BP were systolic levels of <115 mm Hg and 115 to 124 mm Hg and a diastolic level of <75 mm Hg. Stage-1 and stage-2 hypertension and severe hypertension on ambulatory monitoring were systolic or diastolic levels of 125 to 129/75 to 79 mm Hg, 130 to 144/80 to 89 mm Hg, and ≥145/≥90 mm Hg, respectively. If systolic and diastolic BPs were in different categories, the highest level was used to categorize people.

Ascertainment of Events

We ascertained vital status and the incidence of fatal and nonfatal diseases from the appropriate sources in each country, as described in previous IDACO publications.[5] Outcomes were coded according to the *International Classification of Diseases* (*ICD*). Fatal and nonfatal stroke (ICD 8/9 430–434 and 436, ICD 10 I60–I64) did not include transient ischemic attacks. Coronary events encompassed death from ischemic heart disease (ICD 8 411–412, ICD 9 411 and 414, and ICD 10 I20, I24–I25), sudden death (ICD 8 427.2 and 795, ICD 9 427.5 and 798, and ICD 10 I46 and R96), nonfatal myocardial infarction (ICD 8/9 410, and ICD 10 I21–I22), and coronary revascularization. Cardiovascular events included all aforementioned end points plus cardiovascular mortality (ICD 8 390–448, ICD 9 390.0–459.9, and ICD 10 I00-I79 and R96) and heart failure (ICD 8 428, 427.0, 427.1, 427.2, 429, 5191, and 78214, ICD 9 429, and ICD 10 I50 and J81). In the Danish and Swedish cohorts, the diagnosis of heart failure required admission to hospital. In the other cohorts, heart failure was either a clinical diagnosis or the diagnosis on the death certificate. All events were validated against records held by family doctors or hospitals. In the outcome analyses, only the first event within each disease cluster was considered.

Statistical Analysis

For database management and statistical analysis, we used SAS software, version 9.4 (SAS Institute, Cary, NC). We compared means and proportions by the large sample z test or ANOVA and by the χ^2 test, respectively. Statistical significance was a 2-sided probability of ≤0.05. In exploratory analyses, we first plotted incidence rates of mortality and cardiovascular events by the BP categories proposed by the ACC/AHA guideline,[4] while standardizing by the direct method for cohort, sex, and age (<40, 40–60, and ≥60 years). Next, in multivariable-adjusted Cox regression, we accounted for cohort (random effect), sex, and baseline characteristics including age, body mass index, smoking and drinking, serum cholesterol, antihypertensive drug intake, history of cardiovascular disease, and diabetes mellitus. To adjust for cohort, we pooled participants recruited in the framework of the European Project on Genes in Hypertension (Novosibirsk, Kraków, Gdańsk, Pilsen, and Padova).[12] We checked the proportional hazards assumption by the Kolmogorov-type supremum test and by testing the interaction between follow-up duration and the BP variables.

We obtained diagnostic thresholds for ABP monitoring in 5 steps. First, we computed the 10-year incidence rates of mortality and cardiovascular events associated with normal and elevated BP or hypertension on OBP measurement. Second, we computed the 10-year incidence rates of death and cardiovascular events associated with ABP levels ranging from the 5th to the 95th percentile, using intervals of 0.1 mm Hg. In a third step, we selected the ABP levels that were associated with similar 10-year risks as the OBP thresholds. Next, we calculated the bootstrap distribution of the so-obtained ABP thresholds by randomly resampling the study population 1000× with replacement, using the PROC SURVEY SELECT procedure, as implemented in the SAS package. For each new sample, we repeated the first 3 steps. We accounted for tied event times, caused by resampling with replacement, by the TIES=EXACT option in the PROC PHREG procedure. Finally, we calculated the bootstrap point estimates and 95% CIs of the ABP thresholds as the mean±1.96 SEs of the bootstrap distribution.

Results

Characteristics of Participants

Table 1 shows the baseline characteristics of the participants by ethnicity. The whole study population comprised 6958 Europeans (62.4%), 2167 Asians (19.4%), and 2027 South Americans (18.2%). Of the 11 152 participants, 5455 were women (48.9%), 6865 (61.6%) had hypertension on OBP measurement, and 2190 (19.6%) were taking antihypertensive drugs. Of 8962 untreated participants, 2848 (31.8%) and 1106 (12.3%) had a normal or elevated OBP, respectively. Mean age was 53.0±15.9 years. At enrollment, 3059 participants (27.4%) were current smokers and 5864 (52.6%) reported intake of alcohol.

Table 1. Baseline Characteristics of Participants

Characteristics	All	Characteristics by Ethnicity			
		Europeans	Asians	South Americans	*P* Value
No. with characteristic, %	11 152	6958	2167	2027	
Women	5455 (48.9)	2936 (42.2)*	1343 (62.0)†	1173 (57.9)‡	<0.001
Smokers	3059 (27.4)	2171 (31.2)*	468 (21.6)	420 (20.7)‡	<0.001
Drinking alcohol	5864 (52.6)	4531 (65.1)*	714 (33.0)	619 (30.5)‡	<0.001
Diabetes mellitus	847 (7.6)	329 (4.7)*	245 (11.3)†	273 (13.5)‡	<0.001
History of cardiovascular disease	1256 (11.3)	652 (9.4)*	96 (4.4)†	508 (25.1)‡	<0.001
Hypertension status					
Normotension	3012 (27.0)	1952 (28.1)*	528 (24.4)	532 (26.3)	0.002
On treatment	164 (5.4)	81 (4.2)*	56 (10.6)†	27 (5.1)	<0.001
Elevated BP	1275 (11.4)	770 (11.1)*	362 (16.7)†	143 (7.1)‡	<0.001
On treatment	169 (13.3)	71 (9.2)*	83 (22.9)†	15 (10.5)	<0.001
Stage-1 hypertension	2739 (24.6)	1835 (26.4)	534 (24.6)†	370 (18.3)‡	<0.001
On treatment	449 (16.4)	254 (13.8)*	143 (26.8)†	52 (14.1)	<0.001
Stage-2 hypertension	2560 (23.0)	1658 (23.8)*	444 (20.5)†	458 (22.6)	0.005
On treatment	738 (28.8)	437 (26.4)*	174 (39.2)†	127 (27.7)	<0.001
Severe hypertension	1566 (14.0)	743 (10.7)*	299 (13.8)†	524 (25.9)‡	<0.001
On treatment	670 (42.8)	325 (43.7)	138 (46.2)	207 (39.5)	0.14
Mean characteristic (±SD)					
Age, y	53.0±15.9	51.0±16.2*	57.0±13.3†	55.4±16.0‡	<0.001
Body mass index, kg/m^2	25.4±4.3	25.7±4.2*	23.1±3.1†	26.8±4.9‡	<0.001
Serum cholesterol, mmol/L	5.55±1.14	5.71±1.14*	4.96±0.92†	5.66±1.17‡	<0.001
BP, mm Hg					
Office systolic	132.9±23.4	130.2±19.7*	133.7±22.2†	141.3±32.4‡	<0.001
Office diastolic	79.9±12.1	80.2±11.1*	76.8±12.7†	82.3±13.6‡	<0.001
24-h systolic	123.8±14.4	124.2±13.8*	123.2±14.7	123.4±16.1‡	0.006
24-h diastolic	74.0±8.7	73.6±8.1*	74.4±9.5	74.8±9.5‡	<0.001
Daytime systolic	129.9±15.2	131.0±14.7*	128.6±15.3†	127.5±16.4‡	<0.001
Daytime diastolic	78.9±9.3	79.1±8.7*	78.6±10.1	78.8±10.4	0.11
Nighttime systolic	112.9±15.6	112.4±14.6	112.8±16.3†	114.6±18.1‡	<0.001
Nighttime diastolic	65.0±9.6	64.1±9.0*	66.5±10.4	66.6±10.5‡	<0.001

Body mass index was body weight in kilograms divided by height in meters squared. Diabetes mellitus was the use of antidiabetic drugs, fasting blood glucose of ≥7.0 mmol/L, random blood glucose of ≥11.1 mmol/L, a self-reported diagnosis, or diabetes mellitus documented in practice or hospital records. The *P* Value denotes significant overall between-group differences. For the calculation of the prevalence of antihypertensive drug treatment, the number of people with a given BP status was used as denominator; otherwise the column totals. BP indicates blood pressure.

Symbols indicate significant ethnic differences:
*between Europeans and Asians,
†between Asians and South Americans, and
‡between Europeans and South Americans.

The prevalence of elevated BP was the highest among Asians (16.7%), stage-1 (26.4%) and stage-2 (23.8%) hypertension among Europeans, and severe hypertension among South Americans (25.9%) with treatment rates varying from 4.2% to 22.9% among people with normotension or elevated BP and from 13.8% to 46.2% among hypertensive patients (Table 1). Between-ethnicity differences were significant for all variables (P≤0.006), except for daytime diastolic BP (P=0.11) and treatment rates among severe hypertension (P=0.14).

In the whole study population, mean systolic/diastolic levels were 132.9/79.9 mm Hg for OBP and 123.8/74.0, 129.9/78.9, and 112.9/65.0 mm Hg for 24-hour, daytime, and nighttime BP, respectively. Systolic/diastolic BPs were on average 2.9 mm Hg (P<0.001) and 1.0 mm Hg (P<0.001) higher on office than daytime measurement.

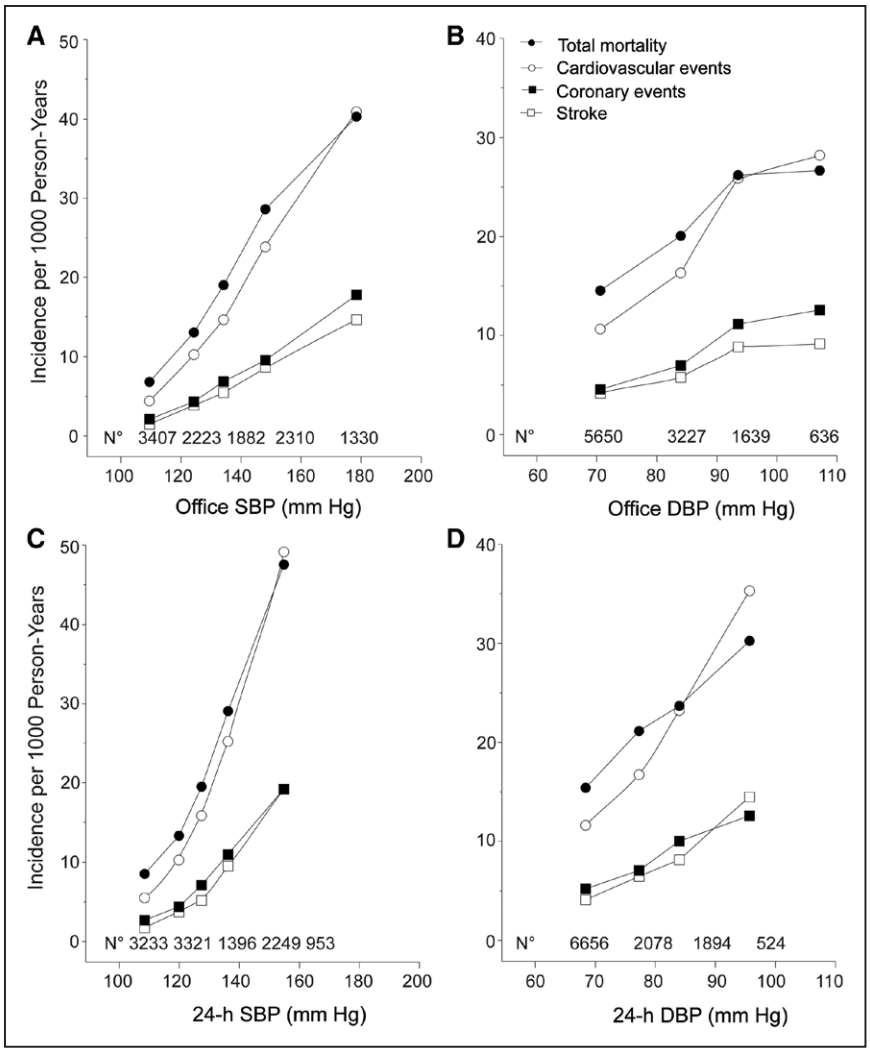

Figure. Incidence rates by office and 24 h blood pressure categories. Incidence rates of total mortality, cardiovascular and coronary events, and stroke by American College of Cardiology (ACC)/American Heart Association (AHA) categories of office systolic blood pressure (SBP; **A**) and diastolic blood pressure (DBP; **B**; SBP: <120, 120–129, 130–139, 140–159, and ≥160 mm Hg; DBP: <80, 80–89, 90–99, and ≥100 mm Hg) and by ACC/AHA categories of 24-h SBP (**C**) and DBP (**D**) (SBP: <115, 115–124, 125–129, 130–144, and ≥145 mm Hg; DBP: <75, 75–79, 80–89, and ≥90 mm Hg) were standardized by the direct method for cohort, sex, and age (<40, 40–60, and >60 y). The number of events contributing to the incidence rates is presented in Table S4. N° indicates the number of participants at risk within each blood pressure category.

Incidence of Events in Relation to BP

In the overall study population, median follow-up was 13.9 years (5th to 95th percentile interval, 3.6–24.9 years). Over 152 156 person-years, 2728 participants died (17.9 per 1000 person-years) and 1988 experienced a fatal or nonfatal cardiovascular event (13.8 per 1000 person-years). Mortality included 1033 and 1585 cardiovascular and noncardiovascular deaths and 110 from unknown causes. The number of end points was 893 for coronary events and 795 for stroke.

The Figure shows the increase in total mortality, cardiovascular and coronary events, and stroke across categories of the OBP and 24-hour ABP with standardization of the rates for cohort, sex, and age. The number of events contributing to the incidence rates is presented in Table S4. With adjustments applied for cohort, sex, age, body mass index, serum cholesterol, smoking and drinking, history of cardiovascular disease and diabetes mellitus, and antihypertensive drug treatment, BP was a highly significant (P<0.001) and consistent predictor of all outcomes, irrespective of the type of measurement (Table 2). The standardized hazard ratios for total mortality in relation to the OBP, 24-hour, daytime, and nighttime BP were 1.14, 1.16, 1.11, and 1.18 systolic and 1.08, 1.14, 1.09, and 1.17 diastolic; the corresponding hazard ratios for fatal combined with nonfatal cardiovascular events were 1.25, 1.32, 1.26, and 1.29 systolic and 1.19, 1.28, 1.22, and 1.28 diastolic, respectively.

ABP Thresholds

Using a bootstrap procedure with adjustments applied for the aforementioned covariates, ABP thresholds were calculated that yielded 10-year absolute risks of total and cardiovascular mortality, cardiovascular and coronary events, and stroke similar to the risks associated with the ACC/AHA thresholds for office systolic (Table 3) and diastolic (Table 4) BP. The thresholds based on the full data set were similar to the means of the bootstraps. Excluding 2190 participants on antihypertensive treatment at enrollment (Tables S5 and S6) or using diary information (Tables S7 and S8) to derive BP during wakefulness and sleep in 7196 participants (64.5%) produced results highly consistent with those reported in Tables 3 and 4. To obtain more easily recallable thresholds, in the last step of our analysis, we rounded the systolic (Table 3) and diastolic (Table 4) point estimates of the ABP thresholds for cardiovascular events to an integer value ending in zero or 5. Table 5 lists the thresholds proposed by the ACC/AHA guideline, as well as the rounded thresholds based on the current analysis. In sensitivity analyses, from which we excluded one cohort at a time, these diagnostic thresholds remained largely consistent.

Table 2. Hazard Ratios for Mortality and Cardiovascular Events in Relation to Baseline BP

	Mortality		Fatal and Nonfatal Cardiovascular Events		
BP	Total	Cardiovascular	All	Coronary	Stroke
End points, n (%)	2728 (24.5)	1033 (9.3)	1988 (17.8)	893 (8.0)	795 (7.1)
Systolic					
Office	1.14 (1.09–1.20)	1.25 (1.16–1.34)	1.25 (1.18–1.31)	1.16 (1.08–1.26)	1.37 (1.26–1.49)
24 h	1.16 (1.12–1.21)	1.34 (1.26–1.41)	1.32 (1.27–1.38)	1.25 (1.17–1.33)	1.44 (1.35–1.54)
Daytime	1.11 (1.07–1.16)	1.26 (1.19–1.33)	1.26 (1.20–1.31)	1.21 (1.13–1.29)	1.35 (1.26–1.45)
Nighttime	1.18 (1.14–1.22)	1.32 (1.25–1.39)	1.29 (1.24–1.34)	1.24 (1.17–1.31)	1.38 (1.30–1.46)
Diastolic					
Office	1.08 (1.04–1.13)	1.16 (1.09–1.25)	1.19 (1.13–1.25)	1.11 (1.03–1.19)	1.25 (1.16–1.35)
24 h	1.14 (1.09–1.18)	1.28 (1.20–1.36)	1.28 (1.23–1.34)	1.16 (1.09–1.25)	1.39 (1.30–1.50)
Daytime	1.09 (1.05–1.14)	1.21 (1.14–1.29)	1.22 (1.17–1.28)	1.12 (1.05–1.20)	1.31 (1.22–1.41)
Nighttime	1.17 (1.12–1.22)	1.30 (1.22–1.38)	1.28 (1.22–1.34)	1.18 (1.10–1.26)	1.38 (1.28–1.48)

Hazard ratios (95% CI) express the risk associated with 1-SD increases in BP. Hazard ratios were adjusted for cohort, sex, age, body mass index, smoking and drinking, serum cholesterol, history of cardiovascular disease, diabetes mellitus, and treatment with antihypertensive drugs. All hazard ratios were significant ($P<0.001$). BP indicates blood pressure.

Discussion

Several studies established that out-of-office BP, measured by ambulatory[10,13] or home[14] monitoring, is a better predictor of mortality and cardiovascular complications than OBP is. The 2017 ACC/AHA guideline for the management of hypertension[4] and other directives[15] recommended that for the proper diagnosis and management of hypertension, out-of-office BP measurement is a prerequisite. The new ACC/AHA guideline reclassified OBP and proposed thresholds for 24-hour, daytime, and nighttime BP corresponding to the new

Table 3. Systolic Ambulatory Blood Pressure Levels Yielding Similar 10-y Risk as Office Thresholds

End Points (n)	Office SBP, mm Hg	10-y Absolute Risk, %	Ambulatory SBP (95% CI), mm Hg		
			24 h	Daytime	Nighttime
Total mortality (2728)	120	3.66	117.1 (113.8–120.3)	118.9 (113.8–124.1)	106.0 (102.7–109.2)
	130	3.91	123.0 (121.5–124.5)	127.7 (125.7–129.8)	111.9 (110.3–113.5)
	140	4.18	128.8 (128.1–129.6)	136.6 (135.0–138.1)	117.7 (117.0–118.5)
	160	4.79	140.6 (136.5–144.8)	153.7 (147.7–159.7)	129.5 (125.6–133.4)
Cardiovascular mortality (1033)	120	1.12	119.1 (116.0–122.1)	122.5 (118.4–126.6)	106.9 (103.3–110.5)
	130	1.24	124.1 (122.3–125.9)	129.1 (126.9–131.4)	112.6 (110.5–114.7)
	140	1.38	129.1 (128.1–130.1)	135.8 (134.6–137.0)	118.3 (117.1–119.5)
	160	1.72	139.1 (136.2–142.0)	149.1 (144.8–153.4)	129.7 (126.3–133.2)
Cardiovascular events (1988)	120	4.34	117.9 (116.0–119.8)	121.4 (118.8–123.9)	105.3 (102.8–107.7)
	130	4.84	123.3 (122.3–124.3)	128.5 (127.2–129.7)	111.7 (110.5–112.9)
	140	5.40	128.7 (128.2–129.2)	135.6 (134.8–136.3)	118.1 (117.5–118.8)
	160	6.71	139.5 (137.3–141.8)	149.7 (146.4–153.1)	131.0 (128.0–134.1)
Coronary events (893)	120	2.02	118.6 (115.4–121.8)	122.7 (119.1–126.4)	106.8 (102.6–111.0)
	130	2.18	123.3 (121.9–124.8)	128.6 (127.0–130.2)	112.2 (110.4–114.1)
	140	2.36	128.1 (127.1–129.0)	134.5 (133.4–135.6)	117.7 (116.6–118.8)
	160	2.76	137.5 (133.3–141.8)	146.3 (141.1–151.4)	128.6 (123.0–134.2)
Stroke (795)	120	1.58	117.2 (114.9–119.4)	120.6 (117.5–123.6)	103.9 (101.0–106.8)
	130	1.84	123.0 (121.9–124.1)	128.2 (126.7–129.6)	111.0 (109.6–112.4)
	140	2.15	128.9 (128.3–129.4)	135.7 (135.0–136.5)	118.1 (117.4–118.9)
	160	2.93	140.6 (138.1–143.2)	150.9 (147.1–154.6)	132.3 (128.9–135.8)

SBP indicates systolic blood pressure.

Table 4. Diastolic Ambulatory Blood Pressure Levels Yielding Similar 10-y Risk as Office Thresholds

End Points (n)	Office DBP, mm Hg	10-y Absolute Risk, %	Ambulatory DBP (95% CI), mm Hg		
			24 h	Daytime	Nighttime
Total mortality (2728)	80	3.98	75.3 (74.7–76.0)	79.7 (78.8–80.7)	66.6 (65.9–67.3)
	90	4.34	80.8 (79.3–82.4)	87.9 (85.2–90.7)	71.8 (70.4–73.3)
	100	4.74	86.3 (83.0–89.7)	94.8 (91.5–98.2)	77.0 (73.8–80.2)
Cardiovascular mortality (1033)	80	1.25	76.3 (75.4–77.2)	80.7 (79.4–82.0)	67.6 (66.5–68.6)
	90	1.46	81.5 (80.1–82.9)	87.8 (85.8–89.8)	73.2 (71.6–74.7)
	100	1.71	86.6 (83.7–89.5)	94.4 (91.3–97.5)	78.7 (75.4–82.0)
Cardiovascular events (1988)	80	4.94	75.2 (74.7–75.7)	79.6 (79.0–80.2)	66.2 (65.6–66.8)
	90	5.86	80.7 (79.8–81.6)	87.1 (85.7–88.4)	72.5 (71.5–73.6)
	100	6.96	86.3 (84.2–88.3)	94.3 (91.9–96.8)	78.9 (76.6–81.3)
Coronary events (893)	80	2.21	74.4 (73.6–75.2)	78.7 (77.5–79.9)	65.5 (64.5–66.5)
	90	2.50	80.2 (78.2–82.2)	86.8 (83.6–89.9)	71.9 (69.5–74.4)
	100	2.82	86.0 (81.5–90.5)	93.9 (89.0–98.8)	78.3 (72.8–83.7)
Stroke (795)	80	1.95	75.7 (75.0–76.4)	80.2 (79.3–81.0)	66.7 (65.8–67.6)
	90	2.43	81.2 (80.1–82.3)	87.4 (85.9–88.9)	73.1 (71.8–74.3)
	100	3.03	86.7 (84.2–89.3)	94.4 (91.6–97.2)	79.4 (76.4–82.5)

DBP indicates diastolic blood pressure.

OBP categories.[4] Of these ambulatory thresholds, the 24-hour systolic and diastolic levels are prognostically the most meaningful because they are based on the largest number of readings. Using the IDACO database, we derived outcome-driven thresholds in 11 152 participants from 13 population studies. The key finding of our study was that we largely confirmed the validity of the ACC/AHA proposal for ABP thresholds in terms of mortality and cardiovascular complications. The thresholds derived by our analysis were identical with the ACC/AHA proposal with the exception of the systolic thresholds delineating elevated BP for 24-hour and nighttime BP (ACC/AHA versus IDACO, 115 versus 120 mm Hg and 100 versus 105 mm Hg, respectively). For severe hypertension, the ACC/AHA and IDACO thresholds differed by 5 mm Hg systolic or diastolic (Table 5) and by 10 mm Hg for the systolic nighttime BP (140 versus 130 mm Hg).

Thresholds for the clinical application of ABP were initially based on the distribution of the ABP in individuals with an OBP in the normotensive range,[16,17] usually defined as a level of <140 mm Hg systolic and 90 mm Hg diastolic or by regression of the ABP on the OBP.[18] In a meta-analysis of summary statistics from 23 studies,[17] the mean ABP plus 2× the SD in 3476 normotensive people amounted to 139/87, 146/91, and 127/79 mm Hg for the 24-hour, daytime, and nighttime BP, respectively. In a participant-level meta-analysis of 7069 individual recordings from 24 clinical research groups, the thresholds were set at the 95th percentiles of the ABP distributions among 4577 individuals, who were normotensive on office measurement. The BP limits derived in this manner were 133/82, 140/88, and 125/76 mm Hg for the 24-hour, daytime, and nighttime BP, respectively.[16] Head et al[18] applied a least-product fit to regress ABP measurements on OBP in 8575 Australians. The thresholds for 24-hour, daytime, and nighttime ABP were 7/6, 4/3, and 19/14 mm Hg lower than the 140/90 mm Hg threshold for OBP, 133/84, 136/87, and 121/76 mm Hg, respectively.

The aforementioned studies relied heavily on the proportion and representativeness of individuals with office normotension in the studies analyzed and entirely on a distributional or statistical approach for setting the ABP thresholds, which ignores what matters most, that is, the incidence of adverse health outcomes. Later studies, therefore, applied a more robust outcome-based approach.[19–21] According to the Ohasama investigators,[19]

Table 5. Proposal for Outcome-Driven Thresholds for the Ambulatory BP

BP Category	ACC/AHA 2017 Thresholds				Ambulatory Thresholds Based on IDACO		
	OBP	24 h	Day	Night	24 h	Day	Night
Elevated BP, mm Hg	120/80	115/75	120/80	100/65	120/75	120/80	105/65
Stage-1 hypertension, mm Hg	130/80	125/75	130/80	110/65	125/75	130/80	110/65
Stage-2 hypertension, mm Hg	140/90	130/80	135/85	120/70	130/80	135/85	120/70
Severe hypertension, mm Hg	160/100	145/90	145/90	140/85	140/85	150/95	130/80

Ambulatory thresholds based on IDACO were obtained by rounding the point estimates reported in Tables 3 and 4 for cardiovascular events to the nearest integer value ending in zero or 5. ACC/AHA indicates American College of Cardiology/American Heart Association; BP, blood pressure; IDACO, International Database on Ambulatory Blood Pressure in Relation to Cardiovascular Outcome; and OBP, office blood pressure.

the 24-hour BP associated with the lowest risk of all-mortality ranged from 120 to 133 mm Hg systolic and from 65 to 78 mm Hg diastolic. Using the same statistical methods as in the current article, the IDACO consortium proposed as ABP thresholds corresponding with an optimal OBP (<120/<80 mm Hg) levels of 116.8/74.2, 121.6/78.9, and 100.9/65.3 mm Hg for 24-hour, daytime, and nighttime BP.[20] The corresponding thresholds for the ABP with a risk equivalent to normal OBP (<130/<85 mm Hg) were 123.9/76.8, 129.9/82.6, and 110.2/68.1 mm Hg, respectively, and the ambulatory thresholds yielding a risk equivalent to office hypertension (≥140/90 mm Hg) were 131.0/79.4, 138.2/86.4, and 119.5/70.8 mm Hg. Rounded upper limits for the 24-hour, daytime, and nighttime BP amounted to 115/75, 120/80, and 100/65 mm Hg for optimal BP, to 125/75, 130/85, and 110/65 mm Hg for normal BP, and to 130/80, 140/85, and 120/70 mm Hg for ambulatory hypertension. In the Jackson Heart Study,[21] 1016 of 5306 African-American participants (19.2%) had their OBP and ABP measured. In an outcome-driven approach, the composite of all-cause mortality and cardiovascular disease was used as an end point. Diastolic was not related to outcome and therefore not analyzed. For systolic BP, the thresholds corresponding with an OBP of 140 mm Hg were 134, 138, and 129 mm Hg for 24-hour, daytime, and nighttime BP, respectively.

The present study must be interpreted within the context of its potential limitations. First, rounded ABP thresholds are a compromise between accuracy and practicability. For instance, the 24-hour systolic BP threshold for stage-1 hypertension was 117.9 mm Hg. The 95% CI ranged from 116.0 and 119.8 mm Hg. We proposed a rounded value of 120 mm Hg, which was only 0.2 mm Hg higher than the upper limit of the 95% CI. Rounding to 115 mm Hg might have been the alternative, but such threshold would have been 1.0 mm Hg lower than the lower limit of the CI. Second, OBP was the average of only 2 readings, obtained on a single occasion, which is less than recommended by the 2017 ACC/AHA guideline[4] which propose that OBP be measured on at least 2 occasions. OBP and ABP were measured in a consistent manner across all IDACO centers. Overall, the pooled correlation coefficient, weighted for sample size in each center, was 0.68 systolic and 0.62 diastolic. It is, therefore, unlikely that our definition of OBP as the average of 2 readings obtained on a single occasion distorted our results. Third, the ABP thresholds based on equivalent risk with OBP, as proposed in the current manuscript and in an earlier IDACO analysis,[20] are equally applicable to women and men and across the adult age range ≤80 years. This approach serves clinical practicability but might disregard the relative and absolute risks associated with BP over a the course of life.[22] However, a participant-level meta-analysis addressing this issue for the self-measured home BP as modality of the out-of-office BP confirmed that the application of single BP targets in both sexes and across the adults age range is justifiable.[23] Finally, our analysis did not include African Americans or blacks born and living in Africa, who are more susceptible to the complications of hypertension than other ethnic groups.[24,25] In this context, the systolic ABP thresholds generated by the Jackson Heart Study investigators are 4, 8, and 9 mm Hg higher than those listed in Table 5 for the 24-hour, daytime, and nighttime BP, yielding equivalent risk with a systolic OBP of 140 mm Hg. If people of African descent were at higher risk than other ethnicities, one would actually have anticipated ABP thresholds slightly lower than those in Table 5. This underscores the concept that multiethnic cohort studies enhance generalizability.

Perspectives

The present study provides outcome-driven BP thresholds for the ABP that yield risks equivalent to those associated with the new ACC/AHA classification of hypertension. Our analysis supports the ACC/AHA recommendation for operational thresholds applicable to ABP. However, one caveat lies in the continuous nature of the association between cardiovascular complications and BP. Operational BP thresholds help clinicians in diagnosing and managing hypertension, but in addition to BP, the complete clinical picture, including other risk factors and comorbidities, should always be considered as recommended in the current guidelines.[4,15]

Acknowledgments

We gratefully acknowledge the clerical assistance of Vera De Leebeeck and Renilde Wolfs at the Studies Coordinating Centre in Leuven, Belgium.

Sources of Funding

The European Union (HEALTH-F7-305507 HOMAGE), the European Research Council (Advanced Researcher Grant 2011-294713-EPLORE and Proof-of-Concept Grant 713601-uPROPHET), the European Research Area Net for Cardiovascular Diseases (JTC2017-046-PROACT), and the Research Foundation Flanders, Ministry of the Flemish Community, Brussels, Belgium (G.0881.13), supported the Studies Coordinating Centre in Leuven. The European Union (grants LSHM-CT-2006–037093 and HEALTH-F4-2007–201550) also supported the research groups in Shanghai, Kraków, Padova, and Novosibirsk. The Ohasama Study was supported by Grants for Scientific Research (16H05243, 16K09472, 16K11850, 16K15359, 17H04126, 17H06533, 17K15853, 17K19930, 18K09674, 18K09904, and 18K17396) from the Ministry of Culture, Sports, Science, and Technology, Tokyo, Japan; a Grant-in-Aid for Young Scientists of Showa Pharmaceutical University H28-4; the Japan Arteriosclerosis Prevention Fund; Comprehensive Research on Cardiovascular and Lifestyle Related Diseases (H26-Junkankitou [Seisaku]-Ippan-001) and (H29–Junkankitou–Ippan–003) from the Ministry of Health, Labor, and Welfare, Tokyo, Japan; a Scheme to Revitalize Agriculture and Fisheries in Disaster Area through Deploying Highly Advanced Technology (NouEi 2-02) from the Ministry of Agriculture, Forestry and Fisheries, Japan. The Asociación Española Primera en Salud supported the research group in Montevideo. The Danish Heart Foundation (grant 01-2-9-9A-22914) and the Lundbeck Fonden (grant R32-A2740) supported the studies in Copenhagen. The JingNing study was supported by the National Natural Science Foundation of China (grants 81470533, 91639203, and 81770455), the Ministry of Science and Technology (2015AA020105-06, 2016YFC1300100, and 2018YFC1704902), Beijing, China, and by the Shanghai Commissions of Science and Technology (grants 14ZR1436200 and 15XD1503200) and the Shanghai Bureau of Health (15GWZK0802, 2017BR025, and a Grant for Leading Academics). The National Institutes of Health and the National Institute of Aging (5 R01 AG036469-05 and 1R03AG054186) and Fondo Nacional de Ciencia, Tecnología e Innovación (G-97000726) supported the Maracaibo Aging Study. Follow-up of the Kraków cohort was supported by the Foundation for Polish Science.

Disclosures

None.

References

1. Staessen JA, Byttebier G, Buntinx F, Celis H, O'Brien ET, Fagard R; for the Ambulatory Blood Pressure Monitoring and Treatment of Hypertension

Investigators. Antihypertensive treatment based on conventional or ambulatory blood pressure measurement. A randomized controlled trial. *J Am Med Ass*. 1997;278:1065–1072. doi: 10.1001/jama.1997.03550130039034
2. Beyhaghi H, Viera AJ. Comparative Cost-effectiveness of clinic, home, or ambulatory blood pressure measurement for hypertension diagnosis in US Adults. *Hypertension.* 2019;73:121–131. doi: 10.1161/HYPERTENSIONAHA.118.11715
3. Lovibond K, Jowett S, Barton P, Caulfield M, Heneghan C, Hobbs FD, Hodgkinson J, Mant J, Martin U, Williams B, Wonderling D, McManus RJ. Cost-effectiveness of options for the diagnosis of high blood pressure in primary care: a modelling study. *Lancet.* 2011;378:1219–1230. doi: 10.1016/S0140-6736(11)61184-7
4. 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: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*. 2018;138:e426–e483. doi: 10.1161/CIR.0000000000000597
5. Yang WY, Thijs L, Zhang ZY, et al; on behalf of the Ambulatory Blood Pressure Monitoring in Relation to Cardiovascular Outcomes (IDACO) Investigators. Evidence-based proposal for the number of ambulatory readings required for assessing blood pressure level in research settings: an analysis of the IDACO database. *Blood Press*. 2018;27:341–350. doi: 10.1080/08037051.2018.1476057
6. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research invovling human subjects. *J Am Med Ass*. 2013;310:2191–2194. doi: 10.1001/jama.2013.281053
7. Ohkubo T, Imai Y, Tsuji I, Nagai K, Watanabe N, Minami N, Itoh O, Bando T, Sakuma M, Fukao A, Satoh H, Hisamichi S, Abe K. Prediction of mortality by ambulatory blood pressure monitoring versus screening blood pressure measurements: a pilot study in Ohasama. *J Hypertens.* 1997;15:357–364.
8. O'Brien E, Mee F, Atkins N, Thomas M. Evaluation of three devices for self-measurement of blood pressure according to the revised British Hypertension Society Protocol: the Omron HEM-705CP, Philips HP5332, and Nissei DS-175. *Blood Press Monit.* 1996;1:55–61.
9. Ornstein S, Markert G, Litchfield L, Zemp L. Evaluation of the DINAMAP blood pressure monitor in an ambulatory primary care setting. *J Fam Pract*. 1988;26:517–521. doi: 10.1021/ma00187a047
10. Hansen TW, Kikuya M, Thijs L, Björklund-Bodegård K, Kuznetsova T, Ohkubo T, Richart T, Torp-Pedersen C, Lind L, Jeppesen J, Ibsen H, Imai Y, Staessen JA; IDACO Investigators. Prognostic superiority of daytime ambulatory over conventional blood pressure in four populations: a meta-analysis of 7,030 individuals. *J Hypertens.* 2007;25:1554–1564. doi: 10.1097/HJH.0b013e3281c49da5
11. Wizner B, Dechering DG, Thijs L, Atkins N, Fagard R, O'Brien E, de Leeuw PW, Parati G, Palatini P, Clement D, Grodzicki T, Kario K, Staessen JA. Short-term and long-term repeatability of the morning blood pressure in older patients with isolated systolic hypertension. *J Hypertens.* 2008;26:1328–1335. doi: 10.1097/HJH.0b013e3283013b59
12. Kuznetsova T, Staessen JA, Kawecka-Jaszcz K, Babeanu S, Casiglia E, Filipovský J, Nachev C, Nikitin Y, Peleská J, O'Brien E; on behalf of the EPOGH Investigators. Quality control of the blood pressure phenotype in the European Project on Genes in Hypertension. *Blood Press Monit*. 2002;7:215–224. doi: 10.1097/00126097-200208000-00003
13. Banegas JR, Ruilope LM, de la Sierra A, Vinyoles E, Gorostidi M, de la Cruz JJ, Ruiz-Hurtado G, Segura J, Rodríguez-Artalejo F, Williams B. Relationship between clinic and ambulatory blood-pressure measurements and mortality. *N Engl J Med.* 2018;378:1509–1520. doi: 10.1056/NEJMoa1712231
14. 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;55:1346–1351. doi: 10.1161/HYPERTENSIONAHA.109.149336
15. Williams B, Mancia G, Spiering W, et al; ESC Scientific Document Group. 2018 ESC/ESH guidelines for the management of arterial hypertension. *Eur Heart J.* 2018;39:3021–3104. doi: 10.1093/eurheartj/ehy339
16. Staessen JA, O'Brien ET, Amery AK, et al. Ambulatory blood pressure in normotensive and hypertensive subjects: results from an international database. *J Hypertens Suppl*. 1994;12:S1–12. doi: 10.1097/00004872-199401000-00014
17. Staessen JA, Fagard RH, Lijnen PJ, Thijs L, Van Hoof R, Amery AK. Mean and range of the ambulatory pressure in normotensive subjects from a meta-analysis of 23 studies. *Am J Cardiol.* 1991;67:723–727. doi: 10.1016/0002-9149(91)90529-t
18. Head GA, Mihailidou AS, Duggan KA, et al; Ambulatory Blood Pressure Working Group of the High Blood Pressure Research Council of Australia. Definition of ambulatory blood pressure targets for diagnosis and treatment of hypertension in relation to clinic blood pressure: prospective cohort study. *BMJ.* 2010;340:c1104. doi: 10.1136/bmj.c1104
19. Ohkubo T, Imai Y, Tsuji I, Nagai K, Ito S, Satoh H, Hisamichi S. Reference values for 24-hour ambulatory blood pressure monitoring based on a prognositic criterion. The Ohasama Study. *Hypertension*. 1998;32:255–259. doi: 10.1161/01.hyp.32.2.255.
20. Kikuya M, Hansen TW, Thijs L, Björklund-Bodegård K, Kuznetsova T, Ohkubo T, Richart T, Torp-Pedersen C, Lind L, Ibsen H, Imai Y, Staessen JA; on behalf of the International Database on Ambulatory Blood Pressure in Relation to Cardiovascular Outcome (IDACO) Investigators. Diagnostic thresholds for ambulatory blood pressure monitoring based on 10-year cardiovascular risk. *Circulation*. 2007;115:2145–2152. doi: 10.1097/MBP.0b013e3282f2b53d.
21. Ravenell J, Shimbo D, Booth JN III, Sarpong DF, Agyemang C, Beatty Moody DL, Abdalla M, Spruill TM, Shallcross AJ, Bress AP, Muntner P, Ogedegbe G. Thresholds for ambulatory blood pressure among African Americans in the jackson heart study. *Circulation.* 2017;135:2470–2480. doi: 10.1161/CIRCULATIONAHA.116.027051
22. Olsen MH, Angell SY, Asma S, et al. A call to action and a lifecourse strategy to address the global burden of raised blood pressure on current and future generations: the Lancet Commission on hypertension. *Lancet.* 2016;388:2665–2712. doi: 10.1016/S0140-6736(16)31134-5
23. Nomura K, Asayama K, Thijs L, et al; International Database of Home Blood Pressure in Relation to Cardiovascular Outcome Investigators. Thresholds for conventional and home blood pressure by sex and age in 5018 participants from 5 populations. *Hypertension.* 2014;64:695–701. doi: 10.1161/HYPERTENSIONAHA.114.03839
24. Jain A, Tandri H, Dalal D, Chahal H, Soliman EZ, Prineas RJ, Folsom AR, Lima JAC, Bluemke DA. Diagnostic and prognostic utility of ECG for left ventricular hypertrophy defined by MRI in relationship to ethnicity: The Multi-Ethnic Study of Atherosclerosis (MESA). *Am Heart J*. 2010;159:652–658. doi: 10.1016/j.ahj.2009.12.035
25. Odili AN, Thijs L, Yang WY, Ogedengbe JO, Nwegbu MM, Jacobs L, Wei FF, Feng YM, Zhang ZY, Kuznetsova T, Nawrot TS, Staessen JA. Office and home blood pressures as determinants of electrocardiographic left ventricular hypertrophy among black nigerians compared with white flemish. *Am J Hypertens.* 2017;30:1083–1092. doi: 10.1093/ajh/hpx114

Novelty and Significance

What Is New?

- The new American College of Cardiology/American Heart Association guideline reclassified office blood pressure (BP) and proposed thresholds for ambulatory BP.
- We derived outcome-driven thresholds for ambulatory BP yielding risks equivalent to the new categories of office BP.

What Is Relevant?

- Rounded thresholds for elevated systolic/diastolic 24-hour, daytime, and nighttime ambulatory BP were 120/75, 120/80, and 105/65 mm Hg.
- Rounded thresholds for stage 1 of 24-hour, daytime, and nighttime ambulatory hypertension were 125/75, 130/80, and 110/65 mm Hg.
- Rounded thresholds for stage 2 of 24-hour, daytime, and nighttime ambulatory hypertension were 130/80, 135/85, and 120/70 mm Hg.

Summary

Outcome-driven thresholds for the ambulatory BP are similar to those proposed by the current American College of Cardiology/American Heart Association guideline. Our analysis supports the American College of Cardiology/American Heart Association recommendation for operational threshold applicable to ambulatory BP.