

# Diagnostic thresholds for ambulatory blood pressure monitoring based on 10-year cardiovascular risk

Masahiro Kikuya<sup>a,d</sup>, Tine W. Hansen<sup>b,c</sup>, Lutgarde Thijs<sup>d</sup>, Kristina Björklund-Bodegård<sup>e</sup>, Tatiana Kuznetsova<sup>d</sup>, Takayoshi Ohkubo<sup>a</sup>, Tom Richart<sup>d</sup>, Christian Torp-Pedersen<sup>c</sup>, Lars Lind<sup>e</sup>, Hans Ibsen<sup>c</sup>, Yutaka Imai<sup>a</sup>, Jan A. Staessen<sup>d</sup> and on behalf of the IDACO investigators

Current diagnostic thresholds for ambulatory blood pressure (ABP) mainly rely on statistical parameters derived from reference populations. We determined an outcome-driven reference frame for ABP measurement. We performed 24-h ABP monitoring in 5682 participants (mean age 59.0 years; 43.3% women) enrolled in prospective population studies in Copenhagen, Denmark; Noorderkempen, Belgium; Ohasama, Japan; and Uppsala, Sweden. In multivariate analyses, we determined ABP thresholds, which yielded 10-year cardiovascular risks similar to those associated with optimal (120/80 mmHg), normal (130/85 mmHg), and high (140/90 mmHg) blood pressure on office measurement. Over 9.7 years (median), 814 cardiovascular end points occurred, including 377 strokes and 435 cardiac events. Systolic/diastolic thresholds for optimal ABP were 118.3/74.2 mmHg for 24 h, 121.6/78.9 mmHg for daytime, and 104.7/65.3 mmHg for nighttime. Corresponding thresholds for normal ABP were 124.3/76.8, 129.9/82.6, and 111.6/68.1 mmHg, respectively, and those for ambulatory hypertension were 130.3/79.4, 138.2/86.4, and 118.5/70.8 mmHg. After rounding, approximate thresholds for optimal ABP amounted to 115/75 mmHg for 24 h, 120/80 mmHg for daytime, and 105/65 mmHg for nighttime. Rounded thresholds for normal ABP were 125/75, 130/85, and 110/70 mmHg,

respectively, and those for ambulatory hypertension were 130/80, 140/85, and 120/70 mmHg. In conclusion, population-based outcome-driven thresholds for optimal and normal ABP are lower than those currently proposed by hypertension guidelines. *Blood Press Monit* 12:393–395 © 2007 Wolters Kluwer Health | Lippincott Williams & Wilkins.

Blood Pressure Monitoring 2007, 12:393–395

Keywords: ambulatory blood pressure monitoring, blood pressure, cardiovascular diseases, epidemiology, hypertension

<sup>a</sup>The Tohoku University Graduate School of Pharmaceutical Science and Medicine, Sendai, Japan, <sup>b</sup>The Research Center for Prevention and Health, Copenhagen, <sup>c</sup>The Copenhagen University Hospital, Denmark, <sup>d</sup>The Studies Coordinating Centre, Division of Hypertension and Cardiovascular Rehabilitation, Department of Cardiovascular Diseases, University of Leuven, Belgium and <sup>e</sup>The Section of Geriatrics, Department of Public Health and Caring Sciences, Uppsala University, Sweden

Correspondence to Dr Jan A. Staessen, MD, PhD, Studies Coordinating Centre, Campus Gasthuisberg, Herestraat 49, Box 702, B-3000 Leuven, Belgium  
Tel: +32 16 34 7104; fax: +32 16 34 7106;  
e-mail: jan.staessen@med.kuleuven.be

Received 27 February 2007 Accepted 28 February 2007

## Background

Current diagnostic thresholds for the ambulatory blood pressure mainly rely on statistical parameters derived from reference populations. We determined an outcome-driven reference frame for ambulatory blood pressure measurement [1].

## Methods

We constructed the International Database on Ambulatory blood pressure monitoring in relation to Cardiovascular Outcomes (IDACO). Eligible studies had to include a random population sample with longitudinal follow-up of fatal and nonfatal cardiovascular outcomes. For this analysis, we considered 2311 residents from Copenhagen, Denmark; 2542 participants recruited from Noorderkempen,

Belgium; 1535 inhabitants of Ohasama, Japan; and 1221 men from Uppsala, Sweden. On 30 April 2006, the number of participants available for analysis thus totaled 7609. Of the 7609 participants, we excluded 1927 either because their conventional or nighttime blood pressures had not been measured, or because their daytime or nighttime blood pressures were the averages of fewer than 10 or 5 readings, respectively. The number of participants included in this analysis thus totaled 5682 [1].

The conventional blood pressure reading is the average of two consecutive readings. We programmed ambulatory blood pressure devices to obtain readings at intervals ranging from 15 to 45 min. We defined daytime as the interval ranging from 10:00 to 20:00 h for Europeans and

from 8:00 to 18:00 h for the Japanese. The corresponding nighttime intervals ranged from midnight to 6:00 h and from 22:00 to 4:00 h, respectively.

Fatal and nonfatal stroke did not include transient ischemic attacks. Cardiac events included death from ischemic heart disease, sudden death, nonfatal myocardial infarction, surgical and percutaneous coronary revascularization, and fatal and nonfatal heart failure. The composite cardiovascular end point included all the aforementioned end points, as well as cardiovascular mortality. In all the outcome analyses, we only considered the first event within each category.

## Results

Over a period of 9.7 years (median), 814 cardiovascular end points occurred, including 377 strokes and 435 cardiac events. We determined the ambulatory blood pressure thresholds that resulted in 10-year cardiovascular risks, similar to those associated with optimal (120/80 mmHg), normal (130/85 mmHg), and high (140/90 mmHg) blood pressure on conventional measurement. We adjusted for cohort and included blood pressure as a continuous linear term in the Cox regression model. The systolic/diastolic thresholds for optimal ambulatory blood pressure were 118.3/74.2 mmHg for 24 h, 121.6/78.9 mmHg for daytime, and 104.7/65.3 mmHg for nighttime. The corresponding thresholds for normal ambulatory blood pressure were 124.3/76.8 mmHg, 129.9/82.6 mmHg, and 111.6/68.1 mmHg, respectively, and those for ambulatory hypertension were 130.3/79.4 mmHg, 138.2/86.4 mmHg, and 118.5/70.8 mmHg. Further adjustment for sex, age, and other cardiovascular risk factors produced consistent results. After rounding off, the thresholds for optimal ambulatory blood pressure approximated 115/75 mmHg for 24 h, 120/80 mmHg for daytime, and 105/65 mmHg for nighttime (Table 1). The rounded-off thresholds for normal ambulatory blood pressure were 125/75 mmHg, 130/85 mmHg, and

**Table 1 Proposal for outcome-driven reference values for ambulatory blood pressure measurement<sup>a</sup>**

	24-h	Daytime	Nighttime
Optimal blood pressure (mmHg)	< 115/75	< 120/80	< 105/65
Normal blood pressure (mmHg)	< 125/75	< 130/85	< 110/70
Ambulatory hypertension (mmHg)	≥ 130/80	≥ 140/85	≥ 120/70

<sup>a</sup>Threshold values were obtained by rounding off the point estimates to an integer value ending in zero or five.

110/70 mmHg, respectively, and those for ambulatory hypertension were 130/80 mmHg, 140/85 mmHg, and 120/70 mmHg (Table 1). Repeating the analyses in the 4344 participants untreated at baseline produced similar thresholds. Adding a quadratic term to the blood pressure in the Cox models slightly but significantly improved the fit for the 24-h and nighttime systolic blood pressures, but did not materially alter the results.

## Conclusion

One should carefully interpret the currently proposed ambulatory thresholds. First, the relation between cardiovascular outcome and blood pressure is continuous. No critical level can be pinpointed, above which the risk suddenly rises. Thresholds only serve the need for clinicians to use cutoff limits for the diagnosis and management of hypertension. Second, the classification of conventional blood pressure into optimal, normal, high normal, or hypertensive levels is specific neither to age nor to sex. In our outcome analyses, we therefore adjusted only for the cohort, and disregarded sex, age, and other cardiovascular risk factors. Further adjustment, however, produced consistent results with little change in the proposed ambulatory cutoff limits. In conclusion, population-based outcome-driven thresholds for optimal and normal ambulatory blood pressure are lower than those currently proposed by hypertension guidelines.

**21st SCIENTIFIC MEETING OF THE INTERNATIONAL SOCIETY OF HYPERTENSION**

Recent Advances in Blood Pressure Monitoring  
 Tohoku University 21st Century COE 'CRESCENDO'  
 SATELLITE SYMPOSIUM  
 Friday 20th October, 2006. 09.00–16.00 Room: Argos A  
 SEA HAWK HOTEL, FUKUOKA, JAPAN

09.00–09.05	Opening remarks and welcome	Yutaka Imai ( <i>Sendai</i> )
<b>SESSION I: TECHNICAL CONSIDERATIONS IN BLOOD PRESSURE MEASUREMENT</b>		
Chairman: Yuhei Kawano ( <i>Osaka</i> ) and Gert van Montfrans ( <i>Amsterdam</i> )		
09.05–09.15	State of the market from the dableducational.org website	Eoin O'Brien ( <i>Dublin</i> )
09.15–09.25	Developments in wrist home BP measurement	Thomas Mengden ( <i>Bonn</i> )
09.25–09.35	New validation methods for automated sphygmomanometer	Osamu Shirasaki
09.35–10.05	Discussion	
10.05–10.45	Coffee	
<b>SESSION II: CLINICAL CONSIDERATIONS IN BLOOD PRESSURE MEASUREMENT</b>		
Chairman: Takuya Tsuchihashi ( <i>Fukuoka</i> ) and Lawrie Beilin ( <i>Perth</i> )		
10.45–10.55	ABPM, SBPM or Both?	Paul L Padfield ( <i>Edinburgh</i> )
10.55–11.05	Clinical significance of white-coat and masked hypertension	Paolo Verdecchia ( <i>Perugia</i> )
11.05–11.15	Which blood pressure measurements in routine clinical practice?	Gianfranco Parati ( <i>Milan</i> )
11.15–11.25	Prognostic value of home blood pressure measurement	George Stergiou ( <i>Athens</i> )
11.25–12.05	Discussion	
12.05–13.30	Lunch	
<b>SESSION III: DATABASES TO GUIDE THE FUTURE</b>		
Chairman: Hirotsugu Ueshima ( <i>Otsu</i> ) Jan Staessen ( <i>Leuven</i> )		
13.30–13.40	Diagnostic thresholds for ambulatory blood pressure monitoring based on 10-year cardiovascular risk	Masahiro Kikuya ( <i>Sendai</i> )
13.40–13.50	ABPM and CV outcomes in hypertensive patients	Thomas Pickering ( <i>New York</i> )
13.50–14.00	Data from the PAMELA studies	Giuseppe Mancia ( <i>Milan</i> )
14.00–14.10	Morning surge and variability in blood pressure in elderly hypertension: a new therapeutic target?	Kazuomi Kario ( <i>Tochigi</i> )
14.10–14.20	The Dublin Outcome Study	Eamon Dolan ( <i>Dublin</i> )
14.20–15.00	Discussion	
<b>SESSION IV: HOW SHOULD THE GUIDELINES RESPOND?</b>		
Chairman: Kazuyuki Shimada ( <i>Tochigi</i> ) Jiguang Wang ( <i>Shanghai</i> )		
15.00–15.10	Incorporating self/home and ambulatory blood pressure measurement into guidelines for clinical practice	Martin Myers ( <i>Toronto</i> )
15.10–15.20	Incorporating SBPM at home in the guideline – from the Ohasama study	Takayoshi Ohkubo ( <i>Sendai</i> )
15.20–15.30	Revision of ESH guidelines on measurement: is it necessary?	Peter W de Leeuw ( <i>Maastricht</i> )
15.30–16.00	Discussion	
16.00–16.10	Closing remarks	Jan Staessen ( <i>Leuven</i> )

Proceedings of meeting to be published in the *Journal of Blood Pressure Monitoring*

**Reference**

- 1 Kikuya M, Hansen TW, Thijs L, Björklund-Bodegard K, Kuznetsova T, Ohkubo T, *et al.* Diagnostic thresholds for ambulatory blood pressure monitoring based on 10-year cardiovascular risk. *Circulation* 2007; **115**:2145–2152.