RESEARCH ARTICLES

AMBULATORY BLOOD PRESSURE AND HEART RATE CHARACTERISTICS - 1. NORMOTENSIVES

Deniz Barlas DURAKOĞLUGİL, M.D.,   Mert CEYHAN, M.D.,   Hakkı Zafer GÜNEY, M.D.,
Uğur HODOĞLUGİL, M.D.,   Hakan ZENGİL, Ph.D.

ABSTRACT

Purpose: Ambulatory blood pressure monitoring (ABPM) is known to be superior to sphygmomanometer, in defining the parameters of blood pressure and heart rate in normotensive subjects and hypertensive patients. The aim of the present study was to evaluate the blood pressure and heart rate in normotensive subjects by using ABPM devices. Methods: Recordings of 126 normotensive subjects, to whom ABPM was applied for 48 hours in our laboratory between 1998 and 2000, were analyzed retrospectively. Linear (mean, maximum and minimum values) and rhythm analysis (peak, trough, mesor, double amplitude, acrophase, bathyphase and slope values) were performed. Results: The mean systolic and diastolic blood pressure values of the subjects were lower than the respective office measurements. The average values of blood pressure and heart rate during the activity period were higher than the resting period. Systolic and diastolic blood pressure and heart rate rhythm profiles were almost identical. Conclusion: Blood pressure and heart rate display rhythmic changes with higher values during the activity period. ABPM recordings provide sufficient data for understanding blood pressure rhythms in normotensive subjects. Understanding and analyzing ABPM data in hypertensive patients may also help in developing efficient treatment strategies.

Key Words: Ambulatory, Blood Pressure, Heart Rate, Rhythm, Normotension.

INTRODUCTION

There is no absolute quantitative definition about the normal limit of blood pressure (BP) and diagnosis of hypertension is mainly based on the results of epidemiological studies which defined the risk between increased BP level and morbid cardiovascular events. According to the JNC-VI, (Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure, National Institute of Health/ National Heart, Lung and Blood Institute) BP values 130 and 85 mmHg are the limits of normotension for systolic (SBP) and diastolic (DBP) pressures, respectively (1).

Conventionally BP is determined at the physician's office using a mercury sphygmomanometer. Several limitations have been reported for the use of office measurements in BP control such as lack of representation of the average blood pressure for an individual (2), inability to describe the circadian variation of BP (3), tendency for observer bias (4), problems in reproducibility (5), and inability to discriminate the white coat effect (6).

BP is variable during 24-hours with a prominent circadian rhythm. Both SBP and DBP levels tend to peak during the hours after awakening, remain high during the activity period (day-time) and fall to its minimum in the middle of resting (night-time). This variability in BP throughout the day can serve for diagnostic purposes and the determination of the optimal schedule for antihypertensive treatment. Ambulatory blood pressure monitoring (ABPM) devices are available now to measure BP repeatedly for 24 hour or longer periods. These are easily carried, automated devices, capable of obtaining and storing the results of repeated BP and heart rate (HR) measurements, without depriving individuals of ordinary daily functions. These devices are increasingly used in clinical trials and are particularly important in determination of the white coat effect and dipping status.

In this study we report the linear and rhythmic characteristics of BP in normotensives.

SUBJECTS AND METHODS

Subjects

This is part of a cohort study designed for the assessment of the prognostic value of ambulatory BP recordings for the development of cardiovascular events. The BP recordings of 126 (98 men and 28 women) healthy and normotensive subjects to whom ABPM devices were applied in our laboratory between 1998 and 2000, were analyzed retrospectively for BP characteristics. Any subject with a known history of cardiovascular event or any significant systemic disease was excluded from the study. The demographic properties of the group were given in table 1.

Table 1: Demographic properties of the normotensive subjects. Data are expressed as mean ± SEM (n=117). (Values in parenthesis indicate the minimum and maximum values).

Age (year)	40.80 ± 0.99 (17-74)
Sex (M/F)	26/91
Height (cm)	161.9 ± 0.79 (145-190)
Weight (kg)	69.13 ± 1.34 (42-105)
Hypertension history in first degree relatives (%)	39.31

Measurement of blood pressure

Office BP measurements were obtained by sphygmomanometry in sitting position at least twice in different days. ABPM devices (Model 90207, Spacelabs, Inc. Redmond, Washington) were attached to a waist belt and the subject wore an arm cuff in appropriate size at the non-dominant arm, which was inflated automatically at programmed intervals for 48 hours. Devices were programmed to measure SBP, DBP and HR in every 20 minutes from 06:00 to 24:00 and in every 30 minutes from 00:00 to 06:00. Subjects were instructed not to restrict their usual daily routine activity, except for staying motionless during measurements, if possible. Since movements of the deviced arm can result in errors, all ambulatory blood pressure monitoring data were screened for erroneous readings and subjects with less than 80% successful readings were excluded.

Subjects were requested to keep a diary for their bed and wake up times. Each 24 hour was divided into activity and resting spans based on the subject's diary data. The reference time (zero) was taken as the awakening time based on the diary records.

A subject was accepted as normotensive if his/her mean SBP/DBP values were less than 135/85 mmHg in activity period and less than 120/70 in resting period and less than 130/80 within 48h.

Data analysis

The stored data in the solid-state memory of the devices were downloaded from the monitors into the Ambulatory Blood Pressure Report Management System software (Spacelabs, Inc. Redmond, Washington, version 1.0308) and analyzed for both linear differences and rhythm properties.

A) Linear analysis:

Mean, maximum and minimum values of SBP, DBP and HR for 48-hour activity and resting periods were calculated. All data were analyzed separately for each individual and the results were expressed as mean ± SEM.

B) Rhythm analysis:

The rhythmic patterns of blood pressure and heart rate were analyzed by using partial Fourier analysis with 4 harmonics (6, 12, 24 h). The significance of best fit was estimated by zero-amplitude test (F-statistics) by using ABPM-FIT software program (University of Heidelberg, Germany, version 2.2) (7). The rhythm characteristics estimated from the fitted Fourier

curves were % rhythm ($r^2 \times 100 \cong$ coefficient of determination x 100; a measure of how well the fit explains the overall data), peak (maximum value), trough (minimum value), mesor (rhythm-adjusted mean), double amplitude (the difference between minimum and maximum levels), the acrophase (time of peak), the bathyphase (time of trough), and the slopes of the morning rise and evening dip. Slopes were calculated for periods of ± 3 hours for bed and wake up time points. All data were analyzed separately for each individual and the results were expressed as mean ± SEM (rhythm detection was considered statistically significant with a "p" value of less than 0.05).

RESULTS

Chronobiologically, 48-hour continuous monitoring of BP profile is recognized as more reliable than 24-hour monitoring (8). To avoid "between-day" variances, data of consecutive days are analyzed separately and compared with each other. In this study, the 24-hour mean values for the first and second days were compared to see whether a difference was present between the days. No statistically significant difference in the mean values of SBP was found in these normotensive subjects.

The rhythmic patterns of SBP/DBP and HR are shown in Figures 1 and 2, respectively. All three of these cardiovascular variables exhibited a clear circadian pattern with higher values during the activity period and lower values during rest.

Results of the linear analyses are given in table 2. The mean values of ambulatory systolic and diastolic blood pressures and heart rate were significantly lower than their respective office measurements (paired Student's t test, p<0.001). Highly significant differences were also observed between the means of activity and resting periods in all three parameters (paired Student's t test, p<0.001).

Ambulatory rhythm characteristics for these cardiovascular variables estimated from the fitted Fourier curves are presented in table 3. Acrophase and bathyphase were found to be nearly at the same time period for blood pressures and HR. There were no difference between the absolute slope values of morning rise and evening dip for SBP and DBP. However morning rise of the HR was significantly steeper than BP rise in this normotensive group.
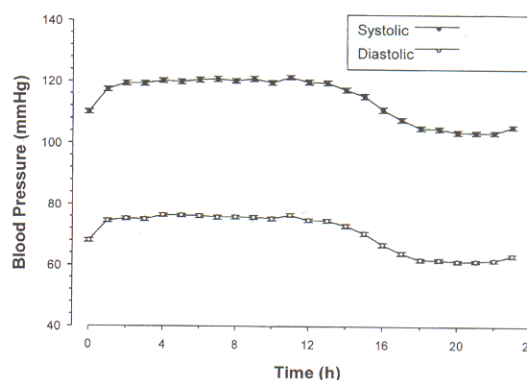

Fig. 1: 24 hour variations in systolic (———) and diastolic (———) blood pressure in normotensive subjects. Each point represents hourly means of the first and the second day. Values are presented as mean ± SEM. "0" point on x-axis corresponds to the average wake-up time.
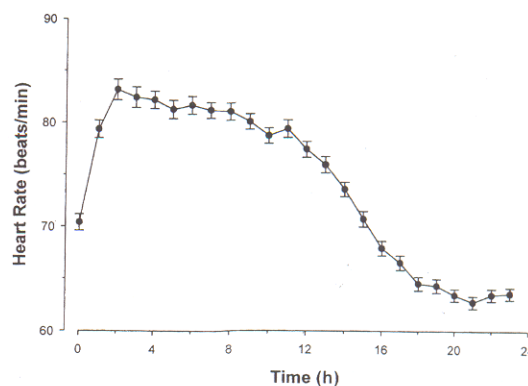

Fig. 2: 24 hour variation in heart rate in normotensive subjects. Each point represents hourly means of the first and the second day. Values are presented as mean ± SEM. "0" point on x-axis corresponds to the average wake-up time.

DISCUSSION

The alterations in the circadian rhythm of cardiovascular functions have raised considerable interest particularly in the last two decades. The progress in ambulatory monitoring devices has provided measurement of BP repeatedly for 24 hour or longer periods. Under daily living

Table 2: Office measurements and linear analysis of 48 hour ambulatory blood pressure monitoring. Results are expressed as mean ±SEM (n=117) (SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate).

	SBP (mmHg)	DBP (mmHg)	HR (beats/min)
Office Mean	123.04 ± 1.17	79.79 ± 0.85	81.05 ± 1.07
Ambulatory Measurements:			
Total Mean	114.01 ± 0.74*	70.50 ± 0.53*	73.97 ± 0.72*
Activity Period Mean	118.91 ± 1.52	74.92 ± 1.19	79.17 ± 2.24
Activity Period Max	143.71 ± 2.46	95.58 ± 2.13	115.95 ± 3.17
Activity Period Min	95.55 ± 0.85	52.54 ± 0.71	55.56 ± 0.87
Resting Period Mean	104.48 ± 1.20	61.90 ± 1.07	64.13 ± 1.19
Resting Period Max	123.68 ± 1.91	80.62 ± 1.72	82.70 ± 1.58
Resting Period Min	86.56 ± 0.76	46.33 ± 0.55	54.40 ± 0.80

* $p<0.0001$ compared to the office mean.

Table 3: Rhythm analysis of 48 hour ambulatory blood pressure monitoring. Results are presented as means of the first and the second days and are expressed as mean ±SEM (n=117) (SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate).

	SBP	DBP	HR
% Rhythm	50.43 ± 1.25	49.98 ± 1.15	55.27 ± 1.42
Peak (mmHg)δ (beats/min)γ	126.37 ± 0.86	81.34 ± 0.59	88.73 ± 0.87
Acrophase (h)*	15:20 ± 00:16	14:53 ± 00:17	14:08 ± 00:14
Trough (mmHg) δ (beats/min) γ	99.42 ± 0.70	57.63 ± 0.52	59.64 ± 0.70
Bathyphase (h)*	04:17 ± 00:13	04:57 ± 00:21	05:14 ± 00:17
Double Amplitude (mmHg) δ (beats/min) γ	26.94 ± 0.78	23.66 ± 0.58	29.08 ± 0.91
Morning Slope (mmHg/h) δ (beats/min/h) γ	5.98 ± 0.24	5.46 ± 0.22	7.46 ± 0.37
Evening Slope (mmHg/h) δ (beats/min/h) γ	-5.68 ± 0.22	-5.42 ± 0.20	-5.46 ± 0.23
Mesor (mmHg) δ (beats/min) γ	114.10 ± 0.69	70.41 ± 0.47	74.00 ± 0.66

*values are presented as the clock time, δ: units for systolic and diastolic blood pressure, γ: units for heart rate.

conditions, BP and HR display characteristic rhythmic profiles with higher values during the activity span both in normotensive subjects and hypertensive patients. In this retrospective data analysis, the circadian profile of BP and HR showed that most of the subjects have approximately 10 % lower values during the resting period than the activity period. This pattern was defined as the normal "dipping" in BP (9). A subject is defined as a "non-dipper" when there is a nocturnal decline of less than 10 % either in SBP or in DBP relative to daytime values. It has been reported that "non-dippers" are subject to a greater risk of cardiovascular complications in the future (10-14).

The differences observed between the means of office measurements and ambulatory recordings have previously been noted for both normotensive and hypertensive groups (3,15). This difference is mainly due to the rhythmic pattern of BP that normally exhibits lower values during the resting period. In clinically healthy and normotensive subjects, BP values have been found to be lowest 2-4 hours before awakening (3). The pressure starts to rise just before awakening and increases sharply in the first hours of the activity span and reaches a plateau 1-2 hours after awakening (3). It is commonly

accepted that arousal and beginning of the daily physical activity significantly contribute to the morning rise in BP (16). The sharp increase of BP at the commencement of the daily activity has been noted to be responsible for some cardiovascular events (17).

Hypertension contributes to the negative outcomes in the cardiovascular system. It might aggravate various clinical conditions such as retinopathy, nephropathy, coronary heart disease, atherosclerosis (or atherogenesis), stroke and central nervous system dysfunction. BP is often assessed by office determinations and may be erroneous due to the rhythmic nature of BP. The possibility of monitoring arterial BP during the entire day offers advantages in diagnosis as well as therapy of hypertension.

Ambulatory monitoring of BP has some advantages when compared to the conventional sphygmomanometric measurements performed by an arm cuff and a stethoscope. Data obtained by ABPM are highly reproducible (18,19), capable of describing circadian variation in BP (18), devoid of observer bias and error (20,21), and are helpful in assessing the white-coat effect (6). In addition to the advantages mentioned above, it has been demonstrated that ABPM can serve as a better indicator for assessing hypertensive end organ damage than sphygmomanometric office measurements (22-24).

In this study we addressed mainly three issues of ABPM in normotensive subjects; the rhythmic variability of BP and HR during the day, the difference between the office measurements and ambulatory recordings, and the estimation of average levels for activity and rest spans. The information on circadian characteristics of BP both in normal and pathological conditions would help us in understanding the underlying mechanisms and also in taking precautions for further cardiovascular events.

Correspondence to: Deniz Barlas DURAKOĞLUGİL, M.D.
Gazi Üniversitesi Tıp Fakültesi
Farmakoloji Anabilim Dalı
Beşevler
06500 ANKARA -TÜRKİYE
Phone: 312 - 214 10 00 / 6936
Fax : 312 - 221 31 12
E-mail: d_barlas@yahoo.com

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