Repeated Ambulatory Monitoring Reveals a Monday Morning Surge in Blood Pressure in a Community-Dwelling Population

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Background: Although weekly variations with a peak on Monday have been reported in the incidence of cardiovascular events, few studies have investigated weekly variations in blood pressure (BP).

Methods: One hundred and thirty-five community-dwelling subjects had 24-h ambulatory BP monitoring for 7 days. We calculated the mean awake, asleep, morning (during the first 3 h after awakening) BP, and morning BP surge (mean morning systolic BP minus mean asleep systolic BP) for each day.

Results: Monday surge in BP was found in the awake and morning BP (awake BP: 128.8 ± 15.4/81.1 ± 9.2 mm Hg, P < 0.01, respectively; morning BP: 127.3 ± 17.8/78.8 ± 11.4 mm Hg, P < 0.01, respectively) but was not found in the asleep BP (112.7 ± 18.3/68.4 ± 10.7 mm Hg, P = NS, respectively). The morning BP surge on Monday was higher than on the other days of the week except for Tuesday (Monday: 19.7 ± 13.3 mm Hg v Friday: 16.4 ± 12.9 mm Hg, P < 0.05; v Saturday: 14.7 ± 13.3 mm Hg, P < 0.01 v Sunday: 13.7 ± 12.0 mm Hg, P < 0.01; v Wednesday: 15.5 ± 14.3 mm Hg, P < 0.01).

Conclusion: Morning BP surge was the greatest on Monday in a community-dwelling population. This may be in accord with clinical evidence that cardiovascular events more frequently occur in the morning on Monday. Am J Hypertens 2004;17:1179–1183 © 2004 American Journal of Hypertension, Ltd.

Circadian rhythms in the onset of cardiovascular events such as acute myocardial infarction,1 sudden cardiac death,2 and stroke3 have been observed in many studies. Most studies have shown an increased incidence of acute cardiovascular events in the morning, between 6 AM and noon. An abrupt and dramatic increase in blood pressure (BP) in the morning has been suggested as a possible trigger for cardiovascular events. Recently, Kario et al4 demonstrated that a morning surge in BP is an independent predictor of stroke using 24-h ambulatory BP (ABP) monitoring.

In addition to circadian variations, weekly and seasonal variations in biological signals can also occur. Weekly variations in the incidence of cardiovascular events, peaking on Mondays, have been reported in many studies.5,6 However, only a few studies have investigated weekly variations in BP using ABP monitoring. The aim of the present study was to evaluate weekly variations in BP using the 7-day (24-h) ABP monitoring.

Methods

Subjects

A total of 175 subjects were initially recruited to participate in this study. All subjects were residents of “U-town,” a rural Japanese town, and had visited and used the free health screening, counseling, and educational services offered by the town office. Subjects with definite neurologic diseases such as Parkinson disease and stroke were excluded from the study. All subjects gave their informed consent. The body mass index (BMI) was calculated as weight(kg)/height(m)^2. Smokers were defined as current smokers.


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Seven-Day (24-h) ABP Monitoring

Noninvasive ABP monitoring was performed using an oscillometric monitor (TM-2431, A&D Co., Tokyo, Japan) to record the systolic BP (SBP) and diastolic BP (DBP). All subjects were fitted with the recorder on a Thursday, usually between 10:00 and 14:00. The recorder was programmed to take readings at 30-min intervals between 07:00 to 22:00 and at 60-min intervals between 22:00 and 07:00 for 7 days. Subjects were instructed to follow their normal daily routine after they left the office and to immobilize their arm during cuff inflation.

Subjects were taught how to attach and remove the recorder and were instructed to remove the recorder when they took a bath. Individuals were asked to keep a diary noting the times they went to sleep and woke up. Subjects were asked to visit the office again after 7 days. Stored data were retrieved on a personal computer using commercially available software for the oscillometric monitor (TM-2430-15, A&D Co. Tokyo, Japan).

Data resulting from the 7-day (24-h) ABP monitoring were divided into seven intervals. The first interval was from the time of the recorder fitting until the time of awakening the next morning (day 1, Thursday). The second interval was from the time of getting out of bed on Friday until the time of awakening the next morning (day 2, Friday). The third to seventh intervals (days 3 to 7, Saturday to Wednesday) were defined in the same manner as the second interval.

We defined the mean of the BP results obtained while the subject was awake as the “awake BP” and the mean of the BP results obtained while the subject was asleep as the “asleep BP.” The “morning BP” was defined as the average BP during the first 3 h after each wake-up time. Subjects with BP readings showing an error of >25% in each 24-h recording period were excluded.

We defined the “morning BP surge” for each day as the rise in BP during the morning (morning BP minus asleep BP).

The dipping/non-dipping status for each day was defined according to the decrease in BP at night (awake BP minus asleep BP)/awake BP); a dipping BP profile consisted of a nocturnal reduction in BP of ≥10%, whereas a non-dipping BP profile consisted of a nocturnal reduction of <10%.

The frequency of the non-dipping status was calculated for each day of the week as the percentage of cases exhibiting a non-dipping status divided by the total number of subjects monitored. The SBP was used for calculation of the dipping/non-dipping status and morning BP surge.

Statistical Analysis

Two-way analysis of variance was used to test for differences among the results for each day, and the Tukey honestly significant differences (HSD) test was performed for multiple pair-wise comparisons of the means for each day. The χ² test was used to detect intergroup differences in daily prevalence rates. Differences with a value of P < .05 were considered significant.

Results

Population Characteristics

A total of 40 subjects were excluded from the study because they removed the recorder during the 7-day study period; 135 subjects remained eligible for inclusion in the study. The mean age of the participants was 56.6 ± 11.0 (SD) years, and the proportion of men was 43.7%. The average BMI was 24.4 ± 3.0 kg/m². Of the subjects, 32 subjects (23.7%) were classified as smokers, and 43 subjects (31.9%) were receiving anti-hypertensive medications.

Novelty Effect and Weekly Variations in Awake and Asleep BP

Figure 1 shows the weekly variations in the awake and asleep BP. The awake SBP and DBP on the day 1 (Thursday) were significantly higher than on the other days of the week (Fig. 1A), but the asleep SBP and DBP on day 1 were not significantly different (Fig. 1B). The awake SBP and DBP on Monday were significantly higher than on Sunday (SBP: 128.8 ± 15.4 vs. 131.5 ± 16.3 mm Hg, P < .01; DBP: 79.1 ± 9.2 vs. 80.7 ± 10.0 mm Hg, P < .01) (Fig. 1A), but the asleep SBP and DBP on Monday were not significantly different from the values on Sunday (SBP: 112.7 ± 18.3 vs. 113.1 ± 17.6 mm Hg, P = .72; DBP: 68.4 ± 10.7 vs. 68.7 ± 10.5 mm Hg, P = .63) (Fig. 1B).

Weekly Variation in Morning BP and Morning BP Surge

Figure 2 shows the weekly variations in the morning BP and morning BP surge. The morning SBP and DBP on Monday was significantly higher than on Sunday (SBP: 127.3 ± 17.8 vs. 132.5 ± 18.2 mm Hg, P < .01; DBP: 78.8 ± 11.4 vs. 81.2 ± 10.0 mm Hg, P < .01) (Fig. 2A).

The morning BP surge on Monday was significantly higher than on Friday, Saturday, Sunday, and Wednesday (Monday: 19.7 ± 13.3 mm Hg vs. Friday: 16.4 ± 12.9 mm Hg, P < .05; vs. Saturday: 14.7 ± 13.3 mm Hg, P < .01; vs. Sunday: 13.7 ± 12.0 mm Hg, P < .01; vs Wednesday: 15.5 ± 14.3 mm Hg, P < .05) (Fig. 2B). The morning BP surge on Tuesday was significantly higher than on Sunday (Tuesday: 18.1 ± 13.0 mm Hg vs Sunday: 13.7 ± 12.0 mm Hg, P < .05) (Fig. 2B).

Weekly Variation in Nondipping Status

We also observed the weekly variation in the nondipping status. The non-dipping status percentage on weekend days (Saturday and Sunday) were significantly higher than on Monday, with a value of P < .01; DBP: 78.8 ± 11.4 vs. 81.2 ± 10.0 mm Hg, P < .01) (Fig. 2A).

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higher than on Friday and Monday (Saturday: 37.8% v Friday: 24.4%, \( P = 0.02 \); v Monday: 25.9%, \( P = 0.04 \). Sunday: 37.8% v Friday: 24.4%, \( P = 0.02 \); v Monday: 25.9%, \( P = 0.04 \)).
Discussion

Use of ABP monitoring has become an important tool in the diagnosis and management of hypertension. Several previous studies have demonstrated that target organ damage and cardiovascular morbidity are more strongly associated with ABP than with office-measured BP. Although most studies performed ABP monitoring for 24 h, some reports have suggested that a 24-h period may be insufficient for proper diagnosis of hypertension and for precise evaluation of treatment efficacy. We found a “novelty effect” whereby the awake BP on day 1 was significantly higher than on the other days of the week, by using 7-day (24-h) ABP monitoring. Previous studies revealed that the BP measured for the initial few hours of ABP monitoring was elevated above the mean value for that day. We also observed weekly variations in BP using ABP monitoring. A “Monday surge effect” was found only in the awake and morning BP and not in the asleep BP. Physical activity, psychological stress, and lifestyle have been shown to exert a substantial influence on BP. In addition, Pieper et al demonstrated that the average BP on a workday was higher than that on a non-workday. Most individuals are free of the mental and physical burdens of work on Sunday, and experience a more stressful change from weekend leisure activities to work activities on Mondays.

The morning BP surge on Monday was higher than on the other days of the week except Tuesday. Several pathophysiologic mechanisms, such as circadian neurohormonal rhythms, sympathetic activation, and systemic vasoconstriction associated with the arousal reaction, have been postulated to account for the morning BP surge. The morning BP surge is not associated only with target organ damage but also increased risk for stroke. The weekly distribution of the morning BP surge showed a distinct peak on Mondays in this study.

Several epidemiologic studies have demonstrated weekly variations in the incidence of cardiovascular events with a peak on Mondays. Willich et al demonstrated that the occurrence of myocardial infarction was increased by 20% on Mondays compared with other days of the week. Arntz et al reported that the incidence of sudden cardiac death was increased by 18.3% on Mondays compared with other days of the week. Data from the Framingham study revealed that significantly more stroke events occurred on Mondays than other days.

The Monday surge in BP and the Monday peak in the weekly distribution of the morning BP surge might play important causative roles in the increased incidence of cardiovascular events on Mondays that has been observed. We also observed a weekly variation in the non-dipping status percentage for each day, which showed a significantly higher percentage on the weekend days (Saturday and Sunday), compared with the percentages for Friday and Monday. Abnormal diurnal BP patterns are also associated with various pathophysiologic factors. In addition, the non-dipping BP profile has been reported to be related to an increase in target organ damage and cardiovascular events, but this association remains controversial. Mochizuki et al showed that the reproducibility of the dipping/non-dipping status was relatively low, and O’Shea et al demonstrated that the level of physical activity was a significant determinant of the diurnal variation in BP dipping. Most subjects are less active on weekend days (Saturdays and Sundays) than on weekdays, especially in Japanese rural towns, resulting in only a small rise in awake BP. As a result, the frequency of non-dipping status was higher on weekend days than on weekdays.

This study had some potential limitations. We could not quantify the influence of several exogenous factors on BP, although subjects were asked to keep a diary noting their sleep quality, physical activity level, and emotional states that might affect their BP. Second, taking into consideration that 40 subjects (22.9%) could not keep the monitoring device attached, 7-day (24-h) ABP monitoring may have caused some stress for the study subjects.

Despite these limitations, this study is important as a first report on weekly variations in BP using 7-day (24-h) ABP monitoring. An important finding of this study is that the Monday surge was observed only in the awake BP, morning BP, and morning BP surge—but not in the asleep BP. If an association between Monday surge in BP and cardiovascular events is confirmed, our findings will have important implications for the prevention of cardiovascular disease.

References


