Original Article

Time-Series Analysis of Systolic Blood Pressure Variation in Thirty-Three Uygur Centenarians in China


The Uygur are reported to have an unusually long life expectancy. The purpose of this research was to perform a time-series analysis of systolic blood pressure (SBP) variations in the Uygur and clarify the role of blood pressure variation (BPV) in their longevity. A cross-sectional survey was carried out in Hotan. We investigated 133 clinically healthy elderly Uygur subjects and divided them into two groups: 1) 33 Uygur centenarians in Hotan (UCH; aged ≥100 years); and 2) 100 elderly Uygur in Hotan (UEH; aged 65–70 years). Blood pressure (BP) was monitored and analyzed with ambulatory BP monitoring. The frequency domain measures were obtained with the maximum entropy method. The mean 24-h SBP was higher in UCH than in UEH. The ratio of non-dipper type BPV was larger in the UCH than in UEH. The highest power spectral density occurred over a 12-h rather than a 24-h period in both UCH and UEH. Ultradian BPVs were more frequent in UCH than in UEH. The least square-fitting curves demonstrated that the maximum values, minimum values, and mean 24-h SBP values were higher in UCH than in UEH. The higher BP and greater number of ultradian BPVs in UCH may have been due to the greater energy expenditure for maintaining daily activities in this population. Factors such as meals, daytime naps, nocturnal micturition, decreased baroreceptor sensitivity, and arterial sclerosis may also have contributed to the higher ultradian BPVs. In conclusion, BPV in the 12-h is more dominant than in the 24-h in both UCH and UEH. BPVs in the 3-h and 4-h are more frequent in UCH than those in UEH. (Hypertens Res 2003; 26: 597–601)

Key Words: blood pressure, aged, circadian rhythm, periodicity

Introduction

Despite their lack of medical treatment, the Uygur living in the southern territory of the Xinjiang Autonomous Region of the PRC have been reported to have a longer life expectancy than any other population in Xinjiang (1, 2). Other studies have reported that the Uygur have a lower prevalence of hypertension than the Han or Kazakhs living in the same region (3, 4). However, the Uygur centenarians have been shown a higher incidence of hypertension than the Uygur individuals (aged 65–70 years, candidates for centenarians) (5). There have been only a few studies on ambulatory blood pressure monitoring (ABPM) in centenarians (5–7). Unfortunately, most of these reports have failed to provide time-series analyses of blood pressure variation (BPV) and its parameters—i.e., frequency, period, acrophase, and maximum and minimum values. In particular, there has been no time-series analysis of BPV on more than thirty centenarians. Accordingly, the purpose of this study was to clarify the role of BPV in the longevity of the Uygur by performing a time-series analysis of BPV in the Uygur centenarians and comparing the results with those for their younger counterparts, Uygur elderly subjects, in Hotan (UEH).

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Methods
A cross-sectional survey of systolic blood pressure (SBP) was performed on people (91 men and 42 women; age ≥65 years), including some centenarians, as described previously (3). Briefly all Uyghur aged ≥65 years in three regions of the Xinjiang Autonomous Region of Hotan were recruited. The survey was conducted using a uniform standardized protocol.

Subjects
Clinically healthy and active elderly subjects were selected from among the Uyghur in Hotan. Written informed consent was obtained from each subject and the ethical committees of our institutions approved the protocol. All subjects were in sinus rhythm and none of them displayed clinical or laboratory evidence of cardiac, renal, hepatic, or metabolic diseases. These subjects were divided into two groups according to age: a group of Uyghur centenarians in Hotan (UCH) (33 subjects; age ≥100 years) and a group of elderly UEH (100 subjects age 65–70 years). The age of subjects was confirmed through resident registration forms and personal histories (5). The height and weight of subjects were measured before the 24-h ambulatory blood pressure monitoring (ABPM). Body mass index (BMI) was determined as weight (kg) divided by height (m) squared.

Twenty-Four-Hour Blood Pressure (BP) Monitoring
All of the subjects were hospitalized at local health care centers and were asked to maintain their regular schedules of daily activity and rest. We used 14 automatic devices that printed out SBP, diastolic BP (DBP), and pulse rate (PR) once every 30 min using the cuff-Korotkoff method (TM2421; A&D Co., Tokyo, Japan). Meals were taken between the hours of 6:30 and 7:30, 11:00 and 12:00, and 17:30 and 18:30. The subjects were fed according to their traditional dietary customs. BP was recorded for more than 26 h, because the data collected during the initial 2 h were discarded to avoid any novelty effect. Each subject was asked to report all daily activities, meals, micturitions, and sleep. All devices were applied and removed at the same local health care center. Twenty-four-hour measurements as well as daytime and nighttime BP were defined as the means of each variable, as described previously (3). Non-dippers were defined as individuals showing a mean nighttime SBP that was 0–10% less than their mean daytime SBP. Data from 24-h measurements were averaged at 30-min intervals to obtain the mean and SD for each 30-min period. Abnormal SBP values were excluded based on the criteria published previously (5).

Maximum Entropy Method Analysis
The observed data were averaged every 30 min (30-min average data) and analyzed using a MemCalc system (Suwa Trust Co. Ltd., Tokyo, Japan), a universal system for time-series data analysis. The system utilizes primarily the maximum entropy method (MEM) and the non-linear least squares method (LSM). The construction and performance of MemCalc have been described in detail previously (6).

The optimum least square-fitting (LSF) curve (underlying variation) was also calculated using four periods calculated by frequency domain. The optimum fitting functions were obtained from the peak frequency and power spectral density (PSD) utilizing LSM.

Statistical Analysis
The data are expressed as the mean±SD. All statistical calculations were performed using SAS software (SAS Institute, Cary, USA). Group comparison tests were made by two-way analysis of variance (ANOVA) followed by multiple comparison tests. Values of p<0.05 were considered to indicate statistical significance.

Results
Physiological Characteristics
There were more men than women enrolled in this study (men/women: UCH 25/8; UEH 66/34). The average age was higher in UCH than in UEH (men/women: UCH 104±5/104±3 vs. UEH 68±2/67±2 year, p<0.001). BMI did not differ between UCH and UEH (men/women: UCH 22±6/18±2 vs. UEH 21±2/21±3).

Short-Term BPV and Non-Dipper Type
Mean 24-h SBP in UCH was higher than that in UEH (SBP: 131±24 vs. 124±16 mmHg, p<0.001). Figure 1 (upper panel) shows the SD of 24-h SBP, which was larger in UCH than in UEH (28.22±2.45 vs. 22.33±1.80 mmHg, p<0.05). The lower panel shows the coefficient of variation in 24-h SBP, which was also larger in UCH than in UEH (21.76±1.97 vs. 18.00±1.15%, p<0.05). Figure 2 shows the ratio of non-dipper type BPV in both UEH and UCH. The ratio was 79% for UCH and 56% for UEH (p<0.02).

Time-Series Analysis of the Optimum LSF Curve
Figure 3 shows the observed and modified SBP values from the time-series measurements of 100 UEH subjects, along with the optimum LSF curve (upper panel). We observed clear circadian variations in SBP that rose during the daytime and fell during the nighttime. There were two peaks (maximum values: 135.49 mmHg at 9:00, 130.70 mmHg at
Fig. 1. The SD of SBP in UEH and UCH (upper panel) and the coefficients of variations (lower panel) of SBP in UEH and UCH. SBP, systolic blood pressure; UEH, Uygur elderly subjects in Hotan; UCH, Uygur centenial subjects in Hotan. *p<0.05.

Fig. 2. The ratio of non dipper-type in UEH and UCH. UEH, Uygur elderly subjects in Hotan; UCH, Uygur centenial subjects in Hotan. *p<0.02.

21:00 and two troughs (minimum values: 118.92 mmHg at 2:00, 122.63 mmHg at 16:00).

Figure 4 shows the observed and modified SBP values from the time-series measurements of 33 UCH subjects, along with the optimum LSF curve (upper panel). We again observed clear circadian variations in SBP that rose during the daytime and fell during the nighttime. There were four peaks (maximum values: 137.36 mmHg at 7:30, 132.10 mmHg at 12:30, 131.67 mmHg at 18:00, 131.03 mmHg at 21:00) and four troughs (minimum values: 123.98 mmHg at 1:30, 129.07 mmHg at 10:30, 125.55 mmHg at 15:00, 130.56 mmHg at 20:00).

We also performed time-series analyses of DBP. However, the BPV in DBP was smaller than that in SBP, and was characterized by two peaks in UEH and multiple peaks in UCH. Therefore, we did not perform a time-series analysis of these parameters in DBP. The nighttime SBP was higher on the optimum LSF curve in UCH than in UEH. All of the maximum and minimum values of SBP in UCH were larger than those in UEH. The daytime peaks in SBP seemed to correspond with mealtimes (breakfast and lunch) in UCH. However, only the daytime peaks in SBP seemed to correspond with mealtime (breakfast) in UEH and the luncheon peak diminished in UEH. The last peaks in both UCH and UEH were observed between 20:00 and 21:00. This peak in SBP appeared to correspond to the timing of ceremonial Islamic activities, such as bowing to the ground, standing, and sitting for prayer. Thus the major difference in BPV between UCH and UEH was that the luncheon SBP peak was smaller in the latter. Furthermore, SBP in UCH did not decline after luncheon and remained higher than that in UEH.
The physiological characteristics did not differ between UCH and UEH, as reported previously (5). In particular, the BMI in UCH was not smaller than that in UEH. There were more men than women enrolled in the study, which we attributed to the fact that the life expectancy of Uygur women is lower than that of Uygur men. This finding was consistent with those of previous Chinese population studies in Xinjiang (5–7). The preponderance of men may also have been related to social and religious factors. The women are engaging in heavy farming, housekeeping, nursing along with childbearing. The official mortality ratio is not available and it is supposedly higher in women than men in this groups.

There have been few studies on ABPM in centenarians (5–7). In particular, whether short-term BPV is altered in centenarians is uncertain. In the present study, the higher SD and higher coefficient of variation in 24-h SBP indicate that short-term BPV was greater in UCH than in UEH. This was also confirmed by our time-series analysis, which showed many ultradian BPVs in UCH. Our findings indicate that there was a higher ratio of non-dipper type BPVs in UCH than in UEH. This finding confirms a reduction in the fall of SBP during the night decreased in UCH. Several previous studies have also reported that nocturnal falls in SBP decline with advancing age in the very elderly, mainly because of higher nighttime SBP (5–7, 9, 10).

The time-series analysis of SBP with the optimum LSF curve revealed four peaks, four troughs, and ultradian BPVs in UCH. On the other hand, the same analysis in UEH showed only two peaks. These two peaks in the circadian pattern of SBP are generally observed in the adult population. The higher lunchtime SBP peak in UCH may have resulted from a decrease in baroreceptor sensitivity, a decrease in endothelial function due to arteriosclerosis, and so forth. Furthermore, SBP in UCH did not decline after lunchtime and remained higher than that in UEH. The power spectrum in UCH revealed that BPVs were more dominant in the 12-h than in the 24-h, as in the UEH subjects. However, the UCH subjects showed a greater dominance of BPVs in the 24-h, 4-h, and 3-h than their UEH counterparts. This finding indicates that UCH maintain good rhythmicities despite more than 100 years.

The increased ultradian BPVs of SBP in UCH are related to a variety of factors, such as eating, stress, work, social activities, and sleeping. Most UCH seemed to manage their own daily activities. Physical activity during the night has a profound effect on SBP elevation and non-dipper type BPV (11). Unfortunately, although we monitored physical activity in a small number of UCH, only one actigraph was available for this purpose, and thus we were unable to include physical activity and sleeping quality in this study. We can speculate that there may have been some sleep disturbance due to nocturnal waking for micturition. Another possible cause of the increase in ultradian BPVs may have been a decrease in baroreceptor sensitivity, which in turn may have been related to arteriosclerosis (12).

The main limitations of our study were that we studied on-
ly 33 centenarians and that our population was predominantly male. In terms of the size of the cohort, however, there has been no previous ABPM study with a cohort of more than 16 centenarians (6, 7). We believe these limitations do not affect the results of our findings. Another limitation is that the BP measurements were taken for too short a period (26-h) to allow proper evaluation of BPV. However, we believe that a period longer than 26-h is not practical for a large-scale study on ABPM in centenarians.

In summary, the Uygur centenarians were found to be more hypertensive than the Uygur aged 65–70 years (candidates for centenarians). The Uygur centenarians showed more non-dipper type BPVs than the Uygur aged 65–70 years. Both the Uygur centenarians and their younger counterparts showed a greater dominance of BPVs in the 12-h than in the 24-h period. However, the Uygur centenarians have more ultradian BPVs than the Uygur aged 65–70 years.

In conclusion, BPV in the 12-h is more dominant than in the 24-h in both UCH and UEH. BPVs in the 3-h and 4-h are more frequent in UCH than those in UEH.

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