Effects of Age and Hypertension on Autonomic Nervous Regulation During Passive Head-Up Tilt
Yoshikage Yo, Masahiro Nagano, Noriko Nagano, Kaeko Iiyama, Jitsuo Higaki, Hiroshi Mikami, Toshio Ogihara

Abstract To study the effects of age and hypertension on autonomic nervous function with passive postural change, we examined 31 normotensive subjects (25 to 85 years old) and 31 hypertensive patients (21 to 71 years old) without any cardiac disease, diabetes mellitus, or neurological disorders. Subjects were passively placed in a 60° head-up tilting position after 15 minutes in the supine position. Autonomic nervous function was evaluated by frequency domain analysis of heart rate with the autoregressive method. Using low-frequency (0.1 Hz) and high-frequency (0.25 Hz) peaks, the ratio of low- to high-frequency power (L/H) was calculated as an index of sympathetic activity and the ratio of high to total power (%HF) as that of parasympathetic activity. With the patient in the supine position, total power spectral density declined logarithmically with age in normotensive subjects and hypertensive patients, but %HF and L/H showed no changes. In response to passive tilting, L/H was increased and %HF was decreased in the normotensive subjects, and these responses declined with age logarithmically. In contrast, hypertensive patients exhibited less autonomic response to postural change regardless of age. These results suggest that autonomic neural response to tilt is decreased with age; however, attenuation of the response by hypertension is not associated with an increase in age. (Hypertension. 1994;23[suppl 1]:I-82-I-86.)

Key Words • aging • autonomic nervous system • spectrum analysis

The autonomic nervous system plays a central role in the regulation of cardiovascular homeostasis. Autonomic regulatory function is known to be impaired with advancing age by demonstration of reductions of heart rate variability,1 baroreceptor control of heart rate,2,3 and ß-adrenergic receptor-mediated increase in heart rate.4,5 These impairments are also observed in young hypertensive patients,2,3 suggesting that hypertension is another modulating factor that regulates autonomic nervous function.

The aim of this study was to clarify the effects of age and hypertension on the regulation of autonomic function at rest and during passive postural tilt. Because power spectral analysis of heart rate variability allows noninvasive and accurate assessment of autonomic nervous function,6,7 we used power spectral analysis by the autoregressive modeling algorithm.8,9

Methods

Subjects

The subjects were 31 hypertensive patients (World Health Organization stages I and II) aged 21 to 71 years (mean±SD, 55±14 years) and 31 normotensive subjects (25 to 85 years, 52±17 years). Patients with cerebrovascular disease, diabetes mellitus, neuromuscular dysfunction, cardiac disease, or arrhythmia were excluded. Exclusion of cerebrovascular disease was based on normal findings on brain computed tomography and magnetic resonance imaging. The diagnosis of hypertension was made when blood pressure in the clinic was 160/95 mm Hg or greater on at least two separate occasions and during admission to the hospital and kept on a diet with a salt content of 7 to 10 g/d. Drugs affecting neural regulation including sedatives and antihypertensive agents were discontinued at least 1 week before the study.

Power Spectral Analysis

Patients were kept in the supine position in a temperature-controlled, quiet room for 30 minutes before postural change. After baseline data were obtained for 15 minutes, patients were passively placed in a 60° head-up tilting position, then returned to the supine position for 15 minutes. Heart rate and blood pressure were continuously measured throughout the study with a monitor (CBM-3000, Nippon Colin, Nagoya, Japan). Blood pressure was measured on a beat-to-beat basis through a sensor placed on the wrist over a radial artery, which was calibrated every 2 minutes by blood pressure in the brachial artery of the opposite side with a sphygmomanometer. A total of 512 RR intervals were obtained from each recording, usually for 7 to 10 minutes of each data acquisition. We used stationary RR intervals free from noise or ectopic beats. When an ectopic beat existed, we excluded the consecutive three beats including the ectopic beat.

Heart rate variability was then assessed by power spectral analysis with an autoregressive model9 using a computer program (AUTONOMIC NERVOUS SYSTEM PACKAGE, version 1.09, Nippon Colin). For analysis, total power was defined as power at 0.03 Hz or greater, low frequency (LF) as the peak at 0.1 Hz, and high frequency (HF) as the peak at 0.25 Hz. The ratio of low- to high-frequency power (L/H) was calculated as an index of sympathetic activity and the ratio of high-frequency to total power (%HF) as that of parasympathetic activity.8,9

The study protocol was approved by the Ethics Committee of Osaka University Hospital, and informed consent was obtained from each subject.
Total Power

\( y = 4275e^{-0.07x} \)

\( r = 0.70 \)

\( p = 0.0001 \)

\( \text{msec}^2 \)

Age (years)

\( 0 \)

\( 20 \)

\( 40 \)

\( 60 \)

\( 80 \)

\( 1000 \)

\( 2000 \)

\( \%

\( \text{HF} \)

\( \text{N.S.} \)

\( \text{L/H} \)

\( \text{N.S.} \)

\( \text{Age (years)} \)

\( 0 \)

\( 20 \)

\( 40 \)

\( 60 \)

\( 80 \)

\( 70 \)

\( 60 \)

\( 50 \)

\( 40 \)

\( 30 \)

\( 20 \)

\( 10 \)

\( \%

\( \text{HF} \)

\( \text{N.S.} \)

\( \text{L/H} \)

\( \text{N.S.} \)

Statistical Analysis

The correlation between age and spectral power was analyzed by a simple regression model. Differences of changes in heart rate and the power spectral indexes (total power, L/H, and %HF) between normotensive subjects and hypertensive patients were assessed by two-way analysis of variance (ANOVA) with repeated measures. Differences in changes of these variables within groups were analyzed by a two-tailed, paired \( t \) test. A value of \( P<.05 \) was considered statistically significant.

Results

In normotensive subjects in the supine position, total power declined with age (Fig 1). Absolute power of HF and LF decreased with age similar to total power, and %HF and L/H showed no age-related changes (Fig 1). Similarly, a decline in total power with no age-related change in %HF and L/H was observed in hypertensive patients (Fig 2). Systolic blood pressure was not significantly altered by passive postural change in the normotensive subjects (from 114±3 to 113±3 mm Hg), but it was decreased in the hypertensive patients (from 149±3 to 145±3 mm Hg, \( P<.05 \)). Diastolic blood pressure was unchanged in normotensive (from 64±2 to 67±2 mm Hg) and hypertensive groups (from 82±2 to 84±2 mm Hg). In response to tilt, heart rate was similarly increased in normotensive subjects (from 64±2 to 76±3 beats per minute, \( P<.01 \)) and hypertensive patients (from 64±2 to 76±2 beats per minute, \( P<.01 \)). The heart rate response to passive tilt decreased with age in both groups. During passive tilt, %HF decreased and L/H increased in both groups (Figs 3 and 4). L/H response was significantly attenuated in the hypertensive patients compared with the normotensive subjects (\( P=.016 \)). In normotensive subjects, the responses of %HF and L/H declined with age (Fig 5), whereas those in hypertensive patients showed no age-related changes (Fig 6).

Discussion

In this study, we examined the effects of age and hypertension on the autonomic nervous function at rest and during passive postural tilt. Results obtained with patients in the supine position confirmed previous reports that heart rate variability, as shown by total power of spectral analysis, decreased with age.\(^6\)\(^-\)\(^8\)\(^-\)\(^10\) These changes may be explained by vascular sclerosis,\(^3\) de-
increased sensitivity of baroreceptor function,7,11 and autonomic dysfunction12 with advanced age. In HF and LF, we demonstrated that the absolute values of LF and HF were decreased with age, but %HF and L/H showed no significant changes. These findings are consistent with previous reports using frequency domain analysis by fast Fourier transformation7 and by the autoregressive method,4 suggesting that the activity of the autonomic nervous system declines with age, but the balance of sympathetic and parasympathetic activities does not change. However, Lipsitz et al10 demonstrated that HF is more markedly attenuated in advanced age. They used a new method in which the regression line was calculated from the log amplitude and log frequency plotting of the heart rate spectra (1/f²) and compared young (18 to 35 years) and elderly (71 to 94 years) subjects. Thus, the difference in analytic method and the relatively higher age in the elderly group may explain the difference of the results. In patients with hypertension, similar changes were observed. Therefore, with patients in the supine resting state, we were unable to demonstrate effects of hypertension on the autonomic nervous function.

In response to passive postural tilt, normotensive subjects showed a significant increase in L/H and decrease in %HF, indicating sympathetic activation and reduction of vagal tone during postural change. These responses declined with age. Thus, autonomic nervous response was reduced in the elderly.

In hypertensive patients, L/H response to tilt was significantly attenuated compared with that in normotensive subjects. Although it did not reach statistical significance, %HF in the hypertensive patients also showed a lower response. These poor responses were observed even in young patients, resulting in no age-related decline of sympathetic and parasympathetic responses to tilt. Therefore, the effect of hypertension on autonomic function was masked in the elderly patients. Gribbin et al2 showed an independent effect of age (19 to 66 years) and hypertension on baroreceptor reflex sensitivity in response to phenylephrine injection. In their study, decrease of baroreceptor function in hypertension was observed even in patients more than 50 years of age.2 It was also...
Yo et al  

Autonomic Function With Postural Change

![Graphs showing changes in %HF and L/H with age](image)

reported that increases in blood pressure and age (21 to 68 years) are associated with a reduction in \( \beta \)-adrenergic receptor response of heart rate. In contrast, similar to our results, Kawamoto et al demonstrated a limited influence of hypertension in older subjects (56 to 76 years) because their autonomic functions have already declined with aging. The lack of interaction between age and hypertension in the elderly in the former two studies may be due to the relatively younger age composition of the aged group as well as the difference in methods used to evaluate autonomic function.

Schwartz et al reported that age-related decline in L/H was observed only in patients under controlled breathing. However, this study needed 45 minutes for the entire recording. Because keeping patients in controlled breathing for 45 minutes is not only difficult but also stressful and may affect autonomic nervous activities, we did not ask for controlled breathing but observed the effects of aging on the autonomic response during head-up tilt. These results suggest that the method used in this study does not require controlled breathing for the assessment of autonomic nervous activity from heart rate variability.

In conclusion, autonomic neural response to tilt is decreased with age; however, attenuation of the response by hypertension is not associated with the increase in age.

![Graphs showing changes in %HF and L/H with age](image)

Fig 5. Scatterplots show effects of age on the response of %HF and L/H to passive tilt in normotensive subjects. Data are expressed as percent change of values for patients during tilt to those with patients in the supine position. %HF indicates percentage of high-frequency power in total power; L/H, ratio of low- to high-frequency power. n=31.

Fig 6. Scatterplots show effects of age on the response of power spectral components to tilt in hypertensive patients. Data are expressed as percent change of values for patients during tilt to those with patients in the supine position. %HF indicates percentage of high-frequency power in total power; L/H, ratio of low- to high-frequency power. n=31.
References


Effects of age and hypertension on autonomic nervous regulation during passive head-up tilt.
Y Yo, M Nagano, N Nagano, K Iiyama, J Higaki, H Mikami and T Ogihara

Hypertension. 1994;23:I82
doi: 10.1161/01.HYP.23.1_Suppl.I82

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/23/1_Suppl/I82

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Hypertension can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Hypertension is online at:
http://hyper.ahajournals.org/subscriptions/