Effects of Aging on Blood Pressure Variability in Resting Conditions

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Abstract The objective of this study was to determine the effect of aging on beat-to-beat blood pressure and pulse interval variability in resting conditions and to determine the effect of aging on the sympathetic and vagal influence on the cardiovascular system by power spectral analysis of blood pressure and pulse interval. We studied three groups of healthy, normotensive subjects: young (10 to 15 years, n=16), adult (20 to 40 years, n=16), and elderly (70 to 90 years, n=25). Beat-to-beat blood pressure was measured by Finapres during 20 minutes supine and 10 minutes standing. Overall systolic and diastolic blood pressures and pulse interval variability were determined. Power of the mid-frequency (0.08 to 0.12 Hz) and high-frequency bands (0.15 to 0.40 Hz) were determined by spectral analysis. Eight subjects in each group were examined. Overall systolic blood pressure variability increased with aging. Power of the mid-frequency band of systolic and diastolic blood pressures was markedly decreased in the elderly, especially in the standing position. Power of the high-frequency band of pulse interval was also decreased in the elderly. Baroreflex sensitivity calculated by fast Fourier transformation spectral analysis was decreased in the elderly subjects compared with the younger groups. In conclusion, we found no change in the overall variability of blood pressure with aging. Mid-frequency spectral power of blood pressure and mid- and high-frequency spectral powers of pulse interval variability were decreased in the elderly. These results suggest that aging does not merely influence the magnitude of blood pressure and pulse interval variability but causes a complex rearrangement of the variability pattern by changes in neurocardiovascular regulation. (Hypertension. 1994;24:120-130.)

Key Words • blood pressure • autonomic nervous system • aging

All biological parameters display a certain variability. Cardiovascular parameters such as blood pressure and heart rate distinguish themselves from many others because their variability has (patho)physiological significance.1 The study of beat-to-beat blood pressure and heart rate variabilities enhances the physiological understanding of neurocardiovascular regulation2-6; from a clinical point of view, interest is currently focused on the possible role of blood pressure variability as a risk factor of hypertensive target-organ damage, independent of the average level of blood pressure.7 Presently, the elderly constitute a large and fast-growing proportion of the population that challenges cardiovascular research. Like hypertension, aging has been shown to increase blood pressure variability.8-10 Heart rate variability, however, decreases with increasing age and blood pressure.9,11,12 Because blood pressure rises with aging,13 there is a substantial covariance, which makes the relative contribution of blood pressure and aging to variability difficult to disentangle. Other factors that may hamper proper understanding of studies on beat-to-beat blood pressure and heart rate variabilities in relation to age are the lack of strict standardization of activities in ambulant subjects and the relatively small age range of the subjects.8-10

Conventional descriptive techniques, such as frequency distribution, are used for the study of beat-to-beat blood pressure and heart rate variabilities.8-10 Additional information can be obtained by power spectral analysis, which breaks down a signal to its constituent frequency components and quantifies the power of these components.2-4,6,14,15 Blood pressure and heart rate modulation by baroreflex and sympathetic and parasympathetic nervous activity has been shown to be involved in the genesis of the various frequency components of blood pressure and heart rate variabilities.2,3,14-21

In the present work we determined the overall variability and frequency distribution of blood pressure and pulse interval in healthy, normotensive subjects, covering an age range of 10 to 90 years, with subjects in the supine and standing positions. We addressed two issues in this study: (1) the separated effects of aging and the rise in blood pressure with aging on overall blood pressure variability in healthy subjects covering a large age range during standardized resting conditions, and (2) the effect of aging on the influence of the baroreflex and sympathetic and parasympathetic nervous systems on the cardiovascular system as determined by power spectral analysis of blood pressure and pulse interval variabilities. Subjects were studied in both the supine and standing positions. These positions are of interest because the supine position increases the vagal drive to
the heart, and the standing position increases the sympathetic vasomotor traffic.22

Methods

Subjects

The data of three studies23-25 were used to compose three different age groups: young, young adult, and elderly. Young (10 to 15 years) boys (n=10) and premenarchal girls (n=10) and healthy elderly (70 to 90 years) male (n=20) and female (n=20) subjects were selected from a general practice. Healthy young adult (20 to 40 years) men (n=10) who were involved in a study on standardization of investigation of cardiovascular reflexes25 comprised the male part of the adult group. This group was extended with seven young adult female subjects (20 to 40 years). Details of the selection procedure have been reported elsewhere.23-25 All subjects were healthy, did not use any medication, and ate a normal diet without salt restriction. The elderly subjects were still physically and socially active. The protocol was approved by the hospital ethics committee, and all subjects gave their informed consent.

Measurements

Noninvasive continuous blood pressure was measured at the finger using a TNO FINAPRES model 5,6,26 which has been shown suitable for assessment of blood pressure variability.28 To avoid interference of hydrostatic errors, subjects were asked to keep the cuffed finger at heart level. The correct position of the finger, the fourth intercostal space in midaxillary line, was marked with a skin electrode. Continuous finger blood pressure and an event marker were recorded on magnetic tape using a cassette data recorder (TEAC R-61, TEAC Corp) for off-line data analysis.

Maneuvers

A 20-minute supine period and 10-minute standing period were used for analysis. The first 2 minutes of standing were omitted to allow for stabilization of blood pressure and pulse interval. The maneuvers were performed in the morning in a room with a constant temperature of 22° to 24°C. At least 2 hours before the experiment the subjects had eaten a light breakfast. All subjects abstained from coffee, tea, and smoking starting the evening before the experiments.

Data Analysis

Finger blood pressure and the event marker were replayed and analog-to-digital converted at 100 Hz (real time). By means of a signal-analysis program, the time of the systolic upstroke was identified for each beat, as were the actual systolic, mean, and diastolic pressures and the interbeat interval (resolution, 10 milliseconds). The automatic calibration of the Finapres (Physio-cal) was kept on during the supine and standing positions. The correct position of the finger, the fourth intercostal space in midaxillary line, was marked with a skin electrode. Continuous finger blood pressure and an event marker were recorded on magnetic tape using a cassette data recorder (TEAC R-61, TEAC Corp) for off-line data analysis.

Noninvasive continuous blood pressure was measured at the finger using a TNO FINAPRES model 5,6,26 which has been shown suitable for assessment of blood pressure variability.28

Integration of the curve for specific frequency bands yields variance for that particular frequency band. We calculated the power in two frequency bands: the mid-frequency (MF) band (0.08 to 0.12 Hz) and the high-frequency (HF) band (0.15 to 0.40 Hz). The percentage power of the MF and HF bands in relation to total power (total variability) in the supine and standing positions was also obtained in the three respective age groups.

Spectral analysis by FFT not only gives variability as a function of frequency, it also quantifies covariance between signals in terms of phase (time shifts) and coherence (squared correlation in a specific frequency band).12,29 We computed phase and coherence between systolic blood pressure and pulse interval to test a baroreflex model for the genesis of variability in the MF and HF bands. Only when coherence exceeded .5 (which is comparable to a correlation coefficient of .7) did we compute the regression between systolic blood pressure and pulse interval in that band in milliseconds per millimeter of mercury, the usual measure for baroreflex sensitivity.

Blood pressure recordings were screened for premature beats and movements artifacts, both known for their influence on the assessment of variability.2 If these were present in a certain subject, that subject was omitted from the analysis. Consequently, 16 of 20 subjects remained in the young group, 16 of 17 subjects in the adult group, and 25 of 40 subjects in the elderly group. Averaged blood pressure in the supine and standing positions of the remaining subjects was comparable to the age group from which they originated. Table 1 lists basic subject characteristics.

Statistics

Statistical analysis was performed with BMDP statistical software (University of California, Los Angeles). Kruskal-Wallis and Mann-Whitney U tests were used to compare the different age groups. Paired comparisons for the effect of posture in the three age groups were performed by Wilcoxon's signed rank test. When no differences in variability (only SD) between age groups were found, the relation of the level of the tested parameter and SD was determined by a linear regression analysis on the data of all subjects, all age groups combined. Correlation coefficients, regression coefficients (rc), and their standard errors (SEM) are given. Results are expressed as mean±SD. A value of P<.05 was considered statistically significant.

Results

Levels of Blood Pressure and Pulse Interval

Table 2 presents the average blood pressure and pulse interval levels in the three age groups. Average systolic and diastolic blood pressures of young and adult subjects were significantly lower than those of the elderly subjects in both the supine and standing positions. The increase in diastolic pressure upon standing was significant (P<.001 in all three age groups).

Average pulse interval in the young was shorter than in the elderly in both the supine and standing positions. Supine pulse interval of the adult group was longer than...
that of the young, whereas standing pulse interval of the adult group was shorter than that of the elderly.

Overall Variability of Blood Pressure and Pulse Interval

Table 3 and Figs 1 and 2 show the main results of overall blood pressure and pulse interval variabilities.

Blood Pressure Variability

Overall blood pressure variability, expressed as SD, did not differ among age groups for both systolic and diastolic pressures in neither the supine nor standing positions. Standing from supine induced an increase in diastolic but not systolic SD for all three age groups. Expressed as the CV, there was no difference in systolic pressure variability between age groups in either the supine or standing positions. For diastolic pressure the variability (CV) in the standing position was even larger in the young and adult subjects compared with the adult and elderly groups. In the supine position there were no differences among age groups.

Using all subjects, regression analysis showed a significant relation between the levels of systolic and diastolic blood pressures and the overall variability (SD) of blood pressure in both the supine and standing positions. For systolic pressure the correlation coefficient was .37 (rc=0.038, SEM=0.013, P<.01) in the supine position and .52 (rc=0.061, SEM=0.013, P<.001) in the standing position. For diastolic pressure the correlation coefficient was .33 (rc=0.043, SEM=0.016, P<.05) in the supine position and .29 (rc=0.033, SEM=0.014, P<.05) in the standing position. Regression of level versus variability of blood pressure for the three age groups separately did not show differences in slopes or intercepts among age groups.

Pulse Interval Variability

Overall pulse interval variability of the elderly, expressed as SD, was lower than that of the young and adults in the supine position. There was no significant difference in the SD of pulse interval in the standing position among the three age groups. Pulse interval variability expressed as CV of the young group was higher than that of the elderly in both the supine and standing positions. The pulse interval CV of the adult group was higher than the CV of the elderly group only in the supine position and not in the standing position.

Spectral Analysis

Fig 4 shows representative examples of blood pressure tracings of an elderly and adult subject in the supine and standing positions. Visually, there was a striking difference in the blood pressure variations in the standing position between the adult and elderly subject, the former apparently having the largest fluctuations. Nevertheless, the SDs of diastolic blood pressure were almost identical: 4.3 mm Hg in the elderly subject this was only 2%. Thus, the frequency distribution of the variability may disclose differences that, by using the SD, would remain hidden.

Fig 5 (left and right) and Table 4 display the principal results of the spectral analysis. The relative power in the MF band in the supine position was larger in the young and adult subjects compared with the elderly for systolic pressure. In the standing position both systolic and diastolic blood pressure variabilities in this band were larger in the young and adult subjects compared with the elderly. Standing up from the supine position induced an increase in power of the MF band of systolic and diastolic blood pressures in all three age groups, but the increase in power was smaller in the elderly than in the young and adult subjects. The relative power of the MF band of both supine and standing pulse interval was significantly smaller in the elderly than in the young and
TABLE 3. Overall Variability of Blood Pressure and Pulse Interval

<table>
<thead>
<tr>
<th></th>
<th>Young</th>
<th>Adult</th>
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<td>NS</td>
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<td>NS</td>
<td>NS</td>
<td></td>
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<tr>
<td>DBP, mm Hg</td>
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<tr>
<td>Supine</td>
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<td>NS</td>
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<td>NS</td>
</tr>
<tr>
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<td>P&lt;.05</td>
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<tr>
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<tr>
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<td>6±1</td>
<td>6±2</td>
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<tr>
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<tr>
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<td>6±2</td>
<td>&lt;.01</td>
<td>NS</td>
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<td>Standing</td>
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<td>6±2</td>
<td>&lt;.001</td>
<td>&lt;.05</td>
<td>NS</td>
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</table>

Definitions are as in Table 2. Values are mean±SD.

adult groups. Standing up from the supine position induced an increase in the power of this band only in the young and adult groups.

The relative power of the HF band of pulse interval in the supine position was larger in young and adult subjects than in the elderly. Standing up from the supine position induced a decrease in the power of this band in all age groups, and in the standing position there was no longer a difference in the relative power of this band among the three age groups.

Table 5 gives the results of the calculation of baroreflex sensitivity by FFT spectral analysis. In the acceptance test based on coherence we had to reject more than half the spectral outcomes in the elderly group. Closer inspection confirmed that most of the blood pressure and pulse interval variabilities in this group were in the low frequencies (<0.08 Hz). It seemed that the characteristic peak of the MF band was not so much absent but had shifted to a lower frequency in the elderly group (between 0.05 and 0.08 Hz), effectively shifting out of the frequency window that had been set at the start of this study. As Table 5 shows, baroreflex sensitivity decreased significantly from the supine to the standing posture in all age groups in both frequency bands. Values for baroreflex sensitivity were not significantly different between the young and the adult group but were significantly reduced in the elderly group.

Discussion

The main findings of this study on beat-to-beat blood pressure and pulse interval variabilities in stable conditions in subjects between 10 and 90 years of age were the following: (1) Absolute overall systolic and diastolic blood pressure variabilities did not change with aging; also, the relative overall systolic and supine diastolic blood pressure variabilities did not change with aging. Standing relative diastolic blood pressure variability of the young subjects was larger than that of the adult or elderly subjects. (2) The power of the MF band of blood pressure and pulse interval variabilities decreased with aging. Standing up from the supine position induced a rise in the power of this band; the magnitude of this rise was decreased in the elderly. (3) In the supine position the power of the HF band decreased with aging; in the standing position there was no age difference.
Overall Blood Pressure and Pulse Interval Variabilities

We found that absolute overall blood pressure variability of elderly subjects did not differ from that of younger subjects, whereas linear regression analysis revealed a significant relation between the height and the variability (expressed as SD) of blood pressure (Fig 3). Also, when we expressed blood pressure variability in relation to blood pressure level as the CV, no difference in blood pressure variability among age groups could be demonstrated, with the sole exception of standing diastolic blood pressure. In this case a decrease in variability with aging was shown. These results are in contrast with some earlier studies describing an increase in the variability of ambulatory recorded beat-to-beat blood pressure with aging independent of the height of blood pressure. However, in one other study by Watson et al, no independent relation of blood pressure variability and age was found. In that study systolic variability increased with the height of pressure.

To explain these differences in the relation between aging and blood pressure variability, consideration of the role of heart rate in blood pressure regulation may be helpful. The studies that show an increase in blood pressure variability with aging were performed by ambu-
Fig 3. Scatterplots show systolic (PS) and diastolic (PD) blood pressure variability expressed as SD vs height of blood pressure of three age groups (young: 10 to 15 years, n=15; adult: 20 to 40 years, n=16; old: 70 to 90 years, n=26) in supine (top panels) and standing (bottom panels) positions. Regression lines for all subjects are displayed when the regression coefficient for the relation between height and variability of blood pressure was significant; see text.

Fig 4. Tracings show typical example of finger blood pressure recordings during supine and standing positions in an elderly and an adult subject. Note pronounced variability in blood pressure that develops on standing in the adult subject, which is absent in the elderly subject.
attributed to diminished vagal activity in the elderly.\textsuperscript{2,4,8,12} The decreased heart rate variability in elderly subjects thus may diminish the ability to limit the variability of ambulatory blood pressure.

The baroreflex plays an important role in buffering the variations in blood pressure in ambulatory conditions, as shown by the large increase in blood pressure variability after surgical denervation of the baroreceptors.\textsuperscript{34,35} It has also been shown that there is an inverse relation between baroreflex sensitivity and blood pressure variability in ambulatory conditions.\textsuperscript{9} Aging causes a decrease in baroreflex sensitivity,\textsuperscript{12,36,37} and thus in elderly subjects the baroreflex may be less able to limit variations in blood pressure in ambulatory conditions.\textsuperscript{8} However, blood pressure variability during rest (night) is reduced,\textsuperscript{8} and physical activity has been shown to be the main source of blood pressure variations during ambulatory conditions.\textsuperscript{33} Thus, during resting conditions blood pressure is less variable, and consequently, the decrease in the efficacy of the baroreflex to inhibit blood pressure variations in the elderly may be of less importance in resting conditions. This can explain our finding that blood pressure variability does not increase with aging in resting conditions, whereas it has been shown to increase with aging in ambulatory conditions.\textsuperscript{8,10}

There is debate about the best way of expressing overall beat-to-beat blood pressure variability.\textsuperscript{38} At

\begin{figure}
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\includegraphics[width=\textwidth]{figure5}
\caption{Bar graphs present results of spectral analysis, showing percent power of mid-frequency (MF, 0.08 to 0.12 Hz) (left panels) and high-frequency (HF, 0.15 to 0.40 Hz) (right panels) bands of systolic (PS) and diastolic (PD) blood pressures and pulse interval (INT) during supine and standing positions of three age groups (young: 10 to 15 years, n=15; adult: 20 to 40 years, n=16; old: 70 to 90 years, n=26). Results are mean±SD. *P<.05, **P<.01, ***P<.001. In the MF bands (left), note the large increase upon standing in the young and adult groups, which is much smaller in the elderly subjects.}
\end{figure}
least two approaches are possible: (1) the use of a measure of absolute variability (SD) alone or (2) the use of a relative measure of variability (CV), an index that expresses absolute variability as a percentage of baseline blood pressure. This choice will clearly affect the results and interpretation of studies on blood pressure variability. Some studies advocate the use of the SD because a relation between the variability and level of blood pressure cannot be demonstrated, although in several other studies such a relation has been found. Our data indicate that a relation between the level and variability of blood pressure exists, but we could not demonstrate such a relation between age and blood pressure variability, even in the wide age range we studied. Thus, because blood pressure variability increased with blood pressure level and blood pressure level also increases with aging, we consider the CV more appropriate for studying the relation of blood pressure variability and aging. However, it can be argued that in studies on blood pressure variability one should use both the CV and SD to represent variability to facilitate comparison with other studies in which the SD was used for the calculation of blood pressure variability.

Another argument brought forward in favor of the use of the SD instead of the CV is that clearly visible differences in the variability of beat-to-beat blood pressure tracings are not supported by differences in CV. But as demonstrated by the tracings in Fig 4, large differences in visible variability are not always represented in differences of either absolute or relative measures of overall variability of beat-to-beat blood pressure. In this case the use of only the SD is just as inappropriate as the use of only the CV; for a more detailed description of these differences in variability and for a better understanding of how the autonomic nervous system controls these beat-to-beat variations, a more sophisticated approach such as power spectral analysis may be appropriate.

### Spectral Analysis

The present study confirmed for a large age range the observations of Pagani et al and Lipsitz et al that in healthy subjects pulse interval variability decreases in

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**TABLE 4. Results of Spectral Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Mid-frequency band</th>
<th>High-frequency band</th>
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<tbody>
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<td></td>
<td>Young</td>
<td>Adult</td>
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<tr>
<td><strong>SBP, %</strong></td>
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<td>Supine</td>
<td>7.5±3.5</td>
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<td>Standing</td>
<td>19.1±10.5</td>
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<td>Supine vs standing</td>
<td>P&lt;.001</td>
<td>P&lt;.001</td>
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<td><strong>DBP, %</strong></td>
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<td>Supine</td>
<td>10.2±4.1</td>
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<tr>
<td><strong>Pulse interval, %</strong></td>
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<td>Supine</td>
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<td>Supine vs standing</td>
<td>NS</td>
<td>P&lt;.001</td>
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| **Definitions are as in Table 2. The mid-frequency band was 0.08 to 0.12 Hz; the high-frequency band was 0.15 to 0.40 Hz. Values are mean±SD.**
the HF and MF bands with increasing age. In elderly subjects the power of the MF band of diastolic pressure and pulse interval was smaller than in young or adult subjects in both the standing and supine positions. For systolic pressure this was only true for the standing position. Standing up from the supine position induced an increase in the power of the MF band of both blood pressure and pulse interval in all three age groups, with the exception of pulse interval MF power in the elderly, which did not increase. Also, in the elderly the increase in power of the MF band of systolic and diastolic blood pressures on arising was smaller than that of young and adult subjects. We did not calculate powers below 0.08 Hz; however, as the power above 0.08 Hz decreased in the elderly and overall blood pressure variability did not change, it is fair to assume that in the elderly the power of these very low frequencies increased.

Several factors influence the blood pressure and pulse interval spectra. Neural mechanisms are considered to be the most important, and most of the spectral components are probably generated by sympathetic and parasympathetic nervous activity and the baroreflex.3,14,21 Blood pressure variations that cause baroreflex modulation of pulse interval by parasympathetic nerves affect both HF and MF powers, although the MF power of pulse interval is also influenced by sympathetic nervous activity due to the time delay of baroreflex action in the MF range.16,21 There is much discussion on the origin of the blood pressure variability in the 0.1-Hz frequency range. Sympathetic vasomotor activity probably plays an important role as well as the baroreflex, as shown by the fact that blood pressure variability around this frequency decreases after sinoaortic denervation, whereas total blood pressure variability increases (mainly by an increase in lower-frequency variability).19 Moreover, there are theoretical arguments for the existence of a 0.1-Hz resonance phenomenon in the feedback arterial baroreceptor-sympathetic vasomotor loop.20 Much simplified, MF oscillations in blood pressure may be the result of the delayed sympathetic vasomotor reaction on blood pressure changes sensed by the baroreceptor and thus impose a specific rhythm on blood pressure.15,16 Spontaneous peripheral vasomotor changes may also contribute to blood pressure variations around and below this frequency range.40,41

The decrease in MF and HF power of pulse interval in the elderly may be related to a decrease of vagal modulation of heart rate with aging11,36 and the decrease in baroreflex sensitivity with aging (Table 5).12,36,37 The decrease in MF pulse interval power in the elderly may also point to a decrease in cardiac sympathetic modulation. The decrease in power of the MF band of blood pressure with increasing age may be caused by a diminution of sympathetic vasomotor modulation2,3,14,21 or to the diminished effectiveness of the baroreflex in the elderly and thereby the weakening of the feedback loop responsible for the 0.1-Hz resonance.12,36,37 Alternatively, slowing of sympathetic responses may have caused the 0.1-Hz band to shift outside the MF window used in this study.

Various methods have been used to estimate the activity of the sympathetic nervous system.22 Compared with measuring plasma levels of catecholamines or muscle sympathetic nerve activity, determining the power of the MF band by spectral analysis has an advantage: It does not determine sympathetic activity at some intermediate stage but may be related to the ultimate influence of the arterial baroreceptor-sympathetic vasomotor loop on the end organ. On the other hand, when changes occur in the power of the MF band, it is not possible to determine which site of the chain is responsible for these changes without information from other methods.

In elderly subjects baseline sympathetic nerve activity per se seems to be increased, as shown by elevated levels of circulating catecholamines49 and by a higher level of muscle sympathetic nerve activity recorded by microneurography.44,45 The evidence concerning the increase in sympathetic nerve activity during orthostatic stress is conflicting. In an earlier study we found that in the same subjects after 10 minutes of standing, compared with

<table>
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<th>TABLE 5. Baroreflex Sensitivity in the Three Age Groups</th>
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<td><strong>Mid-frequency band</strong></td>
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| High-frequency band                                   |
| n            | Young | Adult | Old | Y vs O | Y vs A | A vs O |
| Supine       | 24±14 | 20±6  | 10±9| <.01   | NS     | <.01  |
| Standing     | 10±4  | 10±3  | 5±2 | <.001  | NS     | <.001 |
| Supine vs standing | P<.01 | P<.01 | P<.05 |        |

Y indicates young (10 to 15 years); O, old (70 to 90 years); A, adult (20 to 40 years); and n, number of subjects with a coherence larger than 5 that were included in the calculation (see text). The mid-frequency band was 0.08 to 0.12 Hz; the high-frequency band was 0.15 to 0.40 Hz. Values are mean±SD. Baroreflex sensitivity is expressed in milliseconds per millimeter of mercury.
being supine, the increase in peripheral resistance was much larger in elderly than young subjects. As the increase in peripheral resistance upon standing is mediated by the sympathetic nervous system, it seems that in elderly subjects the sympathetic activation is larger than in young subjects. However, the increase in microneurographically recorded muscle sympathetic nerve activity induced by orthostatic stress was much smaller in elderly subjects than in young subjects, but the increase in circulating catecholamines upon standing was larger in elderly than young subjects.47,48

Thus, catecholamines and total peripheral resistance upon standing suggest an increase in sympathetic activity in the elderly. This makes it unlikely that the decreased MF power of blood pressure in the elderly is related to diminished sympathetic blood pressure modulation, and it is more probable that it is related to the diminished baroreflex sensitivity in the elderly. On the other hand, a decreased sensitivity of adrenergic receptors in the elderly may also partly explain the diminished MF power of blood pressure. Then, increased prereceptor nerve activity can result in less postreceptor effect in the end organ. Until now, a decrease in the sensitivity of these receptors in elderly subjects has been demonstrated unequivocally for \( \beta \)-receptors.49 For \( \alpha \)-receptors the picture is less clear. The number of receptors probably decreases with aging, but the \( \alpha \)-adrenergic receptor agonist response may still be preserved.49

Structural changes in the vessel that occur with aging may also play a role in the decrease of the MF variability of blood pressure and the smaller increase of this variability upon standing in the elderly. We already found that these vessel wall changes seemed to induce more vasoconstriction and thus a larger increase in blood pressure upon standing in elderly subjects than in younger subjects.46 The decrease of MF blood pressure variations with aging may also be explained by vessel wall changes. The fact that the end organ (the peripheral vessels) now reacts by a diminished instead of an increased response to sympathetic activation may be related to the increased stiffness of the vessel wall in the elderly, which may decrease and slow down its ability to react51,52 to changes in neurosympathetic drive.

Conclusions

Overall blood pressure variability at rest does not increase with aging. In other studies it has been found that ambulatory blood pressure variability is increased in the elderly. The difference between our findings and the literature can probably be attributed to the fact that the antioscillatory influence of heart rate, which decreases with aging, is less important at rest than in ambulatory conditions.

The power in the MF band of blood pressure variability is decreased in healthy elderly subjects. This may be related to the decreased baroreflex sensitivity in the elderly or to a decrease in end-organ responsiveness to sympathetic nerve activity due to adrenergic receptor sensitivity decrease or to structural changes of the vessel wall with aging. Overall blood pressure variability does not change in the elderly, and as MF blood pressure variability decreases, it seems that aging does not merely influence the magnitude of blood pressure variability but causes a rearrangement of the variability pattern by changes in neurocardiovascular regulation.

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