Involvement of the Baroreceptor Reflexes in the Changes in Blood Pressure with Sleep and Mental Arousal

JAMES CONWAY, M.D., NICHOLAS BOON, M.B., JOHN VANN JONES, PH.D., AND PETER SLEIGHT, M.D.

SUMMARY We have measured baroreflex sensitivity and blood pressure in 13 subjects during sleep and three stages of progressive mental arousal after waking. Baroreflex sensitivity was measured by correlating the increase in pulse interval with the increase in systolic pressure produced by an intravenous injection of 80 μg of phenylephrine. Blood pressure was measured directly from the brachial artery. During sleep, blood pressure fell and baroreflex sensitivity increased; with increasing mental arousal, blood pressure rose and baroreflex sensitivity decreased. These results suggest that baroreflex activity may be involved in the medium-term regulation of blood pressure during the day and night in addition to its recognized role in buffering acute changes in blood pressure.

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KEY WORDS • mental arousal • baroreceptor reflex • blood pressure • heart rate • sleep •

ALTHOUGH the baroreceptor reflexes modify acute changes in heart rate and in blood pressure, their role in circulatory control throughout the day is not well understood. The reflexes become less sensitive during physical exercise1,2 and possibly also with mental stimulation,3 but during sleep the activity of the reflex is less clear. It was reported to be increased in sensitivity in some subjects4 but in later studies this was not confirmed.5 Others have suggested that there is a circadian rhythm in the sensitivity of the baroreceptor reflex, although this was not associated with changes in blood pressure.6

To clarify the role of the baroreceptor reflex in the control of blood pressure throughout the day, we have measured its control of heart rate during sleep and at varying levels of mental arousal during the day.

Materials and Methods

Thirteen subjects (eight men and five women) gave their consent to take part in a study of direct ambulatory blood pressure measurement over a period of 24 hours by methods previously described.7 All regarded themselves as being in good health and were being investigated for possible hypertension. Only six were subsequently classified as mildly hypertensive, and the remainder were thought to be normotensive.

Blood pressure was measured directly from a cannula in the brachial artery and recorded on magnetic tape. The sensitivity of the baroreceptor reflex was determined by measuring the slope of the regression line between pulse interval (R-R interval) and the rise in systolic pressure following the intravenous injection of 80 μg of phenylephrine.4 Each estimate of baroreflex sensitivity was based on the mean of at least three satisfactory measurements. Injections that produced a correlation coefficient of less than 0.8 were discarded.

After 1 night in the laboratory, to allow the patient to become accustomed to the environment, the arterial and venous cannulas were inserted. After a rest period of 1 hour, the first estimate of baroreflex sensitivity was made and a note was taken of the concurrent blood pressure and heart rate. Thereafter, the subjects were free to move around the hospital but did not take part in any specific work or physical activity; they spent most of their time reading or watching television.

Between 2200 and 2300 hours and after having electroencephalographic (EEG) electrodes applied to the scalp, the subjects returned to the laboratory and slept for a second night. During the night, the EEG was recorded from a frontal and an occipital channel, and when it demonstrated that the subjects were in either Stage 2 or 3 of sleep, injections of phenylephrine were made to test baroreflex sensitivity; the blood pressure and heart rate were noted at that time.

Subjects awoke spontaneously and they were then asked to remain in a drowsy state with eyes closed for a period of half an hour. They were then given a newspaper to read for a similar period. Finally, they were given mental arithmetic tests for a further half an hour.
The subjects remained in the supine position throughout each of these periods.

The 24-hour blood pressure recording and heart rate data were analyzed by computer. The data were then presented as the means and standard deviation of the mean for the hours in the day when the subjects were awake and separately for those when they were asleep. The recording from one subject could not be analyzed because of damping of the arterial pressure wave. However, the blood pressure record at the time of the phenylephrine injections was satisfactory.

Student's t test for paired samples was used to determine difference between periods, and the means and standard errors of the mean are given for each period.

Results

The average waking blood pressure taken from the 24-hour tape was 151.5 ± 6.1 mm Hg systolic and 94.9 ± 4.2 mm Hg diastolic, with a heart rate of 83.3 ± 15.1 bpm. By night, the values were 126.7 ± 6.7 mm Hg systolic, and 75.4 ± 3.6 mm Hg diastolic, with a heart rate of 66.3 ± 14.7 bpm. Blood pressure variability, which has been expressed as the standard deviation of the systolic blood pressure readings, decreased from 16.1 ± 0.7 to 13.2 ± 0.9 mm Hg (p < 0.05) by night.

The blood pressure and heart rate measurements made at the time when the baroreceptor reflex sensitivity was measured showed a fall of 20.1 mm Hg systolic and 6.3 mm Hg diastolic from the baseline resting state during sleep. Heart rate fell by 17.6 bpm. The sensitivity of the baroreflex increased from a control value of 13.9 ± 2.5 to 17.3 ± 2.4 msec/mm Hg with sleep (p < 0.02, fig. 1). The reflex sensitivity returned to the baseline awake value when the subjects were in a drowsy state and were reading, but decreased further during mental arithmetic to 10.0 ± 2.7 msec/mm Hg at the same time that the blood pressure rose to approximately 14.8 mm Hg above the daytime value (fig. 1). The baroreflex sensitivity during mental arithmetic was significantly lower than the values during sleep (p < 0.001), reading (p < 0.01), and the baseline level (p < 0.01).

**Figure 1.** Changes in blood pressure, heart rate, and the sensitivity of the baroreceptor reflex during sleep and varying levels of mental arousal. Values are means ± SEM.
Discussion

This study shows that the fall in blood pressure with sleep is accompanied by an increase in baroreflex sensitivity, and then with increasing levels of mental arousal the rise in blood pressure and heart rate are accompanied by a reduction in the sensitivity of this reflex. The results with sleep confirm the findings of Smyth et al., although they differ from the results also obtained in this laboratory by Bristow et al., who, on the average, found that sleep induced no change in reflex sensitivity but who did find the highest values in the 24 hours during rapid-eye-movement sleep. Not only are the present results based on serial observations in the same subject, but we were fortunate in that the initial baseline baroreceptor sensitivity was considerably higher in the present study (17 msec/mm Hg) than in the earlier ones (6 msec/mm Hg), and it was therefore probably capable of greater variability. Hence, statistically significant results were obtained.

Afferent nerve traffic from the baroreceptors relays to the medulla, pons, and hypothalamus. At these sites, the activity of the baroreceptor reflex can be modified by input from higher centers. During the waking day, the baroreflex normally operates under inhibition from higher centers working through these sites of interaction. With sleep, the reflex appears to be released from central inhibition, and it becomes more sensitive. This plays a part in reducing blood pressure and also in its variability with sleep. Our findings are consistent with experimental work that has demonstrated inhibition of the baroreceptor reflex when the defense reaction is elicited. There appears to be a graded response of the heart rate to blood pressure as subjects pass from sleep through the various stages of mental arousal, in a manner similar to that shown in the conscious cat and baboon with various stressful procedures.

It seems probable that baroreflex sensitivity determines the level of blood pressure and heart rate at any given state rather than vice versa. Smyth et al. have shown that restoration of the blood pressure during sleep to the daytime level did not affect the level of sensitivity of the reflex. Likewise, Eckberg artificially altered the level of the blood pressure and heart rate in normal subjects by use of continued neck suction to the carotid baroreceptors, which altered the baseline blood pressure before an additional brief stimulus was applied to measure baroreflex sensitivity. He found that under these conditions the slope of the baroreflex sensitivity curve remained unchanged even though the test was undertaken at different starting blood pressures and heart rates.

Our results suggest that some part of the fall in blood pressure and heart rate with sleep is achieved by an increase in sensitivity of the baroreflex. Likewise, the rise in pressure with mental arousal is associated with the reduction in the sensitivity of the reflex. Thus, in addition to their role in modifying or buffering acute changes in pressure, the baroreceptor reflexes appear to be involved in the longer term regulation of blood pressure throughout the day and night.

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