RESPONSES OF THE CARDIOVASCULAR SYSTEM OF WAKING CATS TO NOCICEPTIVE STIMULATION OF VARIED INTENSITY

A. A. Zaitsev, A. V. Dmitriev,
Yu. D. Ignatov, V. A. Tsyrlin,
and B. G. Bershadskii

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A state of emotional stress in animals, whether arising in the course of a natural conflict situation or during stimulation of "emotiogenic" brain zones, is accompanied by elevation of the arterial blood pressure (BP) and by tachycardia, in the formation of which an important role is played by central modulation of baroreceptor reflexes [6-8]. Pressor responses, combined with weakening of baroreflexes, have also been observed during stress produced by nociceptive stimulation [2, 11]. However, these data were obtained on anesthetized animals in acute experiments. At the same time, it has been shown that acute experimental conditions [4] and general anesthetics [7, 9], significantly modify homeostatic mechanisms of the cardiovascular system.

The object of the present investigation was accordingly to study changes in BP and in the cardiac frequency (CF) during nociceptive stimulation of the dental pulp in chronic experiments on cats and also to examine particular features of baroreflex function in emotional stress owing its origin to pain.

EXPERIMENTAL METHOD

Forty experiments were carried out on 16 waking cats. As a preliminary step, under pentobarbital anesthesia indwelling catheters were introduced into the aorta and jugular vein [5] and a stimulating electrode was inserted into the pulp of the upper canine tooth [3]. BP was recorded by means of an electromanometer and the momentary values of the intersystolic interval (ISI) were measured by a cardiotachometer and recorded on an N-115 oscillograph. The magnitude of the cardiochronotropic component of the baroreflex was assessed during artificial elevation of BP with phenylephrine (25-35 μg/kg, intravenously), by calculation of the coefficient of linear regression (CLR) [12]. The dental pulp was stimulated with an intensity of between one and 30 thresholds. The intensity of stimulation (usually 0.1-0.2 mA, 1.5 msec, 5-10 stimuli/sec), evoking a mouth-opening reflex and licking in cats [3], was taken as one threshold.

The data were processed by multiple correlation analysis [1]. The significance of differences was assessed by a one-sided Student's t-test.

EXPERIMENTAL RESULTS

Stimulation of the dental pulp with an intensity of one threshold in all animals was not accompanied by changes in BP or ISI. With an increase in the intensity of stimulation the dynamics of the cardiovascular responses which developed varied in different cats. Depending on the intensity and dynamics of the response of BP to nociceptive stimulation, all the animals were divided into two groups (Table 1). In most cats (group 1) stimulation of the dental pulp with an intensity of 2-4 thresholds was accompanied by a significant increase in BP and by shortening of ISI. With a further increase in the strength of stimulation these re-

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TABLE 1. BP, ISI, and CLR for Stimulation of Dental Pulp in Waking Cats (M ± m)

Intensity of stimulation, thresholds	Group 1 (12 animals, 29 experiments)			Group 2 (4 animals, 11 experiments)		
	BP, mm Hg	ISI, msec	CLR, msec/mm Hg	BP, mm Hg	ISI, msec	CLR, msec/mm Hg
Initial value	90±3	353±11	16,0±3,3	87±3	421±11	11,9±2,4
1	93±3	341±12	17,4±2,9	96±4	394±14	25,1±2,6*
2—4	99±3*	321±10*	15,2±3,5	91±5	379±16	38,2±3,9*
8	107±4*	282±14*	11,8±2,1	97±4	316±9*	24,3±2,3*
12	140±9*	240±14*	6,2±1,2*	97±3*	316±14*	10,1±1,7
20	187±14*	226±15*	0	104±6*	307±11*	6,5±1,9
30	—	—	—	119±7*	290±14*	0

*Significant changes in parameter ($P < 0.05$) compared with initial value.

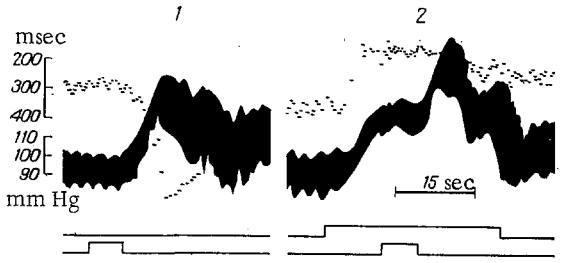

Fig. 1. Changes in cardiochronotropic component of baroreflex to stimulation of dental pulp in waking cat. From top to bottom: ISI, BP, markers of stimulation of dental pulp and of injection of phenylephrine; 1) testing of baroreflex in initial state, 2) during stimulation of dental pulp with an intensity of 20 thresholds.

sponses increased progressively; the tachycardia reached its highest values (210-250 beats/min) during stimulation of the dental pulp with an intensity of 8-12 thresholds.

In the cats of group 2, in which the initial heart rate was a little lower, a much stronger intensity of stimulation of the dental pulp was needed to produce significant changes in the parameters recorded — up to 8-12 thresholds. A subsequent increase in the strength of stimulation led to only a small increase in responses of BP and ISI. Moreover, even in the case of very strong (20-30 thresholds) nociceptive stimulation the changes in BP and ISI in the cats of group 2 did not reach the values observed in the animals of group 1 even after stimulation with an intensity of 8-12 thresholds.

Testing of the baroreflex revealed definite differences in the functioning of the homeostatic mechanism in the animals of different groups (Table 1). In cats of group 1 CLR, reflecting the magnitude of the cardiochronotropic component of the baroreceptor reflex, decreased progressively with an increase in the intensity of nociceptive stimulation. Complete suppression of the reflex bradycardia induced by artificial elevation of BP was observed against the background of stimulation of the dental pulp with an intensity of 20 thresholds (Fig. 1).

Meanwhile, in the animals of group 2 stimulation of the dental pulp with an intensity of 2-8 thresholds (which, as already mentioned, was not accompanied by any change in BP) led to marked strengthening of the baroreflex. Only with a further increase in the intensity of stimulation of the dental pulp was there a tendency toward some weakening of the baroreceptor reflex, but it was completely suppressed only during very strong (about 30 thresholds) nociceptive stimulation.

The experiments showed that the general pressor direction of the hemodynamic changes in waking cats during nociceptive stimulation is accompanied by suppression of the baroreflex. Meanwhile, strengthening of the baroreflex observed in some experiments in the absence of pressor changes in BP is in agreement with existing views [8] on the important role of suppression of the homeostatic mechanism in the formation of hypertensive responses during emotional stress.

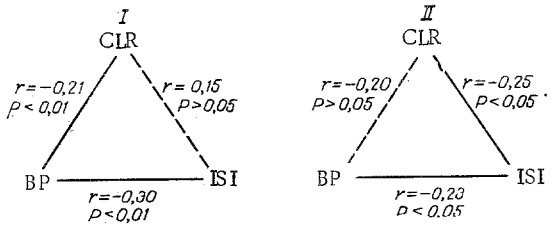

Fig. 2. Correlation analysis of dependence of responses of BP and ISI to stimulation of the dental pulp in waking cats on the magnitude of the baroreflex. I) Animals of group 1, II) of group 2. r) Partial correlation coefficient, P) significance of difference of coefficient of correlation from zero. Correlations indicated by continuous lines are significant, by broken lines not significant.

The differences discovered in the dynamics of responses of BP, ISI, and the baroreflex depending on the intensity of stimulation of the dental pulp enabled two groups of animals differing in the type of vegetative response to pain to be distinguished. Considering that the regulation of BP and pulse rate can be subdivided into pressure-dependent and pressure-independent [10], an attempt was made to analyze these mechanisms in the animals of the two groups by the method of multiple linear correlation [1]. Paired coefficients of correlation were calculated between values of the baroreflex and BP, ISI and BP, and the baroreflex and ISI during a successive increase in the intensity of nociceptive stimulation. On the basis of the paired coefficients of correlation, partial coefficients of correlation were calculated (Fig. 2) to reflect the strength of linear correlation between two parameters with exclusion of the effect of the third. After exclusion of the effect of the baroreflex it was found that the presence of negative pressure-independent correlation between BP and ISI was common to the cats of both groups. However, by the method used significant differences also were discovered in relations between the baroreflex and parameters of the systemic hemodynamics in the cats of groups 1 and 2. For instance, in the animals of group 1 significant correlation was found between the baroreflex and BP and was independent of the value of ISI, whereas in the cats of group 2 significant correlation independent of the value of BP was found between the baroreflex and ISI.

The results of analysis of the experimental data by the method of multiple linear correlation thus confirmed the validity of the distinction of two types of vegetative responses of the waking animals to nociceptive stimulation.

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