

EFFECT OF HIGH-FREQUENCY ARTIFICIAL RESPIRATION ON THE CARDIAC
RHYTHM IN CATS

V. M. Pokrovskii, V. G. Abushkevich,
A. I. Dashkovskii, S. V. Shapiro,
and I. A. Dyak

UDC 612.172.2.014.46:615.816.2].08

KEY WORDS: cardiac rhythm formation; high-frequency artificial respiration

In man, breathing at a rate which exceeds the cardiac rhythm leads to the onset of a phenomenon of synchronization of the cardiac contractions and breathing, when each cardiac contraction corresponds to one respiratory movement and, within certain limits, follows changes in the respiration rate [2]. This strict agreement of the frequencies cannot be explained from the standpoint of myogenic automaticity, and it is evidence that a mechanism of central formation of the cardiac rhythm may exist [1]. A similar phenomenon has been found in a thermoregulatory and conditioned-reflex tachypnea in dogs [3], and it has provided an explanation of the central genesis of the phenomenon and has established the effector role of the vagus nerves in its realization. The experimental models described above were created to discover the triggering influences of the CNS on the heart and did not allow the afferent component of the rhythm binding phenomenon to be studied.

The aim of this investigation was to study the role of afferents of the thoracic organs in the reflex mechanism of the phenomenon described above.

EXPERIMENTAL METHOD

Experiments were carried out on 42 cats weighing 3.4 ± 0.2 kg, lightly anesthetized with chloralose (50 mg/kg) and pentobarbital (10 mg/kg). Tracheotomy was performed on the animals and the vagus nerves dissected in the neck. The ECG, pneumogram, electromyogram of the diaphragm, and pressure in the trachea were recorded. High-frequency artificial hyperventilation of the lungs was carried out by means of a mechanical ventilator giving active inspiration and expiration, which were controlled separately by pressure. Pressure drops and respiratory volumes were varied over a wide range, thus distinguishing this method of artificial ventilation essentially from the high-frequency artificial ventilation currently used in clinical practice. The respiration rate and phase relations of the respiratory cycle also were varied within wide limits and were assigned by an electronic circuit programed by "Iskra-1256" computer.

EXPERIMENTAL RESULTS

The initial heart rate of the cats was 183.4 ± 5.9 beats/min and their respiration rate 14.0 ± 0.8 cycles/min. Bursts of spikes corresponding in amplitude to inspiration were observed on the electromyogram.

During artificial hyperventilation of the lungs at a frequency exceeding the initial heart rate by 1.7-20.4%, and with a pressure in the trachea of not less than 36.4 ± 1.8 mm Hg, the cardiac rhythm of the animals was modified: the heart rate became synchronized with the frequency of artificial respiration. This synchronization took the form that for every respiratory cycle there was one cardiac contraction. A change in the respiration rate led to a synchronous change in heart rate. In other words, by means of artificial high-frequency hyperventilation a rhythm assigned by the experimenter was "bound" on the heart. This rhythm "binding" was possible within the frequency range from 186.6 ± 7.3 to 220.8 ± 8.9 beats/min. The width of the range of control of the rhythm was 34.2 heart beats. The beginning of inspiration preceded the R wave of the ECG at the minimal frequency of synchronization by 220 ± 10 msec, and by 130 ± 15 msec at the peak frequency.

Department of Normal Physiology, Kuban Medical Institute, Krasnodar. (Presented by Academician of the Academy of Medical Sciences of the USSR, B. I. Tkachenko.) Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 108, No. 7, pp. 3-4, July, 1989. Original article submitted July 28, 1988.

The phenomenon occurred 2-3 min after the beginning of high-frequency artificial ventilation of the lungs, and it was clearly achieved under hyperventilation conditions, when the frequency of respiration was extremely rapid and its depth considerable. The duration of observation of this phenomenon was 20-30 min (the period of observation was then discontinued). After termination of artificial respiration the heart rate quickly returned to its original level, and apnea was recorded on the pneumogram, followed by restoration of natural breathing.

During bilateral cooling of the vagus nerves to 10°C, while high-frequency hyperventilation continued, the phenomenon disappeared (under these circumstances the heart rate was reduced on average by 5% relative to the frequency during the phenomenon), and it was resumed on warming of the nerves.

Injection of atropine in a dose of 0.1 mg/kg during the phenomenon abolished it. Under these circumstances the heart rate fell by 4.1% relative to the heart rate during the phenomenon.

In the absence of high-frequency ventilation, cooling of the vagus nerves to 10°C caused an increase in heart rate by 3%. Injection of atropine in these doses was followed by quickening of the heart rate by 3.5%. The paradoxical responses of the heart to cooling of the vagus nerves and to injection of atropine during the phenomenon, expressed as a decrease in heart rate, revealed a special rhythm-forming influence on the vagus nerves, which existed before and disappeared after these procedures were applied.

Synchronization was not the result of any peripheral mechanism: all attempts to induce coincidence of the rhythms by approximating the respiration rate to the heart rate while the vagus nerves were cooled, or during injection of atropine, and also under deep anesthesia, were unsuccessful.

During high-frequency hyperventilation, the electrical activity of the diaphragm lost its rhythmic, bursting character, and it was converted into a random series of oscillations, with recovery of the original pattern when natural breathing was resumed. This indicates that the phenomenon developed when the firing pattern of the respiratory center, in the form of volleys, was depressed, evidence of the secondary role of the receptor apparatus of the lungs in the afferent genesis of the phenomenon.

The creation of pneumothorax during the phenomenon caused it to disappear, if high-frequency ventilation was continued.

The experimental model of high-frequency hyperventilation enables the cardiac rhythm in cats to be controlled at the experimenter's will over a comparatively wide range of frequencies; this provides great opportunities for the physiological analysis of the synchronization phenomenon and confirms the advantage of this model over the similar phenomenon that is observed only briefly during voluntary quickening of respiration in man and over manifestations of the phenomenon during thermoregulatory tachypnea in dogs, which is not controlled by an assigned program.

In previous publications, it was suggested that the cause of the phenomenon of synchronization of respiratory and cardiac rhythms is the irradiation of excitation from the respiratory to the vasomotor center in the medulla [2, 3]. Manifestation of the phenomenon after disappearance of the volley type of firing pattern of the diaphragm makes such a mechanism unlikely in the present experiments.

It can be tentatively suggested that the site of origin of the afferent impulses during high-frequency hyperventilation, inducing the phenomenon of control of the cardiac rhythm, is primarily the receptors of the vascular reflexogenic zones [4], the intramural pressure in which varied synchronously with high-frequency hyperventilation. Support for the baroreceptor afferents also is given by the fact that the phenomenon occurred in the presence of comparatively high pressure drops and was abolished by pneumothorax. The role of the lung mechanoreceptors and of receptors of the respiratory muscles in the formation of the afferent volley cannot, however, be finally rejected, for the character of stretching of the lung tissue is sharply changed in pneumothorax, and a role of receptors of the respiratory muscles is virtually eliminated.

LITERATURE CITED

1. V. M. Pokrovskii, Nervous Regulation of Cardiac Activity [in Russian], Krasnodar (1981), pp. 3-14.
2. V. M. Pokrovskii, V. G. Abushkevich, A. I. Dashkovskii, and S. V. Shapiro, Dokl. Akad. Nauk SSSR, 283, No. 3, 738 (1985).

3. V. M. Pokrovskii, V. G. Abushkevich, A. I. Dashkovskii, et al., Dokl. Akad. Nauk SSSR, 287, No. 2, 479 (1986).
4. M. N. Levy, P. J. Martin, and S. L. Stuesse, Annu. Rev. Physiol., 43, 443 (1981).

EFFECT OF PEPTIDE FACTORS OF THE RIGHT AND LEFT HEMISPHERES ON AMPLITUDE
AND DURATION OF SOMATOSENSORY, VISUAL, AND PARIETAL EVOKED POTENTIALS
IN RATS

V. P. Dobrynin, A. N. Sovetov,
E. N. Pogozheva, V. K. Lutsenko,
and M. K. Ter-Minasyan

UDC 616.831-073.7-092.9

KEY WORDS: interhemispheric integration; peptide regulation; compensatory process

The important role of mechanisms of lateral specialization of the cerebral hemispheres and their mutually complementary functions in activity of the intact CNS is well recognized. This applies to questions of maturation of the brain [11, 13], cognitive activity [1, 14], emotions and perception [1, 7], mental functions [7], etc. It has also been shown that reorganization of the damaged brain is largely based on the same principles of paired function [2, 4], and that some mental disorders may be the result of a disturbance of normal interhemispheric relations. Meanwhile functional asymmetries discovered by clinical, behavioral, and electrophysiological methods, are basically neurochemical in nature [9, 10, 12]. For the correction of states induced by imbalance of the activity of the right and left halves of the brain, it may therefore be the most natural course to use endogeneous biological regulators and, in particular, neuropeptides.

The aim of this investigation was to study the characteristics of peptide regulation of the functions of the right and left cerebral hemispheres.

EXPERIMENTAL METHOD

Experiments were carried out on 30 rats and eight cats. Peptide extracts were obtained from the right and left halves of the rats' brain and their action tested by recording changes in parameters of evoked potentials (EP) in cats. The method of obtaining peptide extracts was described previously [5, 6].

The cats were anesthetized with ether or pentobarbital (30 mg/kg), the cranial cavity widely opened, the dura removed, and EP recorded in the somatosensory, visual, and parietal regions of the cortex in the left hemisphere by Ag-electrodes 0.2 mm in diameter. Before the recordings the animals were artificially ventilated after injections of relaxants. The radial nerve was stimulated by pulses 0.5 msec in duration and with an amplitude of 3-6 V (threshold value 2-2.5 V), and visual stimulation was applied in the form of flashes with an energy of 0.3 J and a duration of 0.1 msec (monocular application). Transcallosal stimuli (TCS) had a duration of 0.1-0.2 msec and an amplitude of 10-20 V. EP were led from a UBP2-03 biopotentials amplifier to a "Disa Indicator" oscilloscope, from the screen of which they were photographed by FOR-2 camera. The EP were processed collectively: 30 control and 30 after application of extracts; superposition of 5-8 responses also was used. Before the electrophysiological experiment the cats were tested by the food-getting method and animals with a dominant right forelimb were selected. The results were subjected to statistical analysis by estimation of the probability of noncoincidence of the two compared curves [3] and by Student's *t* test. To confirm the peptide nature of the brain extracts, control experiments were carried out with inactivation by pronase (Table 1).

Research Institute of General Pathology and Pathological Physiology, Academy of Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR, G. N. Kryzhanovskii.) Translated from *Byulleten' Éksperimental'noi Biologii i Meditsiny*, Vol. 108, No. 7, pp. 5-7, July, 1989. Original article submitted November 25, 1988.