NERVOUS REGULATION OF THE ACTIVITY OF THE HUMAN HEART

(UDC 612.178)

B. M. Simernitskii

N. N. Burdenko Institute of Neurosurgery, AMN SSSR, Moscow

(Presented by Active Member AMN SSSR, B. G. Egorov)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 61, No. 1, pp. 21-24, January, 1966
Original article submitted June 23, 1964

There are relatively few references in the Soviet and Western literature on the question of the nervous regulation of human cardiac activity. The character of the reactions of the human and animal heart to various stimuli has been studied in investigations of the autonomic components of unconditioned reflexes – the orienting, defensive, food, and other reflexes [2, 4, 5, 7, 9, 10, 13, 14] – and also during the formation of conditioned reflexes on their basis [1, 6, 8, 11]. It has been concluded from the results thus obtained that in human ontogenesis an ever-increasing corticalization of the chronotropic influences takes place, whereas the conditioned-reflex dromotropic, bathmotropic, and inotropic influences are inhibited. Hence, the reaction of the heart to all possible forms of stimulation is manifested primarily by a change in the heart rate.

The question of the nervous regulation of the human heart in relation to its activity is one of particular interest. In order to study it, the character of the cardiac reactions arising in response to indifferent exteroceptive stimuli (flashes of light) and to tests requiring the performance of physical and mental exertion was investigated in healthy persons.

EXPERIMENTAL METHOD

The investigation was conducted on 10 healthy subjects (6 men and 4 women) aged from 23 to 32 years and on 40 patients with cerebral tumors, aged 30-42 years. The electrocardiogram (ECG) was recorded in three standard leads on a 15-channel Alvar electroencephalograph, along with the electroencephalogram (EEG), the psychogalvanic reaction, and the respiration. In the present paper only the results of analysis of the ECG will be discussed.

After extinction of the orienting reflex to the situation (after the subject had been in the chamber for 7-10 min) the background character of the cardiac activity was recorded for 2-3 min. The ECG was then recorded during three stages of the investigations.

The first stage consisted of the presentation of an indifferent stimulus – flashes of a frequency of 16 per sec for 10-15 sec (altogether 5 presentations at intervals of 10-15 sec). In the second stage the subject pressed a knob with his finger repeatedly as quickly as possible after the first single flash, and after the second flash the work stopped. The interval between the 1st and 2nd flashes was 10-15 sec. This test was performed five times at intervals of 10-15 sec. The ECG was then recorded for 2-3 min. In the third stage a test involving mental work was used. At the 1st single flash the subject began to count as fast as possible in his head (1, 2, 3, 4 . . . , and so on) and he stopped counting at the 2nd flash. The duration of the work, the number of presentations, and the intervals between them were the same as in the previous stage of the investigation. The ECG was then recorded for 2-3 min.

The variations in the duration of the intersystolic periods reflect the character of the cardiac rhythm much more fully than the mean number of heart beats in an arbitrary period of time [12]. By using the time interval between two consecutive heart beats as index for calculating the frequency of the cardiac contractions, with statistical analysis of the results, information was obtained which reliably reflected the character of the reactions of the heart.

For this purpose cuts of the background ECG tracing (10 sec) were taken and throughout this time interval the distances between the R waves, i.e., the time between consecutive contractions of the ventricles, were measured. A graph was then plotted, with the time between two consecutive cardiac contractions plotted along the axis of or-

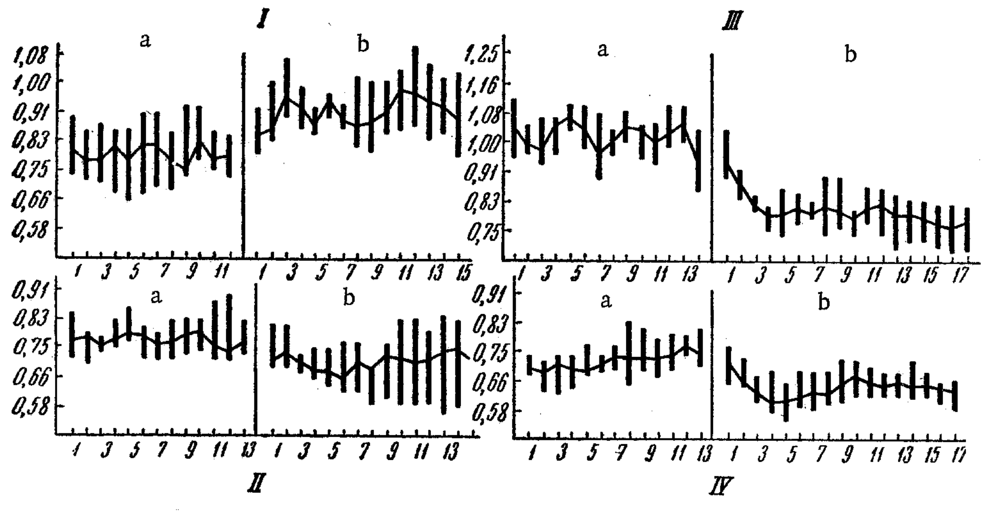

Fig. 1. Reaction to flashes of light. I) (Subject T): a) background; b) flashes (16 per sec), slowing of heart rate; II) (subject K): a) background; b) flashes (16 per sec, quickening of heart rate; III) (subject M): a) background; b) physical exertion; IV) (subject K): a) background; b) mental exertion. Other explanation given in text.

dinates and the number of cardiac contractions in the investigated cut of the ECG along the axis of abscissas. Since in the subsequent stages of the investigation the test was performed no fewer than 5 times, in the background tracing 5 cuts of the ECG, each of 10 sec in duration, and with the same intervals as during presentation of the tests (10-15 sec), were analyzed. When the indifferent stimulus was used, and also during muscular and mental exertion, the ECG was analyzed throughout the time of action of the stimulus (10-15 sec). In the intervals between the tests the ECG was analyzed in a similar manner to the background tracing.

The results obtained after five applications of the stimulus in each stage of the investigation were plotted on the graph, and from it the mean curve of the heart rate in each stage of the investigation was deduced. The scatter of the averaged points was reflected as columns on the curves of the graph. In this way the curve showed the variations in the heart rate throughout the stage of the investigation and the columns showed the variations in the cardiac rhythm at each point of the averaged curve on the graph.

EXPERIMENTAL RESULTS

The background averaged curve of the cardiac rhythm for all the subjects was characterized by continuous variation of the difference between the intersystolic periods within the limits of 0.05 and 1 sec. Meanwhile, the amplitude of scatter of the averaged points varied within wide limits.

The reaction to flashes in one group of subjects (6 persons) took the form of a slowing of the heart rate with a reduction of the amplitude of the scatter of the averaged points, while in a second group (4 persons), on the other hand, the heart rate was increased, and so also was the amplitude of scatter of the averaged points (Fig. 1, I and II).

In the second stage of the investigation the reaction of all subjects to physical exertion was accompanied by an increase in the heart rate and by a marked decrease in the amplitude of scatter of the averaged points (see Fig. 1, III). Stopping the test led to a slowing of the heart rate and to an increase in the amplitude of scatter of the averaged points.

During mental exertion all the subjects showed an increase in the heart rate with a decrease in the amplitude of scatter of the averaged points (see Fig. 1, IV), although in most cases the changes in these indices were less marked than during physical exertion. Stopping the tests as a rule caused a slowing of the heart rate with an increase in the amplitude of scatter of the average points.

At no stage of the investigation were changes observed in the ECG waves.

The changes in the cardiac rhythm throughout the stages of the investigation were not accompanied by any other changes in the ECG, demonstrating the considerable mobility of the chronotropic function of the cardiac ac-

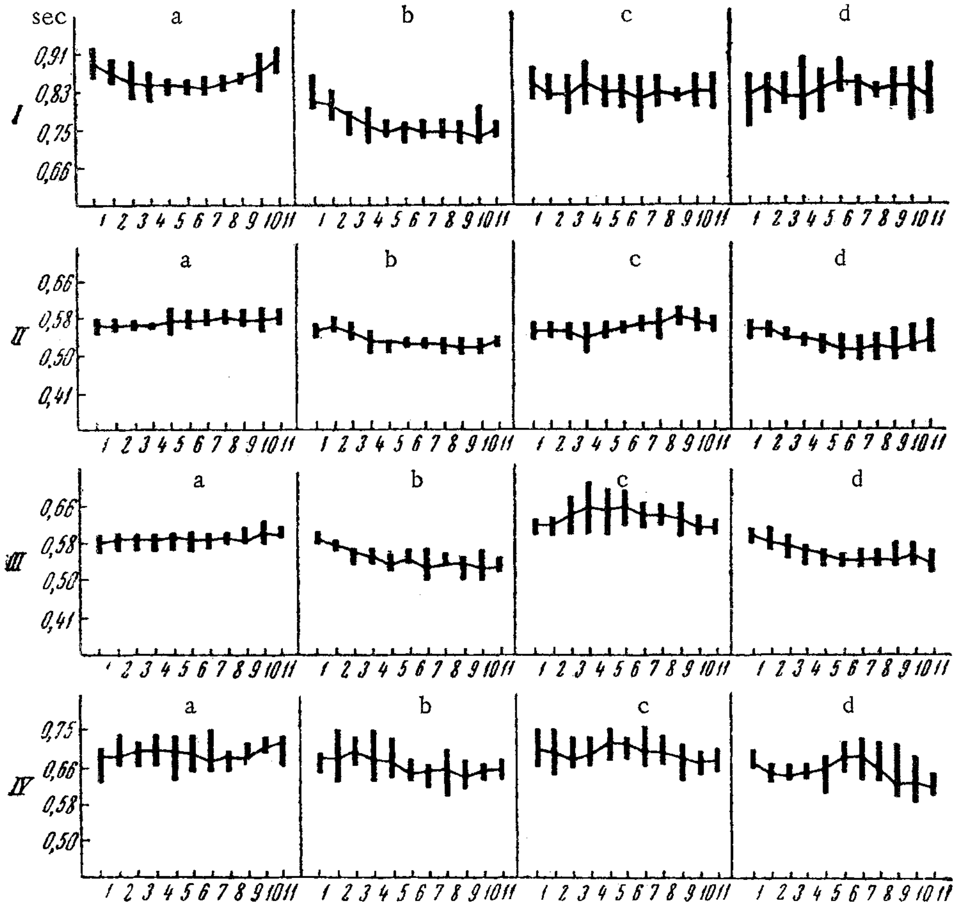

Fig. 2. I) Tumor of the right frontal lobe (patient D., aged 42 years); II) tumor of the postfrontal-parietal region (patient Ya., aged 35 years); III) pituitary tumor, basal arachnoiditis (patient B., aged 30 years); IV) neuroma of the left auditory nerve (patient V., aged 33 years); a) initial heart rate; b) physical exertion; c) test interrupted; d) mental exertion. Other explanation given in text.

tivity. The reports in the literature concerning the manifestation of chronotropic influences during application of an indifferent stimulus are contradictory. During orienting reactions some authors observed an increase in the heart rate, while others, on the contrary, reported a slowing of the heart. The conflicting nature of the experimental data and the significance of the discrepancy have not been explained [3]. Our results obtained during the investigation of healthy subjects in the first stage of the experiment showed that either type of reaction may be observed, probably because of differences in the initial functional state of the central nervous system.

The type of higher nervous activity may also have a definite bearing on the character of the cardiac reactions to an indifferent stimulus. At the same time, regardless of how the subject reacts to an indifferent stimulus – by tachycardia or by bradycardia – the reaction of the cardiac activity to an instruction associated with the performance of mental and physical work always took the form of tachycardia alone.

Investigation of the cardiac reactions of patients with cerebral tumors provides material for the study of the part played by different brain structures in regulating the autonomic functions in the intact organism. Four patients were studied, with extracerebral tumors influencing the right frontal lobe (arachnoidendothelioma of the pole of the right frontal lobe), the superior portion of the central region of the right hemisphere (arachnoidendothelioma of the postfrontal-parietal region), the diencephalon (tumor of the pituitary with basal arachnoiditis), and the brain stem at the level of the left cerebello-pontine angle (neuroma of the left auditory nerve). In all cases the intracranial pressure was increased and the optic discs were choked; all the patients were women. The localization and structure of the tumors were verified at operation and histologically.

The results of these observations of the cardiac reactions in patients with brain lesions clearly demonstrated a disturbance of the regulation of the autonomic functions as a result of the action of the extracerebral pathological process on different parts of the cerebral cortex. For example, in the case of the right frontal lobe lesion there was no change in the heart rate during mental work, while during physical work the reaction of the cardiac activity remained intact (Fig. 2, I). In the case of a tumor in the right central region, no marked reaction to physical work was observed (Fig. 2, II). The action of the space-occupying lesion on the diencephalon and the brain stem at the level of the pons modified the background pattern of the cardiac activity towards the side of tachycardia, but in these circumstances the cortical regulation of the cardiac activity investigated by the author's method remained intact, for the verbal instructions associated with the performance of physical and mental work caused a further increase in the heart rate (Fig. 2, III and IV). All these results are evidence of the unequal participation of the various structures of the brain in the nervous regulation of the heart.

Hence the method of investigation described above can be used to study the relationship between the character of the nervous regulation of the heart, on the one hand, and the state of the central nervous system and the nature of the activity performed by the subject, on the other.

SUMMARY

An original method for statistical processing of the rate of cardiac contractions on the ECG showed a relationship of the nervous regulation of the heart to the character of man's activity in normal health and in the case of affection of various brain regions.

LITERATURE CITED

1. L. Ya. Balonov, Proceedings of a Conference on Problems in Cortico-Visceral Physiology and Pathology [in Russian], Leningrad (1953), p. 16.
2. L. Ya. Balonov and P. I. Kurganovskii, Abstracts of Proceedings of a Scientific Meeting on Problems in Human Age Physiology [in Russian], Leningrad (1954), p. 3.
3. O. S. Vonogradova, The Orienting Reflex and Its Neurophysiological Mechanisms [in Russian], Moscow (1961).
4. S. I. Enikeeva, Byull. Éksper. Biol., No. 7, 15 (1963).
5. A. G. Ivanov-Smolenskii, Zh. Vyssh. Nerv. Deyat., 1, No. 1, 15 (1951).
6. L. I. Kotlyarevskii, Fiziol. Zh. SSSR, 20, No. 2, 228 (1936).
7. N. I. Krasnogorskii, Research into the Study of the Higher Nervous Activity of Man and Animals [in Russian], Vol. 1, Moscow (1954).
8. P. I. Kurganovskii and L. Ya. Balonov, In book: Proceedings of the 1st Conference on Problems of Age Morphology and Physiology [in Russian], Moscow (1952), p. 82.
9. T. B. Levina, Uchen. Zapiski Moskovsk. Pediatr. Inst. Im. V. I. Lenina, 84, No. 2, 43 (1955).
10. V. V. Petelina, In book: The Orienting Reflex and Orienting and Investigatory Activity [in Russian], Moscow (1958), p. 158.
11. E. G. Petrova, Cortical Influences on the Activity of the Heart Muscle. Thesis of Candidate's Dissertation, Leningrad (1946).
12. M. Ardenne, H. Lingen, and J. Heller, In book: Physiology and Pathology of the Heart [Russian translation], Moscow (1963), p. 252.
13. S. Fleck, J. Gen. Physiol., Vol. 48 (1953), p. 432.
14. J. Robinson et al., Bull. Johns Hopkins Hosp., Vol. 80 (1947), p. 231.