NONTHERMAL ACTION OF MICROWAVES ON CARDIAC RHYTHM

COMMUNICATION I. A STUDY OF THE ACTION OF CONTINUOUS MICROWAVES

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Presented by Active Member AMN SSSR V. V. Parin
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 53, No. 1,
pp. 41 - 44, January, 1962
Original article submitted March 16, 1961

The nonthermal action of microwaves on the heart rate was first found in investigations into the working conditions and health of personnel operating microwave generators. A. A. Orlova [2] showed that the prolonged action of microwaves of nonthermal intensity (less than 10 mw/cm^2) induces bradycardia in a considerable proportion of subjects studied. N. V. Tyagin [4] found that a change in the heart rate in dogs under the influence of microwaves of 5 - 10 m watts/cm^2 was induced by either chronic irradiation or irradiation for 30 minutes. However, although in some dogs the heart rate was slowed, in others it was increased, and in some cases it was alternately speeded and slowed.

Up till now, only very general suggestions have been made concerning the nonthermal action of microwaves. Thus A. A. Orlova and N. V. Tyagin consider that the changes of the heart rate result from reflex action of the microwaves, although they do not exclude the possibility of some direct action of the waves on the nervous conductors or on the autonomous action of the heart and vessels.

To explain the action of the microwaves in slowing the heart, we must note that the effect was produced directly during the irradiation of various parts of the body.

METHOD

The experiments were carried out on 8 male rabbits weighing 3 - 3.5 kg. Each animal was irradiated 12 - 13 times for 20 minutes.

Irradiation was applied from a specially built apparatus (A. S. Presman [3]) by means of a horn radiator supplied from a continuous microwave generator (λ=12.5 cm). For irradiation of the dorsal parts of the body, the anima was placed in a sitting position in a box beneath the 40×40 cm^2 aperture of the horn; the box was lined with plastic which absorbed microwaves. For the irradiation of the ventral parts of the body the animal was placed above the aperture of the horn on a plate of foam polystyrene, which is almost completely transparent to the microwaves used. Dosage was regulated by measuring the power conducted into the horn, taking account of the surface area of the body irradiated. In all the experiments, the intensity was 7 - 12 mw/cm^2. The nonirradiated parts of the body were covered with plates which absorbed microwaves.

The electrocardiogram was recorded from plate electrodes (N. A. Levitina [1]). The first records were made 15 minutes after the animal had been placed beneath or above the horn, and were repeated ten times: they were made 10 minutes before irradiation, for 20 minutes during irradiation, and 10 minutes afterwards. Each record lasted 20 seconds.

Control experiments were made on the same rabbits under precisely similar conditions, but without irradiation. The first set of control experiments was made before the beginning of the irradiation series, and the second after all of the latter had been completed.

RESULTS

The results obtained for the heart rate were treated statistically as follows: a) in all experiments for a given type of irradiation, for each moment of the recording (beginning or irradiation) we calculated the arithmetic mean of the deviation from the mean rate before irradiation; b) from the results of the control experiments, we calculated in the same way the mean arithmetic deviations from the mean heart rate in the first 10 minutes of the experiment; c) for corresponding recording times, we calculated the relative change in the rate, i.e. the difference

between the mean changes of rate in the irradiated and in the control group.

Figures 1 and 2 show graphs of the relative changes in the rate calculated in this way. We may consider as significant relative changes which exceed twice the mean error of the difference between the arithmetic means (on the graphs, the magnitudes of twice the mean error are shown by two-headed arrows).

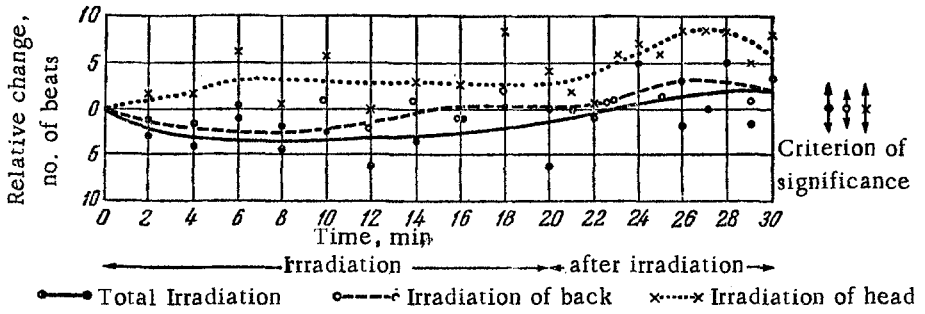

Fig. 1. Relative changes in heart rate in rabbits irradiated on dorsal surface of the body with continuous microwaves of λ = 12.5 cm at nonthermal intensities (7-12 mw/cm^2). Each point represents the mean result of 16 experiments.

As can be seen from Fig. 1, with total dorsal irradiation there was a small reduction in the heart rate, and when the back was irradiated the change in the rhythm was no greater than the random error. During irradiation of the dorsal part of the head, a small increase in the rhythm was noted which increased considerably after irradiation.

In all cases of ventral irradiation (Fig. 2), the heart rate was slowed. With general irradiation it was slowed more and the reduced rate continued afterwards. When the belly was irradiated the change was less well shown, and there was no effect after the irradiation. When the head was treated, a small change was noticed only in the first 10 minutes of irradiation, and subsequently the rate was increased.

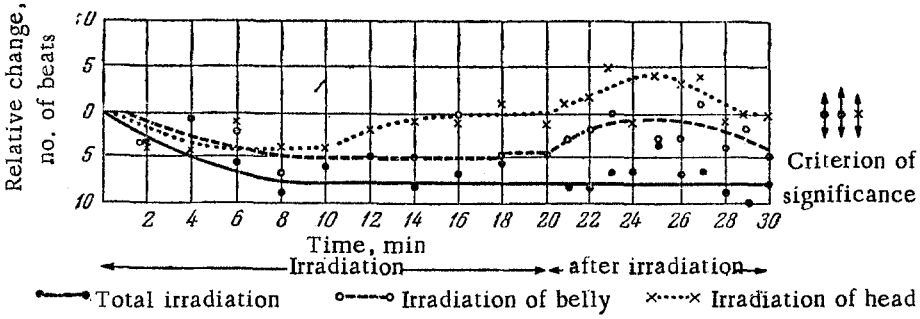

Fig. 2. Relative changes in heart rate of rabbits irradiated on the ventral surface of the body by continuous microwaves of λ=12.5 cm at nonthermal intensities (7-12 mw/cm^2).

We have tried to take into account changes of cardiac rhythm which were no greater than the random changes. For this purpose we treated the experimental results as follows: a) in all the experiments with a given type of irradiation, we calculated the percentage of cases in which the rhythm was slowed or speeded, both during the treatment and subsequently, as compared with the mean value before treatment; b) similar calculations were made for the control experiments; c) we then calculated the difference between the percentages of cases of change in the experimental and control groups; the differences were taken as significant when they exceeded twice the mean error of the difference of the percentages; d) for a quantitative and qualitative description of the effect on the heart rate of irradiating different parts of the body we used the ratio K, which we called the coefficient of the chronotropic effect.

$$K = \frac{100 + m_i}{100 + m_d},$$

where m_i and m_d are the respective significant values of changes in the percentage of cases with rates increased or decreased from the control values (with due account of sign). Insignificant values were recorded as zero.

Evidently, when $K > 1$, a positive chronotropic effect is recorded, and if $K < 1$ the effect is negative, and when $K = 1$ there is no effect.

These results are given as a table, from which it can be seen that in all cases of ventral irradiation, the rate was significantly reduced. With total irradiation, the shift was better shown, both during and after irradiation; when the belly was irradiated, the change was less well shown, and there was almost none subsequently. When the head was irradiated, the slowing was shown still less, and there was none after irradiation.

Change in the Percentage of Cases of Slowing or Speeding of the Sinus Rhythm in Rabbits Irradiated in Different Parts of the Body by Continuous Microwaves of λ = 12.5 cm, power = 7 - 12 mw/cm^2

Part of body irradiated		Total number of measurements	During 20 minutes irradiation			During 10 minutes after irradiation		
			Change in the percentage cases of speeding (m_i)	Change in the percentage cases of slowing (m_d)	Coefficient of chronotropic effect (K)	Change in the percentage cases of speeding (m_i)	Change in the percentage cases of slowing (m_d)	Coefficient of chronotropic effect (K)
Dorsal aspect	Whole dorsal surface	440	0	0	1.0	0	0	1.0
	Back	320	0	0	1.0	-12	+16	0.76
	Head	320	+12	-14	1.3	+18	-17	1.42
Ventral aspect	Whole ventral surface	320	-18	+22	0.67	-18	+22	0.67
	Belly	320	-13	+19	0.73	0	+11	0.91
	Head	320	-15	+12	0.76	0	0	1.0

Note. +) increase in percentage of cases over control value; - decrease.

With general dorsal irradiation there was no significant change in the heart rate. Irradiation of the back caused a decreased rate which was not observed until after the irradiation. Irradiation of the head caused a marked increase in frequency during the irradiation, and a further increase subsequently.

The changes in the rate were reversible. In cases when changes were observed after irradiation, they continued for not more than 30-40 minutes. A comparison of the results of the two series of control experiments, before irradiation and afterwards, showed that the mean random change of the heart rate after 12 - 13 irradiations of each animal did not differ from the mean value before irradiation. Thus, the 12 - 13th irradiation under the conditions described apparently exerted insufficient influence to produce a cumulative chronotropic effect.

From these studies we may conclude that irradiation of animals with continuous microwaves at nonthermal intensitites causes a change in the heart rate both during irradiation, and afterwards. This effect may be considered to result reflex autonomic changes. As evidence we may quote the appearance of a chronotropic effect, its rapid reversibility, and finally the difference in the nature of the effect (whether positive or negative) according to which part of the body was irradiated.

The primary cause of the reflex autonomic reactions was most likely the action of the microwaves on the reflexogenous zones lying in the superficial tissues (receptors of the skin and of the superficial vessels), because the waves are almost completely absorbed in these layers. Evidence for this view is supplied by the increased slowing of the heart rate when greater areas of the ventral surface were irradiated. When irradiation was applied to the dorsal surface of the head, an appreciable proportion of the waves could penetrate into the brain cells. It is possible on this account that there was then an increase in the heart rate.

These considerations must be regarded only as a working hypothesis to be used as a basis for further studies with a view to working out the mechanism of the effect of microwaves on the heart rate and of other effects caused by their nonthermal action.

SUMMARY

Irradiation of various parts of the rabbit body by microwaves of λ=12.5 cm at an intensity below the thermal level (7 - 12 mw/cm^2) influenced the sinus rhythm. This chronotropic effect of the microwaves was observed during the 20-minute period of irradiation, and for 10 minutes immediately after it. Irradiation of the ventral

parts of the body slowed the heart, and irradiation of the dorsal part of the head speeded it. It is suggested that the effect observed was the result of reflex autonomic reactions provoked by the direct action of the microwaves on the superficial reflexogenous zones, and that the effect from irradiation of the head was produced by action on brain cells.

LITERATURE CITED

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4. N. V. Tyagin, Transactions of the Military Medical Academy. Leningrad, Vol. 73 (1957), p. 102.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
