NONTHERMAL ACTION OF MICROWAVES ON THE RHYTHM OF CARDIAC CONTRACTIONS IN ANIMALS

REPORT II. INVESTIGATION OF THE ACTION OF IMPULSE MICROWAVES

A. S. Presman, and N. A. Levitina

From the Central Scientific-Research Institute of Balneology and Physiotherapy, Moscow
(Presented by Active Member of the Akad. Med. Nauk SSSR V. V. Parin)
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In investigations that we performed earlier [1], it was established that irradiation of different parts of the body of a rabbit with continuous microwaves (λ = 12.5 cm) of nonthermal intensity (7-12 milliwatts/cm^2) causes a "chronotropic effect" – a change in the sinus rhythm. The effect is rapidly reversible; it is manifested during the irradiation and for a short time afterward.

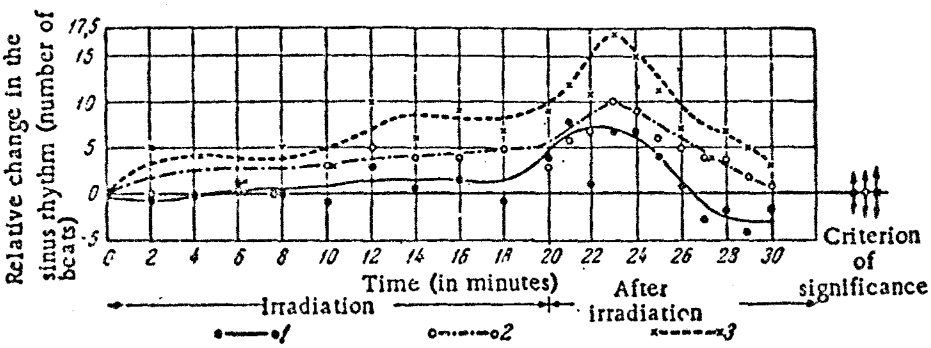

Fig. 1. Relative changes in the cardiac rhythm in rabbits, subsequent to irradiation of the dorsal parts of the body with impulse microwaves (λ = 10 cm, τ = 1 microsecond, F = 700) of nonthermal intensity (P = 3-5 milliwatts/cm^2). Each point represents the mean of 16 trials. 1) Total dorsal irradiation; 2) irradiation of the back; 3) irradiation of the head.

We considered it of unquestionable interest to carry out analogous investigations with impulse microwaves, whose biological activity is sometimes apparently different from the action of the continuous type. The thermal effect of impulse microwaves is determined by their mean intensity, which is usually considerably lower than the impulse intensity (proportionality coefficient – product of the duration of the impulse times the frequency of the impulses). Thus, at a nonthermogenic mean intensity, the impulse intensity will be considerably higher.

In this report, we describe an experiment involving investigation of the sinus rhythm in rabbits subsequent to irradiation of different portions of their bodies with impulse microwaves. The results of these experiments are compared to corresponding data, obtained earlier from trials employing irradiation with continuous microwaves.

EXPERIMENTAL METHOD

As the source of impulse microwaves, we used a generator (developed by the VNIIMIiO*), yielding a wave length of λ = 10 cm, a maximum impulse energy of P_{imp} = 40 kilowatts, and a frequency F of from 1 to 700 imp/sec at an impulse duration of τ = 1 microsecond. In our experiments, we used a frequency of 700 imp/sec, known to be higher than the frequency of possible physiological rhythms. The average intensity of the irradiation P = 3-5

*The All-Union Scientific Research Institute of Medical Instrumentology and Equipment.

milliwatts/cm^2 – approximately half that used in the experiments with continuous microwaves. The impulse intensity exceeded the mean intensity by 1400 times.

To irradiate the animals, we used the same set up as in the investigations with the continuous microwaves referred to above. The procedure, order in which the experiments were carried out (time of irradiation, irradiated area, recording of the rhythm, control experiments, etc), and methods of statistical analysis of the experimental data were also the same as in the experiments with the continuous microwaves. The trials were carried out on 8 male rabbits, weighing 3-4 kg.

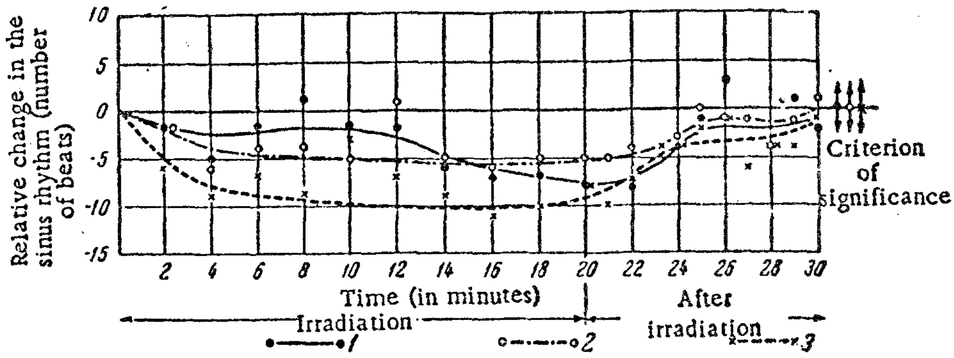

Fig. 2. Relative changes in the cardiac rhythm in rabbits, subsequent to irradiation of the ventral parts of the body with impulse microwaves (λ = 10 cm, τ = 1 microsecond, F = 700) of nonthermal intensity (P = 3-5 milliwatts /cm^2). Each point represents the mean of 16 trials. 1) Total ventral irradiation; 2) irradiation of the stomach; 3) irradiation of the head.

EXPERIMENTAL RESULTS

Figure 1 shows the data on the relative changes in rhythm subsequent to irradiation of the dorsal portion of the rabbit's body. With irradiation of the head and back, we observed acceleration of the rhythm, beginning toward the end of the irradiation and markedly increasing after the exposure. Total dorsal irradiation led to acceleration only after the irradiation.

TABLE 1. Change in the Percent of Cases of Slowing and Acceleration of the Sinus Rhythm in Rabbits, Subsequent to Irradiation of Different Parts of their Bodies with Impulse Microwaves (λ = 10 cm, τ = 1 microsecond, F = 700 imp/sec, P = 3-5 milliwatts/cm^2)

Part of the body irradiated		Total number of measurements	For 20 minutes of irradiation			For 10 minutes after the irradiation		
			change in the percent of cases showing acceleration (m_y)	change in the percent of cases showing slowing (m_z)	coefficient of the chronotropic effect (K)	change in the percent of cases showing acceleration (m_y)	change in the percent of cases showing slowing (m_z)	coefficient of the chronotropic effect (K)
Dorsal side	Entire surface	320	0	0	1.0	0	0	1.0
	Back	320	0	0	1.0	+ 16	− 21	1.47
	Head	320	+ 23	− 23	1.57	+ 31	− 31	1.9
Ventral side	Entire surface	320	− 11	0	0.89	0	0	1.0
	Stomach	320	− 15	+ 14	0.75	0	0	1.0
	Head	320	− 23	+ 25	0.61	0	0	1.0

Symbols: + increase in the percent of cases; − decrease in the percent of cases, in comparison with the control.

Figure 2 presents the data on the relative changes in rhythm subsequent to ventral irradiation. In all cases, we observed slowing of the rhythm during the irradiation, disappearing within the first 5 minutes after the exposure. It must be noted that with general ventral irradiation the slowing was noted only at the end of the exposure.

Table 1 contains the results of statistical analysis of the experimental data, in the form of values for the coefficient of the microwaves' chronotropic effect. The coefficient of the chronotropic effect $K = 100 + m_y/100 + m_z$, where m_y and m_z correspond respectively to the percent expressions of the number of cases of acceleration and slowing of the rhythm as compared with the control.

With dorsal irradiation, we noted a positive chronotropic effect ($K > 1$) only in the case of head irradiation. Total dorsal irradiation and irradiation of the back did not cause changes in the rhythm ($K = 1$). After the irradiation, a positive chronotropic effect was observed in two cases – with irradiation of the back and irradiation of the head.

TABLE 2. Comparison of the Nonthermal Action of Microwaves on the Sinus Rhythm of Rabbits Subsequent to Continuous (λ = 12.5 cm, P = 7-12 milliwatts/cm^2) and Impulse (λ = 10 cm, λ = 1 microsecond, F = 700 imp/sec, P = 3-5 milliwatts/cm^2) Irradiation

Part of the body irradiated		Continuous Irradiation				Impulse Irradiation			
		during irradiation		after irradiation		during irradiation		after irradiation	
		coefficient of the chronotropic effect (K)	maximum change in the rhythm relative to control (number of beats)	coefficient of the chronotropic effect (K)	maximum change in the rhythm relative to control (number of beats)	coefficient of the chronotropic effect (K)	maximum change in the rhythm relative to control (number of beats)	coefficient of the chronotropic effect (K)	maximum change in the rhythm relative to control (number of beats)
Dorsal side	Entire surface	1.0	0	1.0	0	1.0	0	1.0	+ 4
	Back	1.0	0	0.76	0	1.0	+ 1	1.47	+ 5
	Head	1.3	+ 1	1.42	+ 5	1.57	+ 5	1.9	+ 13
Ventral Side	Entire surface	0.67	− 5	0.67	− 5	0.89	− 3	1.0	0
	Stomach	0.73	− 3	0.91	0	0.75	− 5	1.0	0
	Head	0.76	− 2	1.0	+ 2	0.61	− 8	1.0	0

Symbols: + acceleration of the rhythm; − slowing of the rhythm in comparison with the control.

In all cases of ventral irradiation we observed a negative chronotropic effect ($K < 1$), most manifest with irradiation of the head, less with irradiation of the stomach, and least with total ventral irradiation.

The experiments performed made it possible to establish that irradiation of the dorsal and ventral parts of a rabbit's body with impulse microwaves of nonthermogenic intensity causes a chronotropic effect – a change in the sinus rhythm – during irradiation and for a short time afterward. In many ways, this effect is similar to the chronotropic effect of continuous microwaves, but there is also a difference between them.

We refer to the basic characteristics of the chronotropic effect for the impulse microwaves in comparison with the corresponding characteristics of the chronotropic effect for the continuous type, this being analyzed from the comparative Table 2.

As we pointed out, there is a basis for regarding the chronotropic effect of microwaves as a vascular-vegetative reaction, reflexly arising as a result of direct action by the microwaves on reflexogenic zones situated in the superficial tissues.

Above all, it must be noted that the effect of impulse irradiation was basically more manifest than the effect of continuous irradiation, despite the fact that the mean intensity with impulse irradiation was approximately half as great. This is not difficult to understand if it is taken into consideration that the impulse intensity exceeded the mean by 1400 times.

With ventral irradiation, using continuous microwaves, the negative chronotropic effect was proportionately greater with larger irradiated surface areas. This relationship provided a foundation for regarding the effect as a result of direct action by the microwaves on receptors of the skin. With ventral irradiation, using impulse microwaves, we also observed a negative chronotropic effect, but the proportional relationship to the irradiated surface seemed to be inverse in this case.

With dorsal irradiation of the head, both of the continuous and impulse type, we noted a positive chronotropic effect, more manifest in the latter case. One of the probable mechanisms in this case is the direct action of the microwaves on the cells of the brain.

Dorsal irradiation of the animal's back with continuous microwaves leads to a negative chronotropic effect, while with impulse microwaves, the effect is positive.

We see that the chronotropic effect of impulse microwaves differs considerably from the effect of the continuous type, both in expressivity and in character. It is obvious that this difference can only be explained by first analyzing the mechanism of nonthermal action of impulse and continuous microwaves. Here we can only note that with impulse irradiation one can expect a direct action on deeper tissues than with continuous irradiation. This stems from the fact that, in our experiments, the impulse intensity considerably exceeded the intensity of the continuous irradiation.

SUMMARY

Irradiation of various parts of the rabbit body with impulse microwaves (λ = 10 cm, 1 microsec, 700 impulses/sec) of nonthermal intensity (3-5 milliwatt/cm^2) affected the sinus rhythm during the irradiation (10 min) and immediately after it (10 min). Irradiation of ventral parts caused a shift of the rhythm in the direction of retardation and of dorsal ones – in the direction of acceleration. This chronotropic effect of the impulse microwaves was more pronounced than the effect of the continuous microwave irradiation (Communication I). The possible cause of this difference lies in a deeper penetration into the tissues of the impulse microwaves in comparison with the continuous ones.

LITERATURE CITED

1. A. S. Presman and N. A. Levitina, Byull. éksper. biol. i med. Vol. 53, No. 1, p. 41 (1962).

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.