EFFECT OF MICROWAVES ON THE IRRITABLE SYSTEM OF PARAMECIA

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An analysis of the experimental data on the reactions of the human and animal organism to microwave irradiation and also a theoretical evaluation of the possible penetration of microwaves into various tissue structures has permitted the conclusion to be made [2-5] that one of the basic mechanisms of such an effect of microwaves is their direct action on irritable structures (peripheral receptors, brain structures), which is expressed either in stimulation of the structures or in an increase of their irritability.

Recent investigations with paramecia (Paramecium caud.) [6, 8, 9] demonstrated that under the effect of impulses of direct and alternating current, at certain threshold voltages there was an abrupt arrest of the movement of the paramecia—"electroshock reaction" (ESR). The threshold voltages (V) proved to be sufficiently critical, and their dependence on the duration of the direct current impulses (t) and frequency of the alternating current (f) are similar to the corresponding dependences for nervous and muscular tissues of vertebrates: $V_{dc} = \frac{\alpha}{\sqrt{t}} + v$ and $V_{ac} = K\sqrt{f}$. These results confirmed the previously expressed hypotheses [11, 12] on the existence of an irritable system in paramecia and gave us grounds to consider the ESR as a manifestation of the irritability of paramecia as an intact cell.

It was of interest to confirm the indicated data by direct experiments on a simple model of an irritable structure.

Basing our study on these data, which are in accord with the current concepts of the singular nature of biological movement and reception [1, 10], we attempted to experimentally elicit the effect of microwaves on the irritable system of paramecia both in the form of direct stimulation and in the form of a change of irritability.

METHOD

Irradiation of the paramecia (in a hay infusion) with microwaves was carried out in a special device (Fig. 1), which was a segment of a coaxial line, to one end of which was connected the cable from a microwave generator and to the other end a polystyrene rectangular bath (6 × 3 × 1 mm) with silver electrodes (6 × 1 mm) connected with the rod and cylinder of the coaxial line. The device provided for the possibility of acting on the paramecia with impulses of alternating current during microwave irradiation, which was ensured by the profile of the cylinder by means of flanges with a mica lining (a discontinuity for the alternating current and closing of the microwave currents).

The power absorbed in the medium with the paramecia was calculated from the output power of the generator with consideration of partial reflection and radiation.

Observations of the behavior of the paramecia were carried out by means of a MBS-2 microscope. To protect the eyes of the experimenter from side radiation of the microwaves, we used an aluminum casing which was lined inside with absorbing plates; in the casing was an opening for inserting the microscope objective.

Four series of experiments were carried out.

I. Irradiation recurring once per second with continuous microwave impulses (λ = 12.5 cm) with a duration of 5-100 msec.

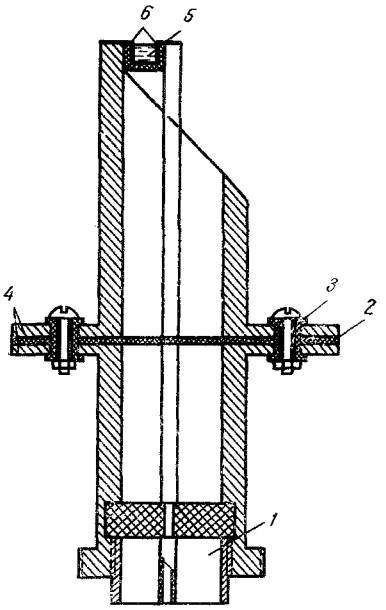

Fig. 1. Coaxial device for irradiating paramecia. 1) Jack connector for switching of cable; 2) mica lining; 3) insulation insert; 4) flanges; 5) silver electrodes; 6) polystyrene bath for paramecia.

II. Irradiation recurring once per second with a series of short (1 μsec) microwaves (λ = 10 cm) with series durations from 7 to 50 msec and repetition rates in the series from 200 to 700 impulses/sec.

III. The effect of alternating current (1 impulse/sec) with a frequency of 240 and 1200 cps with a pulse duration of 120 msec against a background of synchronous irradiation with continuous microwave impulses of the same duration.

IV. Effect of an alternating current (1 impulse/sec) with a frequency of 240 and 1200 cps at a pulse duration of 100 msec against a background of synchronous irradiation with a series of microsecond microwave impulses (repetition rate in the series 700 impulses/sec, duration of the series 100 msec).

RESULTS

It was established in the I series of experiments [7] that at critical threshold values of power (coefficient of variation not more than 6%) each impulse of continuous microwaves induces a reaction of the paramecia similar to the described ESR, in response to impulses of direct and alternating current. Figure 2 shows a curve of the dependence of the threshold power (P in watts) of microwave impulses on their duration (t in microseconds). This dependence is sufficiently well approximated by the equation

$$P = \frac{24}{\sqrt{t}} \qquad (1)$$

In the II series of experiments the ESR was observed during irradiation of paramecia with series of impulses at critical threshold values of the mean power in the series (coefficient of variation not more than 10%). These threshold powers proved to be higher than those for the impulses of continuous microwaves at series durations up to 10 msec and lower in longer series (see Fig. 2).

More regular was the dependence of the threshold power of the impulses (P_{imp} in kilowatts)* entering into the series on its duration. This dependence for all frequencies was approximated by the equation

$$P_{imp} = \frac{1120}{t^2} + 1.5. \qquad (2)$$

For a more detailed analysis of these data it was necessary to express the dependence of the threshold impulse power on the number of impulses in a series. The curve of such a dependence (Fig. 3) testifies in behalf of the summation character of the stimulating action of microwave impulse series.

In the III series of experiments [7] we determined the threshold voltages of the stimulating alternating current impulses (inducing the ESR) during the synchronous effect of continuous microwave impulses with a power 15% below that needed for direct stimulation, which was established in the I series of experiments.

It was found that under the effect of microwave irradiation the threshold voltage of the stimulating alternating current impulses drops, but returns to the initial value when irradiation is stopped. Figure 4 shows (dashed curve) such a drop of the threshold for a 1200-cycle alternating current. At a frequency of 240 cps the drop was almost double.

In the IV series of experiments the threshold voltages of the stimulating alternating current impulses were determined during the synchronous action of trains of short impulses at the average power in the series 15% below that needed for direct stimulation, which was established in the II series of experiments.

*As is known under impulse conditions the average power (P_{av}) depends on the frequency of the impulses (f) and duration of impulses (τ); $P_{av} = P_{imp} \cdot f \cdot \tau$.

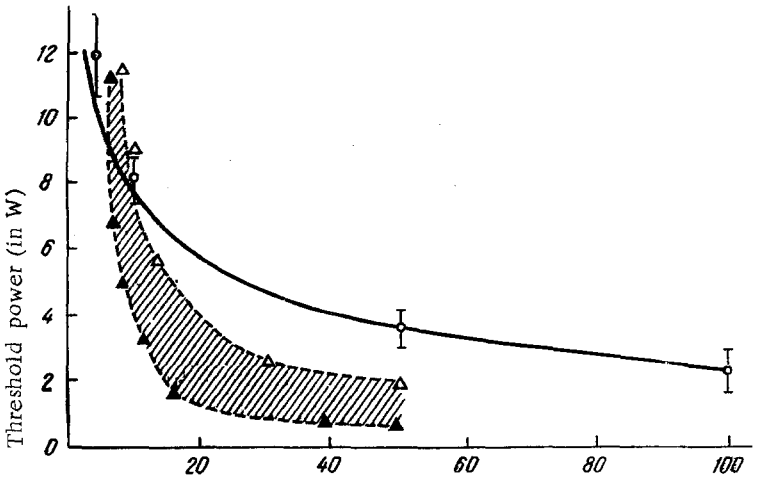

Fig. 2. Dependence of threshold power of microwaves evoking the ESR on the duration of the impulses. ○) For continuous microwave impulses; △▲) for series of microwave impulses. The hatched area indicates the threshold values for series of impulses with frequencies of 200-700 impulses/sec.

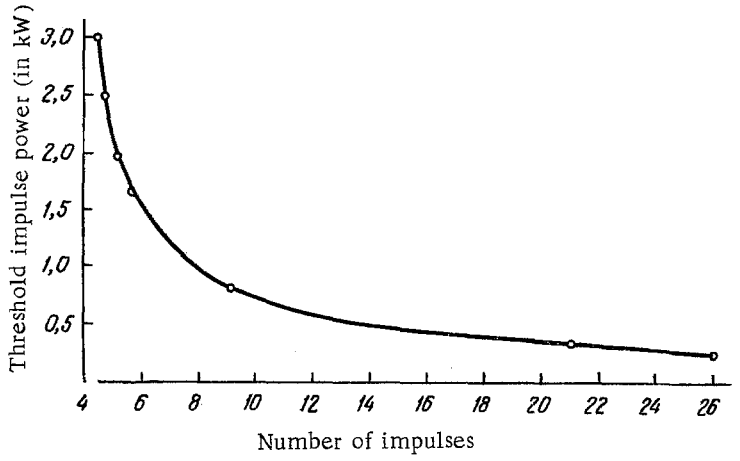

Fig. 3. Dependence of threshold impulse power of series of microwave impulses evoking the ESR on the number of impulses in a series. Intervals between impulses, 1.4 msec.

Under these conditions we observed an appreciably greater drop of the threshold voltages of the stimulating alternating current impulses, as is illustrated in Fig. 4 for 1200-cycle alternating current (solid curve). At a frequency of 240 cycles per second the drop was approximately 30% less.

The data of the I series of experiments give us grounds to assume the stimulating action of microwave impulses on the irritable system of paramecia. The criticalness of the threshold power and the character of its dependence upon the impulse duration testify in behalf of this.

The data of the II series permits the assumption that with irradiation of paramecia by a series of short microwave impulses there is a summation of local changes. Actually, as the number of impulses increases the threshold power drops and then becomes practically constant (see Fig. 3).

The effects observed in the III and IV series of experiments illustrate the sensitizing action of microwave impulses of subthreshold power, i.e., an increase of the irritability of paramecia to other stimulating factors.

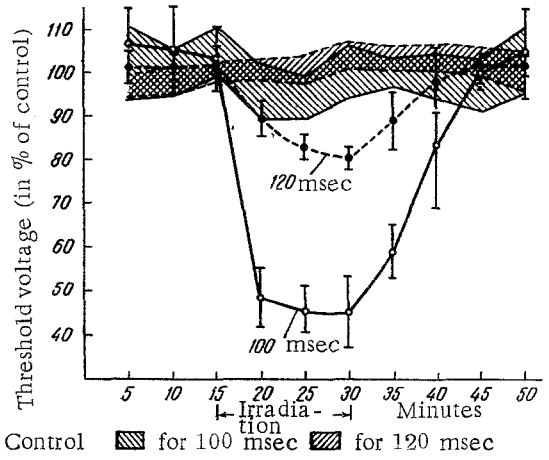

Fig. 4. Change of threshold voltage of alternating current impulses (1200 cps) evoking the ESR under conditions of synchronous microwave irradiation. – – – Effect of irradiation with continuous microwave impulses with durations of 120 msec; —— effect of irradiation with series of microwave impulses at a frequency of 700 impulses/sec and series duration of 100 msec; hatched areas—variations of threshold voltage of alternating current impulses (duration 120 and 100 msec) without microwave irradiation.

The described reactions of the paramecia can be considered as a convincing example of the nonthermal biological effect of microwaves, which is based on the following considerations.

1. Calculations showed that during the action of continuous microwave impulses or a series of impulses, heating of the medium with the paramecia did not exceed 1-1.5°. Summation heating from impulse to impulse (or from series to series) is improbable in view of the considerable interval between them (1 sec) and small size of the irradiated mass (0.02 g). Since the optimal temperatures for paramecia are 24-28°, it is improbable to attribute such a pronounced reaction as the electroshock reaction to the negligible increase of temperature during microwave irradiation.

2. The thermal nature of the ESR to microwave impulses is contradicted by the dependence of the magnitude of the threshold power of the stimulating continuous wave impulses and series of short impulses on the square root of the impulse series duration and not on the first power of these magnitudes.

3. The thermal mechanism of the ESR is not in accord with the fact that during irradiation with impulse series, the threshold impulse power was virtually independent of the frequency of the impulses in the series, although the average power in the series (determining heating) is proportional to the frequency.

In conclusion we noted that the results of the investigations of the effect of microwaves on the irritable system of paramecia can prove to be useful for explaining the mechanism of action of microwaves on the irritable structures of highly organized animals.

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