THE ACTION OF ULTRASOUND ON PERIPHERAL NERVE FIBERS AND NERVE ENDINGS

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(Presented by Active Member AMN SSSR, V. V. Parin)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 50, No. 12, pp. 98-102, December, 1960
Original article submitted October 3, 1959

During the last two decades many reports have been published on the therapeutic use of ultrasound. Ultrasonic therapy has been used particularly in neurological diseases. The influence of ultrasound on the peripheral nervous system has, however, been neglected. Most research has been devoted to the study of the action of high-intensity ultrasound, which has a destructive action on nerve tissue.

Only isolated communications have appeared dealing with the influence of therapeutic doses of ultrasound on the peripheral nervous system. R. Pohlman [2] in particular states that therapeutic doses ultrasound have a very weak action on healthy nerves and nerve endings. N. P. Krylov and V. I. Rokityanskii [1] draw attention to the high sensitivity of the nerve endings to the action of ultrasound, basing this conclusion on the development of pain in animals in the area so treated.

We found no reference in the Soviet literature specifically concerned with the morphological changes in the peripheral nerve fibers and endings resulting from the action of therapeutic doses of ultrasound, and we therefore decided to study this problem.

METHOD

We carried out experiments on 20 guinea pigs (see table).

The first series of experiments was conducted on 14 animals which were irradiated with ultrasound of an intensity of 0.5 W/cm^2 and frequency 1625 kc with pulsed operation of the generator; in six cases irradiation lasted 3 minutes, in four cases—5 min and in four more—10 min.

In the second series of experiments on six guinea pigs ultrasound was applied with an intensity of 1 W/cm^2 and frequency of 1625 kc with continuous operation of the generator. Irradiation lasted 3 min.

In all the experiments contact between the vibrator and the skin surface was made through vaseline oil. The lateral surface of the right thigh, from which the hair was removed, was irradiated. During irradiation the head of the vibrator was slowly moved about through very short distances, so that the central area of skin did not escape the action of the ultrasound.

Under the action of ultrasound the animals always appeared restless, giving frequent, repeated jerky movements. After irradiation, only in one case did we observe a state of paresis of the corresponding limb of the animal, passing off after two hours, and in the remaining cases the animals behaved normally.

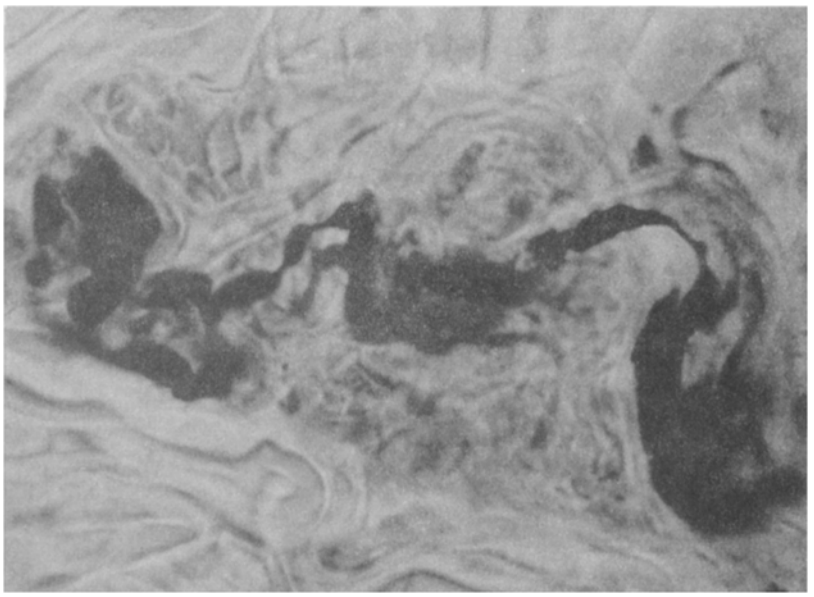

Fig. 1. Skin 3 days after irradiation with continuous ultrasound. Nerve fibers undergoing swelling and fragmentation can be seen. Silver impregnation by the Bielschowsky-Gros method, with subsequent gilding. Photomicrograph. Objective 40 ×, ocular 10 ×.

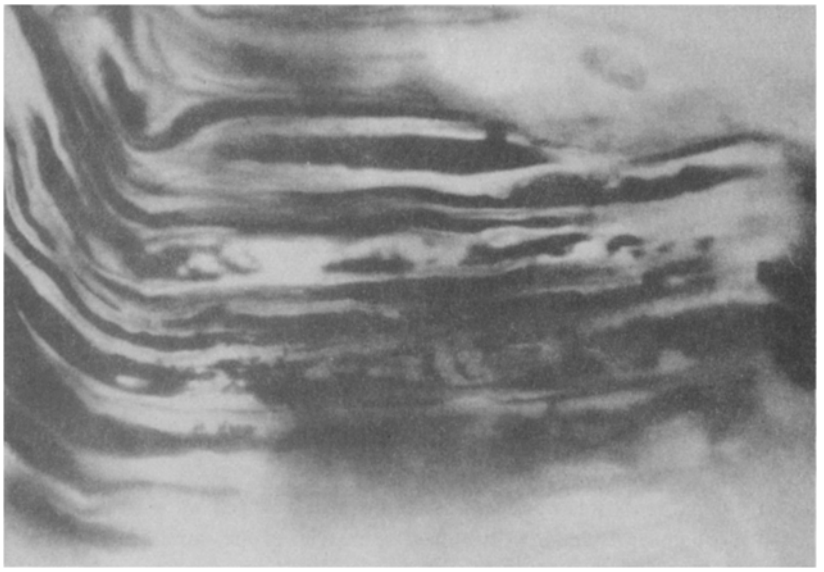

Fig. 2. Sciatic nerve 3 days after irradiation with continuous ultrasound. Irregularly thickened axis cylinders with signs of dyschromia are seen side by side with axis cylinders undergoing vacuolation and fragmentation. Impregnation by the Bielschowsky-Gros method. Photomicrograph. Objective 40 ×, ocular 10 ×.

Specimens for investigation were taken 2 hours and 1, 2, and 3 days after irradiation. In order to study the action of ultrasound on the peripheral nerve fibers and endings, the skin, underlying muscle tissue and a portion of the sciatic nerve were removed from the irradiated area. As controls we used corresponding material from the unirradiated left thigh. The specimens were fixed in 10% neutral formalin. Microscopic preparations were impregnated with silver by the Bielschowsky-Gros method, often followed by gilding and staining with hematoxylin-eosin.

Experimental Conditions

Series of experiments	Intensity of ultrasound (in W/cm²)	Frequency of ultrasound (in kc)	Mode of operation of generator	Time of irradiation (in min)	No. of experimental animals	Time from moment of irradiation to taking of specimens
First	0.5	1625	Pulsed	3	2	2 hr
					2	1 day
					2	3 days
				5	2	2 hr
					2	3 days
				10	2	2 hr
					2	3 days
Second	1	1625	Continuous	3	2	2 hr
					2	2 days
					2	3 days

RESULTS

Microscopic examination of the specimens obtained in the first series of experiments, when the action of ultrasound lasted 3 min, revealed no changes in the nerve fibers and nerve endings in the skin, muscle tissue and sciatic nerve. In the skin of the other guinea pigs, irradiated for 5 and, in particular, for 10 min, side by side with unchanged nerve fibers could be seen other fibers whose axis cylinders appeared swollen and contained varicosities; the latter often gave the axis cylinders the appearance of a string of beads. The swellings were usually small in size, oval or round in shape, and homogeneous or loosely woven in texture.

Varicose axis cylinders were characteristically found in nerve fibers in the early stages, 2 hr after irradiation with ultrasound, and in far smaller numbers after one and three days; this indicates the reversible character of the changes. The free nerve endings in the skin and the motor end-plates in the muscle fibers remained visibly unchanged. Axis cylinders with indented, uneven outlines and signs of loosening of the structure and dyschromia were seen from time to time in the sciatic nerve after irradiation for 10 min.

Disintegration of the axis cylinders into fragments was not observed in the first series of experiments. It was found incidentally that, 2 hr after irradiation with ultrasound for 10 min, the lumen of the cutaneous vessels was greatly dilated and fully distended with blood cells. On the third day after this degree of irradiation, dilatation of the lumen of these vessels was observed to be less marked and not present in every case. Our findings thus agree in this respect with those of N. P. Krylov and V. I. Rokityanskii [1], who reported hyperemia of the tissues after a single irradiation of animals.

In the second series of experiments, in which constant operation of the generator was used, the changes observed in the first series were present but were more pronounced in character. In two cases in the second series of experiments, moreover, side by side with intact nerve fibers in the skin and muscle tissue we observed a large number of fibers with signs of vacuolation and disintegration into fragments (Fig. 1).

Some of the motor endings in the muscle fibers were also in a state of granular disintegration. In the sciatic nerve in these cases, on the third day after irradiation, a considerable number of nerve fibers was seen whose axis cylinders had disintegrated into fragments. Nerve fibers undergoing fragmentation mingled with unchanged fibers or with fibers whose axis cylinders were irregularly thickened, with signs of dyschromia. Often the outlines of the axis cylinders were indented and tortuous in appearance (Fig. 2).

It follows from the foregoing account that the morphological changes arising in the tissues as a result of the action of ultrasound are primarily dependent upon the mode of operation of the generator: with pulsed ultrasound the changes are expressed to a much smaller degree than when the generator operates continuously.

SUMMARY

Changes were revealed in the peripheral nerve fibers in the form of reversible irritation phenomena following irradiation of guinea pigs extremities with therapeutic doses of pulsed ultrasound, the intensity being 0.5 W/cm^2 and the frequency 1625 kc for 5 to 10 min. In irradiating for 3 minutes with constant ultrasound, the intensity being 1 W/cm^2 and the frequency – 1625 kc, the changes seen in the nerve, skin and muscles were not only reversible but also degenerative.

LITERATURE CITED

1. N. P. Krylov and V. I. Rokityanskii, Ultrasound and its Therapeutic Application [in Russian] (Moscow, 1958) p. 100.
2. R. Pohlman, cited by L. Bergmann, Ultrasonics and Their Scientific and Technical Application [Russian translation] (Moscow, 1957) p. 559.