EFFECT OF ULTRASOUND WAVES ON NUCLEIC ACID CONTENT IN THE ORGANS OF ALBINO RATS

A. A. Chirkin, I. A. Chirkina, and O. N. Detinkin

UDC 612.398.145.1.014.45

Experiments on rats showed that ultrasound waves with a frequency of 830 kHz and intensity of 0.2 to 1.8 W/cm^2 give rise to complex and periodic changes in the nucleic acid content.

Reports of the activation of tissue regeneration in animal organisms by ultrasound have recently been published [4, 13]. The nature of this effect, however, has not yet been determined.

In the analysis of the role of nucleic acids in regeneration [3], it was decided to investigate the dynamics of changes in the RNA and DNA content in the organs of albino rats during exposure to ultrasound.

EXPERIMENTAL METHOD

Experiments were carried out on 300 female rats weighing 150-200 g. The animals were exposed to ultrasound waves with a frequency of 830 kHz (UTP-1 apparatus) and intensities of 0.2, 0.6, and 1.8 W/cm^2, by the method described previously [6]. Half of the rats were irradiated with ultrasound five times, with intervals of 24 h between procedures, and were sacrificed by decapitation 10 min, 2 h (1.2×10^2 min), 24 h (1.4×10^3 min), 7 days (1.008×10^4 min), 30 days (4.32×10^4 min), and 90 days (1.296×10^5 min) later. The other half of the rats were exposed once to ultrasound, and these animals were sacrificed 10 min, 2, and 24 h, and 7 days later. The content of DNA and RNA was determined in the skin, the abdominal wall muscles, the liver, small intestine, and kidneys [10].

EXPERIMENTAL RESULTS

The dynamics of the nucleic acid content in the organs of the albino rats showed complex and periodic fluctuations under the influence of ultrasound waves (Fig. 1). The greatest changes in the DNA and RNA levels were produced by ultrasound with an intensity of 1.8 W/cm^2. The organs examined can be placed in the following descending order of the sum of statistically significant differences in nucleic acid content: kidney > muscle > skin > intestine > liver. These results show good agreement with those of morphological studies according to which the liver is more resistant that other organs to ultrasound [15]. The reason for these changes could be that tissue structures with a complex cytoarchitectonics (kidneys) absorb much more ultrasonic energy than tissues with a less complex cellular organization (adipose tissue, liver) [7].

A single exposure to ultrasound did not produce significant changes in the nucleic acid content of the liver, except for a decrease in the RNA level after 7 days in an intensity of 1.8 W/cm^2. In the same intensity, the DNA content in the intestine was reduced after 10 min, 2 h, and 7 days, and in the muscles after 24 h and 7 days. With a lower intensity of ultrasound (0.2 and 0.6 W/cm^2), a decrease in the DNA and RNA content could also be observed in the intestine and muscles. The opposite effect was observed in the skin and kidneys after a single exposure of the rats to ultrasound. The DNA content in the skin was increased after 24 h and 7 days in ultrasound with an intensity of 1.8 W/cm^2, and after 2 and 24 h in an intensity of

Central Research Laboratory and Department of Dermatological and Venereal Diseases, Vitebsk Medical Institute. (Presented by Academician V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 71, No. 4, pp. 58-61, April, 1971. Original article submitted June 23, 1969.

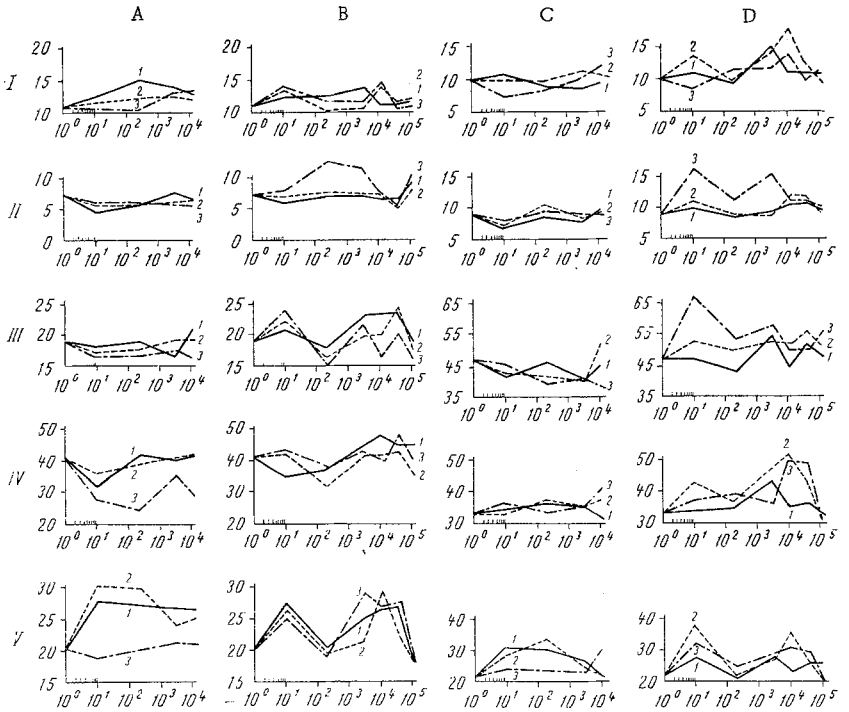

Fig. 1. Dynamics of nucleic acid content in organs of rats exposed to ultrasound: A and B) DNA content after 1 and 5 exposures to ultrasound respectively; C and D) RNA content after 1 and 5 exposures to ultrasound respectively: I) skin, II) muscles, III) liver, IV) intestine, V) kidney; 1) 0.2 W/cm^2; 2) 0.6 W/cm^2; 3) 1.8 W/cm^2. Abscissa, time (in min; logarithmic scale). Ordinate: in A and B) DNA content (in mg% phosphorus of fresh tissue; in C and D) RNA content (in mg% phosphorus of fresh tissue); in C and D) RNA content (in mg% phosphorus of fresh tissue).

0.2 W/cm^2. A similar increase in the DNA level also took place in the kidneys of all times of the experiment when the intensity of ultrasound was 0.2 and 0.6 W/cm^2.

The most typical effect of five exposures to ultrasound was an increase in the nucleic acid level, and for intensities of 1.8 and 0.6 W/cm^2 the curves of DNA and RNA content often had two maxima: the first after 10 min and the second between the first and 30th days. For low intensities, a curve with one maximum in the interval between the 1st and 7th day or, less frequently, the 7th and 30th day was more characteristic. A close correlation between the dynamics of the changes in DNA and RNA content was found only in the skin and kidneys. In the other organs changes in the RNA level (especially for intensities of 0.6 and 1.8 W/cm^2) were greater than the changes in the DNA level. This effect was also seen to a greater degree after prolonged exposure to ultrasound. For example, in the hepatocytes of the mice, disintegration of the microsomes was observed. This was accompanied by the appearance of large quantities of RNA in the cytoplasm of the cells (ultrasound of frequency 800 kHz and intensity 1 W/cm^2 was applied for 30 min) [20]. An increase in the RNA content in rat hepatocytes exposed to ultrasound has also been demonstrated by cytochemical methods [16]. Changes in nucleic acid metabolism, chromosomal aberrations, and spatial dislocations of the cytoplasmatic and intranuclear structures have been found in the ovaries and intestine of animals irradiated with ultrasound [2, 5, 7]. However, it must be emphasized that the most significant changes in the structure, metabolism, and quantitative content of nucleic acids (both in vitro and in vivo) are observed after exposure to ultrasound of more than therapeutic intensity (2-20 W/cm^2 and above) [7]. Interpretation of these results is made difficult by the severe necrobiotic changes, the hydration of the tissues, the marked elevation of the interstitial temperature, and so on. After exposure to ultrasound in a therapeutic intensity, these phenomena were all much less marked. The role of intracellular microcurrents and changes in the activity of certain enzymes

assume predominant importance [1, 8, 9]. At present virtually nothing is known of the effect of ultrasound on the state of the enzyme systems responsible for nucleic acid metabolism [7]. An attempt was therefore made to explain the results of the present investigation in terms of morphological evidence.

Ultrasound of high intensity (in these experiments 1.8 and, to some extent, 0.6 W/cm^2) is known to produce changes of different types in muscles [17], liver [12], kidneys [18], and certain other organs [11, 14], and in the early periods of the experiment, the changes produced are inflammatory in character, accompanied by cellular infiltration, to be followed in the later stages by cellular proliferation at the sites of necrosis. The processes described above could probably influence the character of the bimodal curves of nucleic acid content, for changes in the DNA and RNA levels during repeated exposure to ultrasound coincide with the times of morphologically recorded phases of damage and subsequent regeneration [4]. Ultrasound of low intensity (0.2 W/cm^2) had no harmful action on rat tissues. In morphological investigations, however, evidence of "rejuvenation" and "stimulation of tissue activity" [4] was found, in experiments similar to those now described, on the 3rd-30th days. An increase in the frequency of mitoses and in the degree of hyperchromia of the nuclei and pyroninophilia of the cytoplasm of the cells was observed. Comparison of the morphological data with the present results suggests that the increase in content of nucleic acids in the tissues during five exposures to the action of ultrasound of low intensity is probably due to activation of physiological regeneration. If this hypothesis is correct, it will explain the beneficial effect of ultrasound in the treatment of indolent diseases [19].

LITERATURE CITED

1. M. I. Gol'din, I. M. Raikin, and I. E. Él'piner, Dokl. Akad. Nauk SSSR, 166, No. 5, 1221 (1966).
2. N. F. Lipkan, in: Problems in Biophysics and the Mechanism of Action of Ionizing Radiation [in Russian], Kiev (1964), p. 132.
3. V. F. Sidorova, Z. A. Ryabinina, and E. M. Leikina, Regeneration of the Liver in Mammals [in Russian], Leningrad (1966).
4. A. P. Speranskii and I. L. Martsveladze, Vopr. Kurortol., No. 1, 60 (1963).
5. N. E. Khursin, in: Problems in Biophysics and the Mechanism of Action of Ionizing Radiation [in Russian], Kiev (1964), p. 135.
6. A. A. Cherkin and V. M. Kozin, Vopr. Med. Khimii, No. 3, 274 (1970).
7. I. E. Él'piner, Ultrasound. Physicochemical and Biological Action [in Russian], Moscow (1963).
8. I. E. Él'piner, Pat. Fiziol., No. 1, 3 (1969).
9. I. E. Él'piner, Biofizika, No. 2, 333 (1970).
10. R. G. Tsanev and G. G. Markov, Biokhimiya, No. 1, 151 (1960).
11. W. Bejdl, Schweiz. Med. Wschr., 84, 1395 (1954).
12. A. Dönhardt and H. R. Presch, Strahlentherapie, 91, 311 (1953).
13. M. Dyson et al., Clin. Sci., 35, 273 (1968).
14. E. Fischer, Am. J. Phys. Med., 33, 174 (1954).
15. W. Gloggengisser, Münch. Med. Wschr., 20, 1015 (1952).
16. J. Jankowiak et al., Am. J. Phys. Med., 37, 135 (1958).
17. J. Jankowiak et al., Arch. Phys. Ther. (Leipzig), 10, 54 (1958).
18. H. Klup et al., Arch. Phys. Ther. (Leipzig), 4, 44 (1952).
19. R. Pohlman, Die Ultraschalltherapie, Bern (1951).
20. C. M. Southam, H. Beyer, and A. C. Allen, Cancer, 6, 390 (1953).