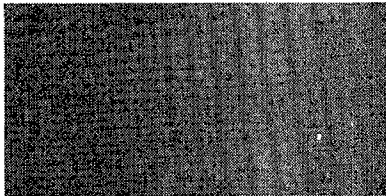
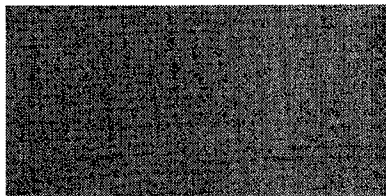
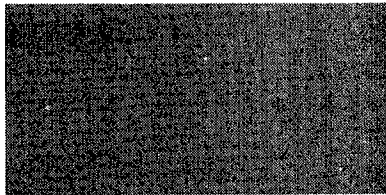


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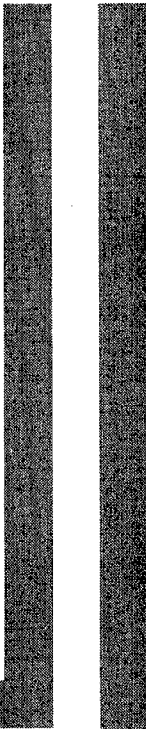
EFFECTS OF NONIONIZING  
ELECTROMAGNETIC RADIATION

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No. 48

EFFECTS OF NONIONIZING  
 ELECTROMAGNETIC RADIATION

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EFFECT OF A CONSTANT MAGNETIC FIELD ON THE REST POTENTIAL, IONIC CONDUCTIVITY AND NEUROMUSCULAR TRANSMISSION IN SMOOTH MUSCLES

Kiev FIZIOLOHICHNY ZHURNAL in Ukrainian No 5, 1977 pp 622-626

[Article by Bohach, P.H. and Davydovs'KA, T.L., Institute of Physiology at Kiev University]

[Text] Besides being of general physiological interest, investigations on the effect of a constant magnetic field [CMF] on cells are of considerable importance in solving many practical problems of public health and medicine, where the studies of the mechanism of action of this factor are necessary for an effective utilization of CMF.

Attempts to systematize experimental data on the effect of CMF on smooth muscles and on skeletal and nerve tissue (1, 9, 14, 15) are far from being complete. This is so because the results reported by various authors differ quantitatively and qualitatively, reflecting the effect of CMF on the rest potential of a membrane, with no electrophysiological data available on the effect of CMF on the ionic conductivity of muscle cell membranes and their nerve-muscle transmissions, where they should be especially effective.

We investigated changes in the rest potential [RP], anelectrotonic potentials [AET] and the inhibitory postsynaptic potentials [IPSP] of guinea pigs smooth muscle cell membranes taenia coil [TC] resulting from the effect of CMF within the therapeutically acceptable range.

#### Experimental Method

Experiments were performed on 20 mm long isolated fascia of guinea pigs TC. Krebs solution of the following composition was used (in millimoles): NCL-120.7;  $\text{NaHCO}_3$ -15.5;  $\text{NaH}_2\text{PO}_4$ -1.2; KCL-5.9;  $\text{CaCl}_2$ -2.5;  $\text{MgCl}_2$ -1.2 and glucose-11.5.

The Berger and Barr (5) modification of the "sucrose gap" method was used to determine the inhibitory postsynaptic potentials, the anelectrotonic potentials, and to study the relative changes in the membrane potential of the smooth muscle cells.

Stimulation of nerve formations found in the tissue fascia fat was achieved by perpendicular stimuli ( $1 \times 10^{-5}$  a) lasting for 0.2-0.5 ms. The impulse electrodes were connected to the high ohm input of the preceding amplifier (4). After stimulation, the signal was passed onto the vertical deflection slate of the electronic tube on the C1-18 oscillograph.

Electric reactions of the muscle tissue were imaged on the C1-18 oscillograph screen and photographed for future reference: KSP paper recording was made as well.

CMF was reproduced by means of an electromagnet. The magnetic field feed was supplied by a stabilized rectifier BC-25 (current pulsation coefficient  $K=0.03$  percent).

The strength of the magnetic field was measured by Hall counters consisting of the crystals n-G and the measuring chain F 4354/1. The size of the counters was about  $2 \times 1 \times 0.2$  mm<sup>3</sup>. The accuracy of the determination of the magnetic field was 0.1 percent.

Electrophysiological data of the effect of CMF on smooth muscle cells was obtained directly from the magnetic field.

#### Experimental Results

Single intramural stimulation of muscle fascia with perpendicular stimuli evoked inhibitory postsynaptic potential (Fig 1.). Determination of the IPSP parameters resulting from maximum intramural stimulation under normal conditions and under the effect of CMF showed that the latent period of IPSP due to 30 min field action (on the average  $150 \pm 12$  ms) remained unchanged. Also, stability of IPSP did not change ( $1250 \pm 120$  ms), while the amplitude of IPSP due to the effect of CMF increased about half as much again (Fig 1a, v). The amplitude of the anelectrotonic potentials [AET] and the stability of the drop due to the CMF effect were diminished (Fig 1b, g). Fig 2a shows that these changes occurred during the first minutes of exposure to the magnetic field with a strength of 300 Oe, and by 30 min the amplitude of IPSP reached 121.0 percent ( $p < 0.05$ ).

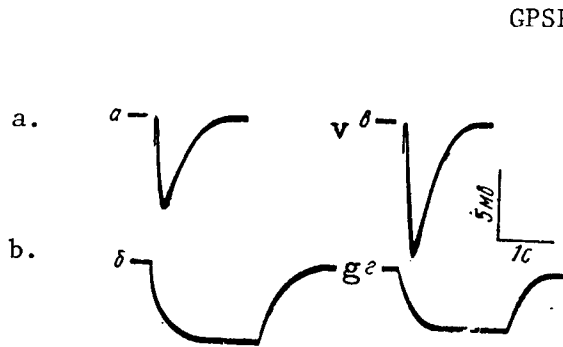


Fig 1. Effect of the magnetic field with a strength of 600 Oe on the amplitude of inhibitory postsynaptic and anelectrotonic potentials of the guinea pigs TC

a,b - IPSP and AEP under normal conditions

v,g - IPSP and AEP after 30 min exposure to CMF

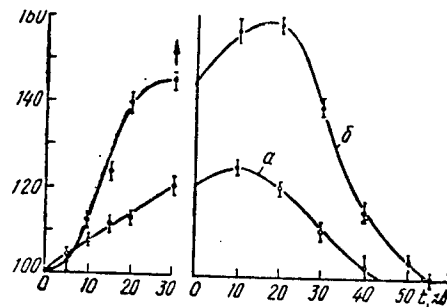


Fig. 2. Change in the IPSP amplitude due to the effect of CMF and the postaction effect

Vertical axis - IPSP in percent  
Horizontal axis - duration of the magnetic field action,  $\uparrow$  - after-action time

a,b - IPSP due to the CMF effect of 300 and 600 Oe respectively

Increasing the magnetic field to 600 Oe (Fig 1a, v; 2b) resulted in a significant increase of the IPSP amplitude. Numerically this exceeded significantly the effect of a 300 Oe field; in 30 min the amplitude of the IPSP reached 145.4 percent ( $p \ll 0.05$ ) compared to a normal control value of 100 percent. It is noteworthy that the curves of the IPSP amplitude different field strengths, were not identical. The curve corresponding to CMF strength of 300 Oe was approximately linear, while the 600 Oe curve had an S-shape.

In both cases the IPSP amplitude continued to increase even after the CMF (Fig 2) was switched off. When the 300 Oe CMF was cut off, the IPSP amplitude continued to increase for another 10 min, only then beginning to drop off, reaching the starting value after some 40-45 min. (Fig 2a,  $\uparrow$ ).

Switching off the 600 Oe magnetic field was accompanied by a significant increase in the IPSP amplitude over that of the 300 Oe CMF, which lasted 20-25 min (Fig 2b,  $\uparrow$ ). Then the IPSP amplitude began to drop off quite sharply, reaching the starting level after about one hour.

Studies of the effect of CMF on anelectrotonic potentials and relative changes of the RP of smooth muscle TC cell membranes showed that the magnetic field with a given strength also affects the RP and ionic transmission of smooth muscle cells. During the first moments of the field action, the transmission of cell membranes diminished by about 10 percent after which

it increased (Fig 3a, b) in spite of the continued effect of the field. One should also note that the changes in membrane transmission due to the 300 and 600 Oe field strength were generally similar.

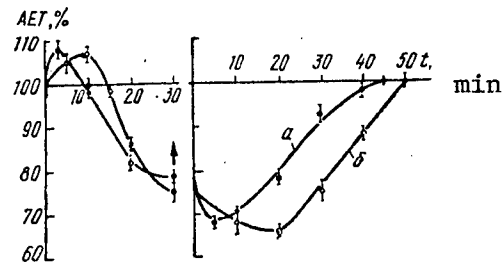


Fig. 3. The amplitude change of anelectrotonic potentials during the action of CMF and the effect of afteraction

Vertical axis - AET amplitude in percent

Horizontal axis - duration of the magnetic field action,  $\uparrow$  - time of the afteraction

a, b - AET during and after the action of CMF with the strength of 300 and 600 Oe respectively

The magnetic field with the strength of 300 and 600 Oe led to an increased RP lasting about 30 min. With the 300 Oe field, this amounted to 2-3 mv ( $p \leq 0.05$ ), while in case of the 600 Oe field--about 4-5 mv ( $p \leq 0.05$ ).

About 3-5 min (Fig 3a) after the 300 Oe field was switched off, and 20-25 min after stopping the 600 Oe field, the AET amplitude began to raise, gradually returning to the normal level. The RP of smooth muscle cells continued to increase after the magnetic field was switched off, reaching a maximum within about 10 min of the 300 Oe CMF afteraction and within about 35-40 min in the case of the 600 Oe field. At these points the change in RP was 5.8-6.4 and 11-12 mv respectively. After 60 min of the afteraction (magnetic field strength 300 and 600 Oe) the RP decreased, remaining slightly above the normal level.

#### Discussion of Experimental Results

Our experimental results have shown that CMF leads to an increased RP of smooth muscle TC cell membranes, along with an insignificant temporary elevation followed by a decrease of membrane resistance. One can assume that the latter changes are responsible for the increased RP under experimental conditions. During the early phase of field action the predominant effect is a decrease of sodium permeability of the membrane followed by a marked increase in potassium permeability, leading to hyperpolarization.

The increase in RP due to the influence of CMF could be considered as the basis for the increased amplitude of IPSP under the influence of CMF. The inhibitory postsynaptic potentials relate to potassium and therefore their

amplitude is inversely related to the RP (3), i.e., the change of the starting cell RP in the direction of depolarization leads to an increased amplitude of IPSP and, at a 26-40 mv hyperpolarization, IPSP's become totally suppressed (16). As it was already stated, we observed an increased amplitude of IPSP on the background of the hyperpolarization of RP and a decrease of anelectrotonic potentials, neither of which could be responsible for the increased amplitude of inhibitory postsynaptic potentials; on the contrary, one would expect that the IPSP amplitude should have decreased.

The amplitude of smooth muscles IPSP is determined by the subsynaptic and presynaptic membranes (2, 6, 11, 12). If the CMF affects the electric excitability of muscle tissues, then it is possible that the magnetic field should show an effect on the nerve fiber's membrane and, furthermore, the physiological properties of smooth muscle and nerve fibers being practically identical, one could assume that the magnetic field would change the rest potential in nerve cells toward hyperpolarization, analogously to the muscle cells. Liley (13) and Eckles and Liley (8) have shown that, during the hyperpolarization of the presynaptic fiber, the amplitude of the action potential increases markedly during the passage of the impulse. Theoretical calculations of Eckles (7) have shown that a 5 mv increase of the presynaptic peak should increase the postsynaptic potential by 220 percent. According to the hypothesis of Hubbard and Willis (10), hyperpolarization of nerve terminals leads to an increased number of quanta generated by the nerve impulses. Hence, it may be assumed that the magnetic field affects the presynaptic membrane by hyperpolarization, leading in turn to an increase of the potential at the nerve terminals and eventually to increased mediator outcome resulting from a single stimulus.

Finally, one cannot exclude the possibility that CMF could increase the sensitivity of the subsynaptic membrane of muscle cells towards the mediator, thus also increasing the effectiveness of synaptic transmission. The latter assumption, however, calls for further experimentation.

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THE ENHANCEMENT OF THE EFFECT OF RADIATION THERAPY FOR MALIGNANT TUMORS BY MEANS OF SHF HYPERTHERMAL TREATMENT

Leningrad VOPROSY ONKOLOGII in Russian Vol 24 No 8, 1978 pp 14-19

[Article by N.N. Aleksandrov, S.Z. Fradkin, E.A. Zhavrid, G.V. Muravskaya, I.I. Malinovskiy, A.A. Mashevskiy, V.A. Bezmen, Yu.T. Neborak, A.V. Furmanchuk, M.M. Val'shteyn, D.M. Murav'yeva and A.G. Salamatina of the Scientific Research Institute for Oncology and Medical Radiology of the Belorussian SSR Ministry of Health (Professor N.N. Aleksandrov, director and corresponding member of USSR Academy of Medical Sciences)]

[Text] The authors conducted an experimental (605 animals) and clinical (145 patients) study of the influence of superhigh frequency electromagnetic hyperthermy in conjunction with ionizing radiation on various malignant tumors. It was determined that SHF hyperthermy enhances the effect of radiation therapy on tumors.

Key words: Radiation therapy, enhanced effect, electromagnetic hyperthermy.

Methods of selectively increasing the antitumor activity of ionizing radiation, in particular, by means of hyperthermal exposure, have increasingly attracted the attention of researchers in recent decades [1, 2, 3, 5, 6, 7, 8]. The theoretical aspects of this problem still remain unclear, however, the fact of selective enhancement of the radiation damage to malignant neoplasms under hyperthermal conditions can be considered proved. Various questions of this problem were discussed at the Second All-Union Conference of Oncologists (Tallin, 1972), the Fourth All-Union Conference of Oncologists (Vil'nyus, 1975) and at the International Symposium on the Application of Hyperthermy and Irradiation in the Treatment of Malignant Neoplasms (Washington, 1975). It was considered promising to continue the theoretical, experimental, and especially the clinical studies in this direction. Beginning in 1968 in the Scientific Research Institute for Oncology and Medical Radiology of the Belorussian SSR Ministry of Health, a systematic study was conducted on the effectiveness of radiation therapy under conditions of local and general overheating (thermal radiotherapy).

Chosen as the experimental models were a solid Ehrlich tumor, transplanted into the femur of mongrel mice (105 animals), and sarcoma-45, intertwined in the tails of mongrel rats (500 animals). The effectiveness of thermal radiotherapy was evaluated in a comparative study of the results of groups of trials in which only SHF exposure was used, only gamma therapy was used, as well as for animals which were not subjected to any therapeutic exposures. The SHF hyperthermy was produced by means of equipment with a wavelength of 12.6 cm at an exposure angle of  $41.5^\circ$  for 30 - 60 minutes. The measurement of the temperature in the tumor was accomplished by means of copper-constantan thermocouples. The gamma irradiation ( $\text{Co}^{60}$ ) was carried out with a Luch-1 unit (the exposure range was 60 cm, and the power of the dose was 120 - 125 R/min). The one-time radiation doses amounted to 5.0 - 10.0 J/kg, and the overall doses were 10.0 - 20.0 J/kg.

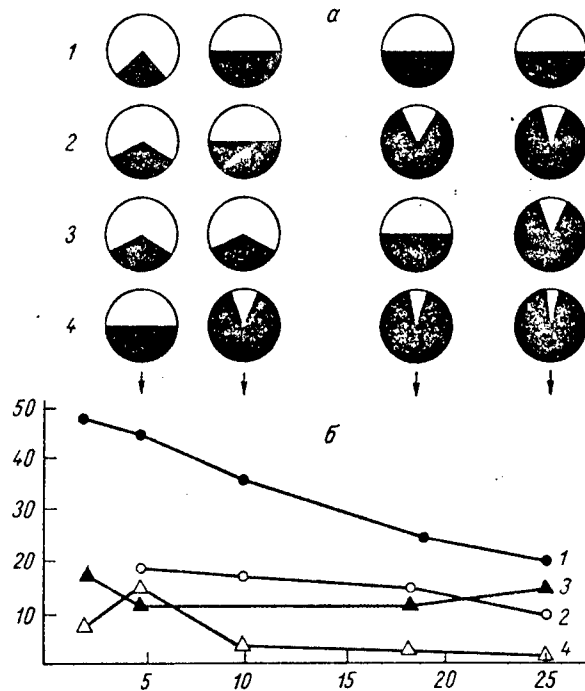


Figure 1. Pathomorphological changes in an Ehrlich tumor as a function of the type of exposure (a: Necrosis area; b: Mitotic index).

Key: 1. Control;  
 2.  $\text{Co}^{60}$  therapy (5.0 J/kg x 4);  
 3. Local SHF hyperthermy ( $41.5^\circ$  for 30 minutes x 4);  
 4. Thermal radiotherapy ( $41.5^\circ$  for 30 minutes, +5.0 J/kg x 4). The black sector is the part of the tumor undergoing necrosis (in percent). The light sector is the surviving part of the tumor. The arrows indicate the days material was taken for histological studies. Plotted along the abscissa are the days from the start of the exposure, and along the ordinate, the mitotic index.

The criteria for the evaluation of the effectiveness of the various exposures were as follows: change in the volume of the tumor, the survival rate of the animal, the specific features of the morphological changes occurring in the tumors (the extent to which destructive changes were pronounced, the necrosis area, and the mitotic index). The changes in the volume of a tumor were computed from the formula:

$$V_t/V_0 = e^{\gamma t} \quad (4)$$

[sic]

A study of the dynamics of tumor growth in the indicated groups of animals showed that both with one-time and repeated radiation under hyperthermal conditions, a significantly greater retardation of tumor growth is observed (no less than 1.5 times) than with radiotherapy alone. The most pronounced necrotic changes were likewise observed in tumors subjected to thermal and radiation exposure (Figure 1). As a result of thermal radiotherapy, the life span of tumor bearing mice proved to be substantially greater than with irradiation or heating alone ( $50.6 \pm 2.9$ ,  $42.8 \pm 2.6$  and  $38.6 \pm 2.0$  days respectively).

For the purpose of ascertaining the optimum time interval between SHF heating and the irradiation, tumor growth dynamics were studied for the following time intervals: less than 5 minutes, 24 hours, 48 hours and 72 hours (Figure 2). As can be seen from the graphs shown, the effectiveness of thermal radiotherapy proved to be the greatest in those cases where the local SHF hyperthermy immediately preceded the irradiation (the interval between two exposures did not exceed 5 minutes), while the least effectiveness was observed at an interval of 72 hours.

To study the question of how often it is necessary to repeat the thermal and radiation therapeutic radiation exposures, we set up three series of trials using rats, into the tails of which sarcoma-45 had been transplanted. In the first series of trials, the tumors were subjected to irradiation by radioactive cobalt alone, and in the second, by SHF hyperthermy alone, and in the third, using a combination of these effects (thermal radiotherapy). Each of the indicated exposures was employed twice at intervals of 24, 48 and 72 hours. In the subsequent days, the degree of regression of the tumor was studied as a function of the size of the interval. The most pronounced regression occurred in animals where the time intervals between the thermal radiation therapeutic exposures were at 24 hours. Based on these data, one can assume that the interval between exposures should as yet not be made greater than 24 hours.

At the present time we have considerable experience in the experimental and clinical use of general and local hyperthermy and hyperglycemia. The equipment, methods and procedures have been developed which assure the control of the hyperthermy modes and make it completely safe for the patient [3].

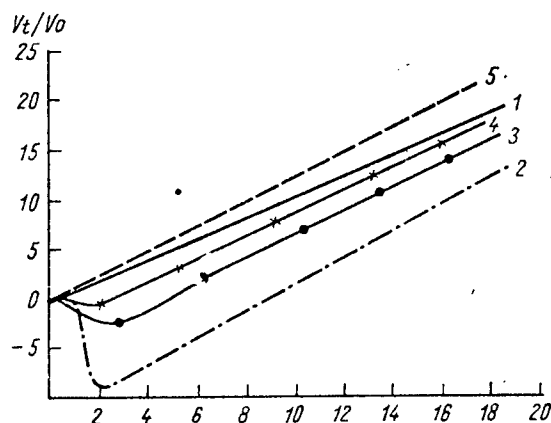


Figure 2. The influence of the time intervals between sessions of one-time local SHF hyperthermy ( $41.5^{\circ} \times 60 \text{ min}$ ) and gamma radiation ( $10.0 \text{ J/kg}$ ) on the growth of sarcoma-45.

- Key:
1. Control;
  2. An interval of less than 5 minutes;
  3. 24 hours;
  4. 48 hours;
  5. 72 hours.

Plotted along the abscissa are the days from the start of the exposure, and along the ordinate, the relative volume of the tumors.

Given below are the basic data on the use of local thermal radiotherapy. Some 145 patients with various malignant neoplasms were subjected to comprehensive treatment using irradiation under conditions of local superhigh frequency electromagnetic hyperthermy (Tables 1 and 2). Some 74 of the 145 patients had cancer of the mammary gland, where more than half were in stage III of the illness. The second most numerous group (41 people) had dermal melanoma. Of them, 12 presented at the clinic in stage II of the illness, and the remainder were in stage III (9), stage IV (6), or suffering relapses and tumor metastases following radical treatment (14). Among the number of other factors complicating the prognosis of patients with dermal melanoma were numerous metastases at the regional lymphatic nodes (15), remote metastases in the lungs, liver, cerebrum (4), pregnancy (1), etc. As far as the 19 patients with malignant tumors of soft tissues were concerned (synovial sarcoma - 5, angiosarcoma - 5, fibrosarcoma - 4, malignant mesenchymoma - 3, and undifferentiated tumors - 2), in 17 of them the tumors were located in the extremities. For 14 of these patients with tumors in the extremities, based on generally accepted indications, it was necessary to perform high amputations or exarticulations of the extremities, and for 2 of the patients such surgical intervention could not be carried out because of the extensive local propagation of the process. Of the 19 patients with soft tissue tumors, only one presented in stage I, neoplasm relapses had occurred in 5, 6 were in

stage III and 4 were in stage IV; 3 of the patients presented at the institute clinic from other treatment institutions following nonradical excision of the tumor. Included in the group of 11 patients with other malignant tumors were patients with metastases and relapses of cancer of the lungs, rectum, gall bladder, larynx (5), hypernephroidal renal cancer (1), extensive cancerous ulcerated skin (1), bone reticulosarcoma (2) and lymphogranulomatosis (2).

**Table 1:** The Distribution of Patients According to the Diagnosis and the Number of Sessions of Local SHF Thermal Radiotherapy

Diagnosis	The Number of:	
	Patients	Sessions
Dermal melanoma	41	346
Including, by stages:		
Stage II	12	90
Stage III	9	68
Stage IV	6	62
Relapses and metastases of the melanoma following radial treatment	14	127
Malignant tumors of soft tissues (synovioma, angiosarcoma, fibrosarcoma and others)	19	212
Cancer of the mammary gland	74	522
Including, by stages:		
Stage II	34	216
Stage III	40	306
Other malignant tumors	11	134
Total	145	1,214

**Table 2:** The Distribution of Patients Subjected to Comprehensive Treatment using SHF Thermal Radiotherapy by Sex and Age

Пол Sex	Age Возраст							Всего In all
	10-19	20-29	30-39	40-49	50-59	60-69	70 лет и более	
Males Мужчины . . . . .	3	9	2	9	4	4	—	31
Females Женщины . . . . .	—	9	18	47	28	10	2	114
Всего больных . . . . .	3	18	20	56	32	14	2	145
For all patients 16							70 yrs and more	

We employ superhigh frequency electromagnetic waves to produce local hyperthermy in the region of a tumor. For the case of relatively small tumors located at the surface (up to 8 cm measured longitudinally or transversely,

and up to 3 - 4 cm in height or depth), an electromagnetic field at a frequency of  $2,450 \pm 49$  MHz was used, and for deeper tumors, a frequency of 460 MHz. The tissue in the irradiation zone was warmed to  $42^\circ$ . In this case, the duration of the hyperthermy for 43 of the patients amounted to 60 minutes and 120 minutes for 102 of them. It must be noted that during the local SHF hyperthermy, sharp changes in the power of the electromagnetic field are to be avoided. The antenna-radiators must be positioned individually in each specific case, thereby achieving the maximum absorption of energy by the tumor.

The ionizing radiation session was conducted at the conclusion of the hyperthermy period. Depending on the dimensions and localization of the tumor, the following types and sources of ionizing radiation were employed: X-ray (TUR-60, RUM-11), gamma rays ("LUCh-1", "ROKUS"), fast electrons (LUE-25, and the betatron of the "Siemens" company with a maximum radiation energy of 42 Mev). The radiation was administered with conventional fractionating (31 persons) or strong fractionating (114 persons) of the zone. In the case of conventional fractionating, a one-time dose of 2.0 - 2.5 J/kg was employed, and the overall dose was from 35.0 to 55.0 J/kg. With strong fractionating, the size of the one-time dose usually amounted to 4.0 - 5.0 J/kg, and the overall dose was 20.0 - 35.0 J/kg. In individual cases, higher overall doses were used (up to 70.0 J/kg).

Local SHF thermal radiotherapy was used as an independent treatment (12 persons) or as preoperative radiation, i.e. as a component of comprehensive therapy (133 persons). In the case of comprehensive treatment, surgical intervention was carried out during the first week after thermal radiotherapy for 65 of the patients (48.9%), after 2 - 2.5 weeks for 54 (40.6%), and at later times for 14 (10.5%). Patients with mammary gland cancer underwent radical mastectomy, those with dermal melanoma underwent as wide an excision of the tumor foci as possible, and in the case of tumors of soft tissues, organ preserving operations were performed (a femur was amputated in only one of the 16 patients for which this operation was generally indicated). For 28 of the 145 patients, the SHF thermal radiotherapy was supplemented with sessions of general hyperthermy, where for 7 persons, these preceded the local thermal radiotherapy, and for 21 persons, they were carried out following thermal radiotherapy and surgery.

In studying the condition of several vitally important systems and functions of the organism, it was determined that cardiovascular activity, liver and kidney functions, acid-alkaline balance and the hemotological status did not undergo any changes which would require intensive corrective treatment because of the influence of local SHF thermal radiotherapy. The course of the postoperative period was not distinguished by any special or specific features. The length of hospital stays did not increase for patients subjected to comprehensive treatment using SHF thermal radiotherapy. Thus, for example, for the case of mammary gland cancer, it amounted to  $65.6 \pm 5.0$  days in the group of patients treated with thermal radiotherapy, and  $79.0 \pm 5.4$  days in the control group.

Table 3: Histological Changes in the Tumors of Patients Following Preoperative SHF Thermal Radiotherapy

<u>The Level of Tumor Destruction</u>	<u>The Number of Patients</u>	
	<u>Absolute</u>	<u>In Percent</u>
Complete disappearance of malignant cells, complete necrosis	36	27.1
Pronounced destructive changes, subtotal necrosis	75	56.4
<u>No pronounced changes</u>	<u>22</u>	<u>16.5</u>
Total	133	100

For 6 of the 12 patients for which SHF thermal radiotherapy was employed as the independent method, disappearance of the tumor was noted, and for 4 of them, a 25-30% decrease in the size of the neoplasm was observed; for 2 of the patients (following previously performed nonradical intervention), the growth of the tumor did not recur.

Of 133 patients for which SHF thermal radiotherapy was conducted for the purpose of preoperative devitalization of the tumor, at the time of the operation, it had ceased to be clinically detectable in 12 of them (9.0%), it had decreased in 96 of them (72.2%), and had retained its previous size in 25 of them (18.8%).

Morphological studies of biopsies showed that in the overwhelming majority of observations, pronounced damage to the tumors was done with SHF thermal radiotherapy, right up to their complete necrosis (Table 3); no such changes were observed in the surrounding normal tissues.

Of the 145 patients treated, 122 are alive at the present time (84.1%), including 106 (73.1%) without a relapse or metastases of the tumor. Of the 122 surviving, 6 have lived less than a year following the completion of treatment, 49 have been observed for up to two years, 47 have been observed for up to three years, 19 for up to four years and 1 up to five years. In the most numerous group of patients, having mammary gland cancer, the results are as follows: all 74 patients survived one year; 54 of 55 survived two years and 17 of 18 survived more than three years. Although the observation periods indicated are still small, nonetheless, if one considers the special features of the contingent of patients described above who were subjected to treatment using SHF thermal radiotherapy, as well as the morphological changes in the tumors following this treatment, then the results obtained immediately and shortly thereafter can be considered reassuring.

The given data show that superhigh frequency electromagnetic hyperthermy represents one of the real ways of increasing the radio sensitivity of tumor tissue. The joint utilization of ionizing radiation and SHF hyperthermy provides for the directed and rapid deactivation of tumor cells. It only

stands to reason that the numerous theoretical and practical aspects of this problem still require further study in depth. In this case, it is necessary to first of all specify more precisely the questions relating to the optimum duration and frequency of the administration of hyperthermal procedures, the intervals between them, as well as the optimum dosage and time relationships between the components of thermal radiotherapy.

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SUTURELESS ANASTOMOSES IN SURGERY OF THE GASTROINTESTINAL TRACT WITH AND WITHOUT STEADY MAGNETIC FIELD (EXPERIMENTAL INVESTIGATION)

Moscow ARKHIV PATOLOGII in Russian No 8, 1978 pp 56-61

[Article by N. N. Kanshin, N. K. Permyakov, R. A. Dzhalagiya, B. I. Nikulin and A. A. Kuznetsov (Moscow), 3d Surgical Clinic (headed by Prof N. N. Kanshin) and Department of Pathological Anatomy (headed by Prof N. K. Permyakov) at Moscow Municipal Scientific Research Institute of Emergency Medical Care imeni N. V. Sklifosovskiy, submitted 22 Mar 78]

[Text] Summary: "Deferred" sutureless gastroduodenal and cecocolic side-to-side anastomoses were made using the devices proposed by N. N. Kanshin to connect hollow organs, in experiments on 52 dogs; studies were made of distinctions of fusion of organ walls under the influence of simple mechanical compression and compression using a steady magnetic field. In both variants, the process of formation of anastomoses is completed on the 6th-7th postoperative day, while spontaneous elimination of compressing elements occurs on the 7th-8th day. Morphological studies of sutureless anastomoses formed with and without exposure to a magnetic field failed to demonstrate a difference between them. The obtained data are indicative of substantial advantages of sutureless methods of joining tissues over the traditional, manual, intestinal suture.

Key words: gastrointestinal tract, sutureless anastomosis, morphology.

We are impressed by the current Soviet and foreign literature dealing with intestinal sutures because of the diversity of sutures and suturing materials. But, at the present time, none of the types of intestinal sutures can be considered perfect. Many operations on the gastrointestinal tract are associated with such terrible complications as postoperative peritonitis, which constitutes 14-15% of all cases of peritonitis (I. A. Petukhov). The chief cause of postoperative peritonitis is patency of anastomotic sutures (N. I. Makhov and G. F. Seleznev; T. P. Makarenko et al.) which occurs in 3-10% of all operations on the gastrointestinal tract (L. I. Sneshko; V. I. Gvindzhiliya et al.; B. P. Ladnyuk et al.).

Data in the literature of recent years indicate that a search is continuing in surgical practice for new techniques to joint tissues, especially different parts of the gastrointestinal tract. Surgeons are striving to develop simpler and more reliable methods of forming anastomoses. Various apparatus and devices are used, which shorten operations considerably and simplify the techniques thereof.

The new technical capabilities and new problems have compelled some researchers to return to the seemingly forgotten question of possibility of forming sutureless anastomoses with mechanical devices such as the Murphy button. Thus, Bacon and Boerema (1954, 1955), Brumelkamp and Sugarbaker designed more sophisticated apparatus for making sutureless anastomoses in organs of the digestive tract.

After analyzing the data in the literature pertaining to the use of suture mechanical appliances for sutureless unions, we concluded that they are contradictory and not backed up by morphological studies of tissues.

The devices proposed by N. N. Kanshin et al. to join hollow organs of the gastrointestinal tract were developed at the Scientific Research Institute of Emergency Medical Care imeni N. V. Sklifosovskiy, Institute of chemical Physics and one of the plants in Moscow. They have the advantage of simple and original design, as well as the possibility of controlling the load on tissues of organs to be joined. By means of these devices, it is possible to create end-to-end, end-to-side and side-to-side anastomoses. Circular appliances make it possible to obtain anastomoses that are patent from the moment they are formed; appliances in the shape of strips, which form "deferred" anastomoses, function only after the compressing elements are sloughed off. For the first time in the history of surgery, a new technique for sutureless anastomoses involves the use of magnetic compressing elements of diverse geometric shapes and dimensions, where the system of complex mechanical appliances is replaced with two magnets. There are specific indications for the use of each of these devices. The common feature of all appliances is that the walls of anastomosed hollow organs are united by means of prolonged compression. This enabled us to pursue the goal of conducting an experimental study of the distinctions of union of walls of hollow organs under the influence of simple mechanical compression and compression with exposure to a steady magnetic field, and to compare this type of union to an intestinal suture, rather than discuss the specific and individual properties of each appliance.

Experiments were conducted in the Department of Experimental Pathology (headed by Prof Yu. M. Gal'perin). "Deferred" sutureless, side-to-side gastroduodenal and cecojunal anastomoses were made in experiments on 52 dogs, with retention of natural patency of the digestive tract, using the simplest magnetic and nonmagnetic appliances (Figure 1).

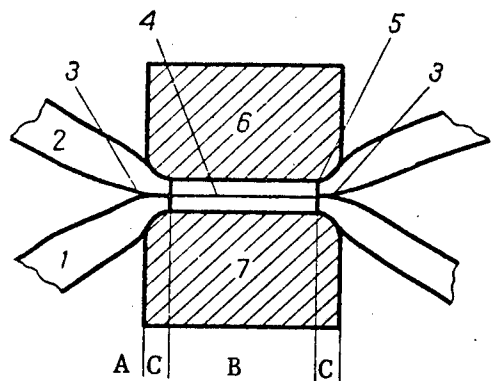


Figure 1.  
Diagram of tissular union by means of constant compression appliances

- 1, 2) tissues to be joined
- 3) area of tissular union
- 4) clamped tissues
- 5) line of tissular necrosis
- 6, 7) compressing elements
- A) tissular area not subject to compression
- B) area of crushing of tissues
- C) area of moderate compression

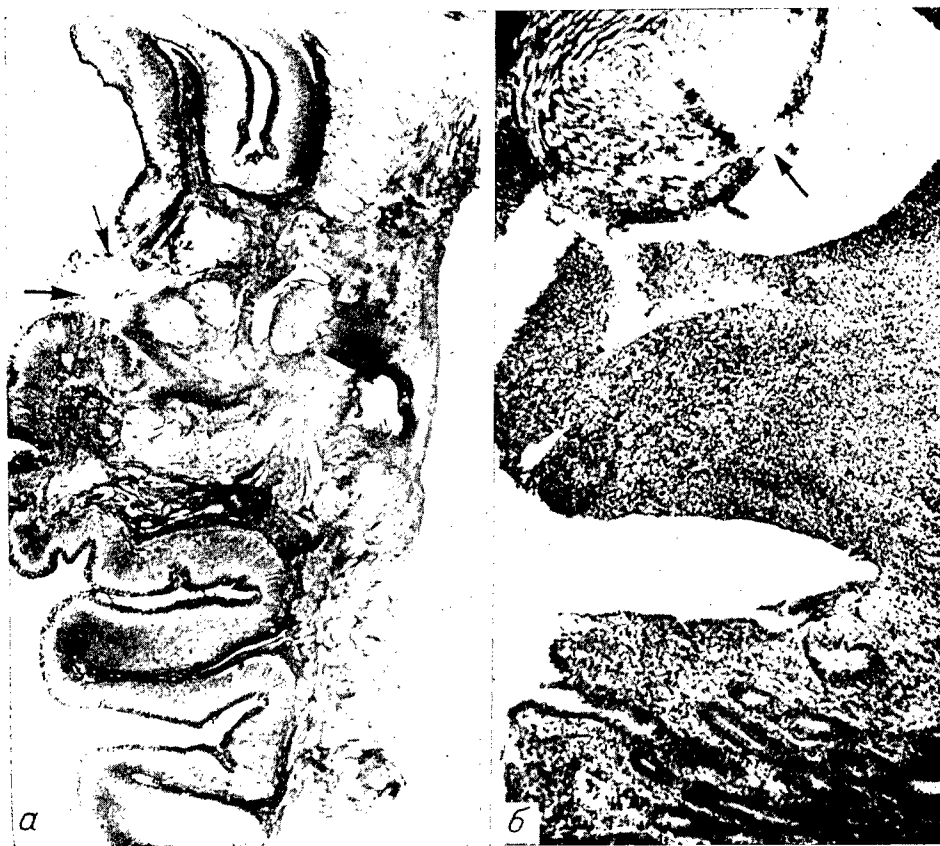


Figure 2. Manual suture, enterotomy, 4th day; hematoxylin-eosin stain

- a) ulcerative defect in suture region (arrows), 15×
- b) large ulcerative defect of mucosa in region of anastomosis; silk suture seen at bottom of ulcer (arrow); 42×

The areas of gastrotomies and enterotomies, through which the compressing elements were inserted in the lumen of the organs were sutured with a Lamber-Albert suture. This type of suture was chosen as the most commonly used in surgery.

We had the animals under careful observation in the post-operative period. They were given water on the 1st day, liquid food from the 2d-3d day on and the usual diet after 5-6 days. The animals were sacrificed on the 2d, 4th, 6th, 7th, 8th, 19th, 15th, 20th, 25th, 30th and 270th days in order to make a more comprehensive study of processes occurring during formation of anastomoses. Morphological studies of the region of sutureless anastomoses were pursued at the same times. After fixation in 10% formalin, pieces of organs were imbedded in celloidin to prepare histotopographic sections through the entire region of the anastomosis. The sections were stained with hematoxylin-eosin, picrofuchsin, according to Mallory, tested for fibrin according to Weigert and, when necessary, the iron reaction was run according to Perls.

The microscopic study confirmed the well-known fact that a manual suture causes severe trauma to all layers of the walls of organs that are joined (Figure 2).

In all cases, we observed adhesion processes, more marked in operations on the large intestine and less so on the small. In the case of a manual suture, massive inflammatory infiltrates are formed in the organ walls around the foreign body, such as suturing material, and a large ulcerative defect develops in the region where the tissular ridge is sloughed off, on the side of the mucosa. Suturing material adherent to the bottom of the ulcer is gradually passed into the lumen of the organ. Mucosal ulcerative defects, particularly when there is much suppurative suturing material at the bottom of the ulcer, undergo epithelization at the late stage (15th-30th postoperative day). Healing processes in the region of union are retarded by microabscesses, which are consistently formed around the suturing material and gradually drain into the intestinal lumen.

Examination of sutureless anastomoses formed with and without a magnetic field failed to demonstrate a difference between them, and wound healing proceeded in a similar manner. As a rule, the process of formation of an anastomosis ends on the 6th-7th postoperative day, while natural elimination of compressing elements occurs on the 7th-8th day. Macroscopic examination of the anastomoses shows that they are formed with minimal inflammatory reaction and in the absence of adhesions.

Histological examination of sutureless unions showed how tissues unite at the edges of the anastomoses. On the 2d postoperative day, the compressed areas of walls of united organs are adherent to one another, thinned down; the mucosa, as well as submucosal and subserous areas are necrotic. There is relative integrity of smooth muscle elements of the walls of organs. At the edges of anastomosed organs, on the boundary of necrosis, an inflammatory

infiltrate of polynuclears develops, which gradually forms a narrow inflammatory ridge by the end of the 2d day. The subserous areas of anastomosed fragments are somewhat edematous and joined by thick fibrinous film. The mucosa adjacent to the future anastomosis line is somewhat atrophic; it is of normal structure in remote areas. By the 4th day, there is proliferation of fibrin film by fibroblasts with formation of more dense adhesions; there is proliferation of granulation tissue, which demarcates entirely the necrotic compressed regions, in the region of the demarcation line. On the 6th day after applying the compressing elements, a rather dense fibrous adhesion is formed at the edges of the anastomosis, in which we encounter islets of unorganized fibrin and fatty tissue. In the sloughing area, there is a small (2-3 mm long) defect, the bottom of which consists of fibrin-covered granulation tissue. At the edges of the ulcerative defect, there is proliferation of lining epithelium of the mucosa, with a tendency toward epithelization of the surface of the ulcer. The margins of the mucosa of anastomosed organs are suspended over and connect above this defect, as a result of which the latter cannot be discerned with the naked eye. The edges of the anastomosis are firmly united by a narrow band of newly formed connective tissue by the 7th-8th day; the ulcerative defect is completely covered by single-layer columnar epithelium (Figure 3).

Thereafter, there is increasing consolidation and collagenization of the adhesion that joins the edges of anastomosed organs; the union of the walls becomes more and more firm, while the adhesion proper changes into a narrow fibrous band that is barely discernible upon microscopic examination. There are regeneration and reorganization of mucosal membranes of anastomosed organs, with total restoration thereof, and it is only in the actual area of union of anastomosed small and large intestine, or small intestine and stomach, that one can detect microscopically that the narrow band of the region of union of heterogeneous mucosal membranes is covered with single-layer columnar epithelium.

The distinctive features of this type of healing of anastomoses are the absence of massive inflammatory infiltrates in the walls of the organs that are being joined and the fact that healing of anastomoses occurs like primary healing of a wound defect. Experimental investigation of this type of tissular union revealed several appreciable advantages over traditional, manual intestinal sutures. A high degree of technical training of the surgeon is required to make a manual intestinal suture, while the technique for anastomoses using compressing elements is of the utmost simplicity and can be performed by a surgeon of any qualification. The use of sutureless methods of joining tissues saves considerable time, as compared to manual methods of making anastomoses. The substantial advantage of the sutureless method is that it is aseptic; there are no conditions in the anastomosis that would allow infection to penetrate deep into the intestinal wall and free abdominal cavity, whereas gastric and intestinal contents always seep through along suturing lines. Sutureless anastomoses are formed with a minimal inflammatory reaction in tissues of organs to be united, and this is confirmed by the absence of an adhesion process in the anastomotic region.



Figure 3. Sutureless anastomoses formed with the use of magnetic compressing elements; hematoxylin-eosin stain

- a) cecojejunal anastomosis, 8th day; total closure of ulcerative defect by single-layer columnar epithelium (arrows); 42×
- b) gastroduodenal anastomosis, 15th day; anastomotic region (arrows) is of the same thickness as walls of anastomosed organs--small intestine (1) and stomach (2); 15×

All of the positive features of sutureless methods of joining organs, demonstrated in experiments on dogs, have been confirmed in clinical practice pertaining to diverse operations on the esophagus, biliary tract, stomach, small and large intestine, with good immediate and long-term (up to 3 years) results.

#### Conclusions

1. Experimentally, a new method of forming "deferred" anastomoses between various organs of the gastrointestinal tract was applied, with the use of solid [without openings] compressing elements. This model made it possible to investigate the distinctions of union of tissues that are joined by means of compressing elements.

2. We failed to demonstrate differences between healing of anastomoses made by means of sutureless union of tissues with or without a magnetic field.

3. A comparison of various sutureless methods of uniting tissues to manual intestinal sutures revealed several substantial advantages to anastomoses formed by compressing elements: the operation is easy to perform, no special instruments are required with the use of magnetic elements, the inflammatory reaction of tissues to the compressing elements is less marked than in the case of an intestinal suture, and there is virtually no adhesion process in the region of the anastomosis.

4. Morphological studies of sutureless anastomoses revealed that union of the walls of anastomosed organs occurs like the primary healing of a wound defect, without formation of a coarse cicatrix that leads to narrowing of the anastomosis.

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## BIOLOGICAL EFFECTS OF STATIC ELECTRIC FIELDS AS FUNCTION OF DIRECTION OF THEIR LINES OF FORCE

Moscow GIGIYENA I SANITARIYA in Russian No 7, 1978 pp 24-26

[Article by K. I. Stankevich, doctor of medical sciences, All-Union Scientific Research Institute of Hygiene and Toxicology of Pesticides, Polymers and Plastics, Kiev, submitted 5 Sep 77]

[Text] In view of the fact that man is exposed to static electric fields (SEF) with different directions of lines of forces in relation to his body, it is quite important to know about the nature of biological effects of SEF; however, in the literature available to us there is no information on this score. There are only data (Guy et al.) pertaining to differences in absorption of magnetic fields by different parts of the body, which were obtained on a human model. An electric field that is perpendicular to the transverse plane elicits maximum absorption in the region of the neck, malleoli and knees, i.e., where the transverse section is very small. Areas of large transverse section, such as the trunk and head, are less susceptible. A field perpendicular to the frontal plane forms vertical current that increases the distance to the line that is perpendicular to the frontal plane to the center of the trunk, and it reaches a maximum on the circumference of the trunk. Peak levels are formed in areas that are close to the axis and perineum, where there are acute angles in tissues. The density of absorption increases with the square of field frequency and magnitude.

In order to investigate the biological effects of SEF under model conditions, we developed a special unit consisting of a glass chamber. There are plate electrodes over and under the chamber, and they can be moved closer or farther from the chamber, or their position in relation to the chamber can be altered, by means of brackets, generating different SEF voltage in the chamber and different directions of force lines in relation to the animal's body. Aero-franklinizers are used as the SEF generator. A kilovoltmeter was installed between the aerofranklinizer and chamber to monitor the SEF generated by the former. The aerofranklinizer is connected to a 220 W alternating current system. The voltage of the field in the chamber is regulated on the basis of the formula,  $E = \frac{U}{H}$ , where  $U$  is voltage read on kilovoltmeter dial,  $H$  is the distance between electrodes. The field in the chamber is regulated by both the aerofranklinizer and by changing the distance between electrodes.

The studies of biological effects of SEF were conducted on mongrel white rats, the voltage and direction of lines of forces of SEF varying in different tests. The experiment lasted for 2 months, exposing the animals to electric fields of 1100, 300 and 150 V/cm. We used tests that are widely known in the literature, which we had tried previously for setting hygienic SEF standards and which were found to be the most informative, to study the effects of SEF as function of voltage of lines of forces: levels of serotonin in brain tissue and blood, the product of its breakdown, 5-hydroxyindoleacetic acid (5-HOIAA), 24-h diuresis and calcium content of blood serum.

Table 1. Serotonin content of brain tissue (in  $\mu\text{g/g}$  wet tissue) of animals exposed to SEF varying in direction of lines of forces

SEF, V/cm	Direction of SEF force lines in relation to animal's body	Exper. No	Time after start of experiment	Statistical index		
				$M \pm m$	$t$	$P$
1100	Perpendicular	1	Background	$0,039 \pm 0,001$	1,81	$< 0,05$
			2 weeks	$0,051 \pm 0,0013$	6,4	$> 0,05$
			1 month	$0,053 \pm 0,0016$	8,8	$> 0,05$
	Horizontal	2	2 months	$0,051 \pm 0,0007$	20,0	$> 0,05$
			Backgr.	$0,041 \pm 0,0014$	0,5	$< 0,05$
			2 weeks	$0,038 \pm 0,0012$	4,0	$> 0,05$
300	Perpendicular	1	1 month	$0,058 \pm 0,0012$	14,0	$> 0,05$
			2 months	$0,071 \pm 0,004$	10,0	$> 0,05$
			2 weeks	$0,035 \pm 0,001$	4,0	$> 0,05$
	Horizontal	2	1 month	$0,038 \pm 0,0006$	1,0	$< 0,05$
			2 months	$0,04 \pm 0,0025$	0,4	$< 0,05$
			2 weeks	$0,058 \pm 0,002$	1,2	$< 0,05$
150	Perpendicular	1	1 month	$0,047 \pm 0,006$	1,3	$< 0,05$
			2 months	$0,042 \pm 0,0025$	0,9	$< 0,05$
			2 weeks	$0,033 \pm 0,001$	1,3	$< 0,05$
	Horizontal	2	1 month	$0,039 \pm 0,003$	0	—
			2 months	$0,04 \pm 0,001$	1,0	$< 0,05$
			2 weeks			

Table 2. Serotonin content of blood ( $\mu\text{g/ml}$ ) of animals exposed to SEF varying in direction of lines of forces

SEF, V/cm	Direction of SEF force lines in relation to animal's body	Exper. No	Time after start of experim.	Statistical index		
				$M \pm m$	$t$	$P$
1100	Perpendicular	1	Backgr.	$0,02 \pm 0,0023$	0,7	$< 0,05$
			2 weeks	$0,0161 \pm 0,0002$	8,0	$> 0,05$
			1 month	$0,054 \pm 0,00012$	2,0	$> 0,05$
	Horizontal	2	2 months	$0,020 \pm 0,0003$	3,0	$> 0,05$
			Backgr.	$0,025 \pm 0,0007$	1,1	$< 0,05$
			2 weeks	$0,019 \pm 0,026$	1,7	$< 0,05$
300	Perpendicular	1	1 month	$0,061 \pm 0,0014$	15,0	$> 0,05$
			2 months	$0,052 \pm 0,0003$	14,5	$> 0,05$
			2 weeks	$0,02 \pm 0,001$	0,09	$< 0,05$
	Horizontal	2	1 month	$0,019 \pm 0,001$	1,0	$< 0,05$
			2 months	$0,017 \pm 0,0004$	2,0	$> 0,05$
			2 weeks	$0,024 \pm 0,001$	0,03	$< 0,05$
150	Perpendicular	1	1 month	$0,016 \pm 0,0006$	2,0	$> 0,05$
			2 months	$0,019 \pm 0,006$	5,0	$> 0,05$
			2 weeks	$0,028 \pm 0,003$	1,8	$< 0,05$
	Horizontal	2	1 month	$0,02 \pm 0,0002$	1,79	$< 0,05$
			2 months	$0,013 \pm 0,0004$	1,9	$< 0,05$
			2 weeks			

Table 3. 5-HOIAA content ( $\mu\text{g}$ ) in urine of animals exposed to SEF varying in direction of lines of forces

SEF, V/cm	Direction of SEF force lines in relation to animal's body	Exp. No.	Time after start of experim.	Statistical index		
				$M \pm m$	$t$	$P$
1100	Perpendicular	1	Backgr.	$52,7 \pm 3,3$	1,9	$< 0,05$
			2 weeks	$18,0 \pm 2,1$	7,0	$> 0,05$
			1 month	$16,57 \pm 1,07$	9,4	$> 0,05$
			2 months	$10,55 \pm 1,1$	4,8	$> 0,05$
	Horizontal	2	Backgr.	$54,2 \pm 2,8$	0,2	$> 0,05$
			2 weeks	$32,1 \pm 4,18$	0,8	$< 0,05$
300	Perpendicular	1	2 weeks	$30,5 \pm 1,17$	2,4	$> 0,05$
			1 month	$40,85 \pm 3,0$	0,8	$< 0,05$
			2 months	$14,0 \pm 0,99$	9,0	$> 0,05$
			1 month	$24,82 \pm 1,3$	5,0	$> 0,05$
	Horizontal	2	2 months	$30,5 \pm 2,9$	2,1	$> 0,05$
			2 weeks	$20,7 \pm 0,5$	4,0	$> 0,05$
150	Perpendicular	1	1 month	$20,2 \pm 1,99$	6,0	$> 0,05$
			2 months	$34,3 \pm 0,28$	1,6	$< 0,05$
			2 weeks	$25,9 \pm 0,8$	0,1	$< 0,05$
			1 month	$32,2 \pm 1,4$	1,8	$< 0,05$
	Horizontal	2	2 months	$36,7 \pm 0,3$	1,0	$< 0,05$
			2 weeks			

Table 4. 24-h diuresis (ml) in animals exposed to SEF varying in direction of lines of forces

SEF, V/cm	Direction of SEF force lines in relation to animal's body	Exp. No.	Time after start of experim.	Statistical index		
				$M \pm m$	$t$	$P$
1100	Perpendicular	1	Backgr.	$5,8 \pm 0,03$	0,5	$< 0,05$
			2 weeks	$3,28 \pm 0,4$	5,0	$> 0,05$
			1 month	$2,35 \pm 0,1$	18,3	$> 0,05$
			2 months	$2,7 \pm 0,48$	6,0	$> 0,05$
	Horizontal	2	Backgr.	$6,0 \pm 0,1$	1,7	$< 0,05$
			2 weeks	$5,9 \pm 0,57$	0,8	$< 0,05$
300	Perpendicular	1	1 month	$5,5 \pm 0,07$	2,5	$> 0,05$
			2 months	$3,03 \pm 0,2$	5,1	$> 0,05$
			2 weeks	$2,16 \pm 0,06$	1,6	$< 0,05$
			1 month	$3,9 \pm 0,2$	4,5	$> 0,05$
	Horizontal	2	2 months	$5,0 \pm 0,3$	4,0	$> 0,05$
			2 weeks	$2,35 \pm 0,155$	0,7	$< 0,05$
150	Perpendicular	1	1 month	$3,0 \pm 0,19$	3,0	$> 0,05$
			2 months	$5,6 \pm 0,1$	1,9	$< 0,05$
			2 weeks	$2,3 \pm 0,04$	1,0	$< 0,05$
			1 month	$4,7 \pm 0,1$	0,9	$< 0,05$
	Horizontal	2	2 months	$7,0 \pm 0,21$	0,4	$< 0,05$
			2 weeks			

The data we obtained, which are submitted in Tables 1-4, indicate that there are substantial differences in biological effects of SEF, depending on the direction of force lines in relation to the body of experimental animals. Thus, in the case of a 1100 V/cm SEF, there is a statistically reliable increase in serotonin content of brain tissue from the 2d week of the experiment on with vertical direction of force lines, and this parameter remained high throughout the experiment. Consequently, the SEF elicits a more active

effect and earlier changes with vertical force lines in relation to the animal's body. SEF of 300 V/cm intensity also elicits statistically reliable changes in serotonin content of brain tissue, but they are temporary and disappear by the end of the 1st month. There is no appreciable change in serotonin content of both the brain and blood with exposure to 150 V/cm SEF, regardless of the direction of lines of force, whereas at 1100 and 300 V/cm this index remains impaired in blood throughout the experiment. Statistically reliable changes were observed in 5-HOIAA content with both directions of force lines of SEF; however, they were more marked with vertical direction. This index changed in the direction of decrease, and this is probably indicative of decreased metabolism of serotonin and accumulation thereof in tissues in excess of the physiological norm. In animals exposed to 1100 and 300 V/cm SEF, oliguria was particularly significant with vertical lines of force, and this is probably attributable to spastic reactions of afferent arterioles, on the one hand, and increased secretion of antidiuretic hormone, on the other. There was no impairment of diuresis with 150 V/cm SEF. The opposite tendency was observed with exposure to 1100 and 300 V/cm SEF varying in direction of lines of force: blood serum calcium content increased with vertical direction and decreased in the case of horizontal direction.

Thus, these studies confirmed the hypothesis that SEF has different biological effects, depending on the direction of its lines of force in relation to the body. The obtained data indicate, once more, that the hygienic standard for SEF is in the range of 150-200 V/cm. The difference in biological effects as function of direction of force lines in relation to the body must be taken into consideration when man is exposed to rooms or ecosystems where SEF can build up not only in horizontal but vertical planes.

#### Conclusions

1. The biological effectiveness of SEF was established as a function of direction of its lines of force in relation to the body of experimental animals.
2. With vertical direction of force lines, earlier and more marked changes are observed in such indices as serotonin content of brain tissues and blood, its metabolite 5-HOIAA, diuresis and blood serum calcium. This is probably attributable to greater absorption of SEF lines of force that are vertical in relation to the animal's body.
3. The data pertaining to the biological effects of SEF varying in direction of lines of force in relation to the body must be taken into consideration in setting hygienic standards for SEF in inhabited premises.

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PROBABLE ROLE OF HYPOTHALAMUS IN PATHOGENESIS OF VEGETATIVE DISTURBANCES IN PRESENCE OF SHORT-TERM EXPOSURE TO A CONSTANT MAGNETIC FIELD

Moscow PATOLOGICHESKAYA FIZIOLOGIYA I EKSPERIMENTAL'NAYA TERAPIYA in Russian No 3, 1978 pp 23-27

[Article by N. P. Smirnova and L. D. Klimovskaya, Moscow; submitted 13 May 1976]

[Text] The effect of a constant magnetic field of 1,000-4,000 oersteds on the functional state of the hypothalamus was studied in chronic experiments on 20 rabbits. It was demonstrated that exposure to a constant magnetic field causes the bioelectric activity spectrum of the hypothalamus to shift to higher frequencies and the reaction of photic rhythm assimilation to become more intense. A study of the effects of high-frequency stimulation revealed intensification of the descending effects of the hypothalamus on the circulation and respiration with maintenance of the usual level of its intracranial stimulating influence. The results obtained suggest participation of the hypothalamus in the development of vegetative disturbances occurring in response to exposure to a constant high-intensity magnetic field.

There are 2 illustrations and 17 references.

The constant magnetic field is becoming a more and more significant environmental factor. The problem of the nature of the effect of a constant magnetic field on the organism is being discussed at the present time: on the one hand, the possibility of the occurrence of pathological phenomena is considered, and on the other hand, application in medical practice. In people exposed to a constant magnetic field under production conditions over a prolonged period of time, stable functional disturbances of the cardiovascular system were discovered: an inclination toward hypotension, bradycardia or tachycardia, a reduction in the voltage of the abdominal complex and a shift of the T-curve on the EKG, and local vasovegetative disturbances [3]. In the experiments on animals, it was demonstrated that exposure to a constant high-intensity magnetic field in a wide range (from 200-400 to 7,000

oersteds) can lead to a reduction in the arterial pressure and heart contraction rate, slowing of respiration, disturbance of thermal regulation [4-7, 11, 16-17]. The nature of the observed vegetative shifts and their reversibility suggest that they are based on a disturbance of the regulation mechanism. The special role of the hypothalamus in maintaining homeostasis, including integration of the neuroendocrine and vegetative regulatory mechanisms, provides a basis for estimating the functional state of this division of the brain on exposure to a constant high-intensity magnetic field. Based on the intensity of the bioelectric reaction, some authors consider the hypothalamus to be among the brain structures most sensitive to a constant magnetic field [2, 8-10, 14-15].

In the present paper the changes in the background and imposed bioelectric activity of the hypothalamus, its intracentral effect and also the descending effects on the vegetative functions were studied in rabbits with total exposure to a constant magnetic field of 1,000-4,000 oersteds for 1-24 hours.

Procedure. Chronic experiments were performed on 20 awake rabbit with implanted electrodes. An SP-15A electromagnet with flat parallel pole shoes was used in the experiments. The magnetic field was in practice uniform in the central part of the space between poles 300 x 200 mm in size. The intensity drop in the remaining section did not exceed 15-20 percent. For exposure times of 1 hour the rabbits were placed in the gap of the magnet held belly down on the bench; for 24-hour exposures they were placed in a plexiglass cage. Thus, the rabbits were subjected to total exposure to the constant magnetic field with vertical passage of the lines of force. The given intensity was reached in 30 seconds. Control experiments were run on the same animals in an analogous situation under analogous holding conditions. The spontaneous bioelectric activity was picked up unipolarly by silver electrodes from the cerebral cortex and by nichrome electrodes with a tip diameter of 150 microns from the subcortical structures. An inert electrode was attached to the concha auricularae. The biocurrents were recorded on an electroencephalograph with automatic frequency analyzer. The analysis time was 10 seconds, and the averaging of the frequency integrator readings was performed in 1 minute. In order to study the reaction of photic rhythm assimilation, the rabbit was exposed to rhythmic flashes of light at a frequency of 2, 6, 12, 18 and 24 hertz from a photo-phonostimulator for 1 minute with a minute interval between them. The degree of assimilation of one rhythm or another was estimated by the variation in intensity of the corresponding band in percentages of the initial value. The EKG at the II standard lead and respiration were recorded in parallel on an encephalograph; the arterial pressure was measured by the acute method in the femoral artery by a mercury manometer. The high-frequency stimulation of the hypothalamus was realized by unipolar rectangular current pulses lasting 0.1 millisecond from an electronic stimulator. The stimulation frequency was 300 pulses/second lasting 30 seconds. The stimulation intensity was selected individually for each rabbit in preliminary experiments. It corresponded to the subthreshold current for the occurrence of an expressed motor reaction. The location of the implanted electrodes was monitored histologically on removal of the animal from the experiment.

Results and Discussion. High-voltage activity spikes in the alpha- or beta-frequency range appear on the electrohypothalamogram (EHG) of the rabbits during exposure to the constant high-intensity magnetic field (see Figure 1). The expression of the changes varies to a significant degree in individual animals, but on the whole it increases with an increase in the intensity of the effect. For an intensity of 3,000-4,000 oersteds, the total power of the EHG is elevated to 130-150 percent, and a shift of the bioelectric activity spectrum to higher frequencies is observed. According to the average data, the content of delta and theta rhythms decreases and the beta<sub>1</sub>- and beta<sub>2</sub>-rhythm content increases on the EHG in 1 minute of exposure to the constant magnetic field (4,000 oersteds) (see Figure 1, bottom). After the exposure is over, the frequency characteristic is basically recovered. The theta-rhythm content reaches the initial level during the exposure time and significantly exceeds it in the aftereffect period. It must be noted that the changes in the bioelectric activity on exposure to a constant magnetic field are of a generalized nature and extend obviously to many regions of the brain [12, 14-15]. In order to estimate the functional significance of the frequency shift of the bioelectric activity a study was made of the capacity of the hypothalamus to assimilate the imposed rhythms. Exposure to the constant magnetic field (1,000 oersteds) led to intensification of the photic rhythm assimilation reaction, which was expressed both in an expansion of the range of assimilated frequencies and in an increase in the reaction to individual frequencies. These changes were observed both while the animal was in the field and during the aftereffect period, which is obvious from the examples presented in Figure 2. In the presence of a more intense constant magnetic field, it was possible to observe attenuation of the reaction to the light stimuli in the range of frequencies intensified in the background rhythmic, and at the end of exposure, on restoration of the frequency characteristic of the EHG just as on exposure to a field of 1,000 oersteds, intensification of the reaction. In the rabbit, the results of the experiment on which are presented in Figure 2, clearly only the 24-hertz rhythm was assimilated before exposure to the constant magnetic field; in the constant magnetic field (3,000 oersteds) this rhythm ceased to be assimilated, but slow rhythms--2 and 6 hertz--began to be assimilated. After switching the electromagnet on, by comparison with the initial data the assimilation of a frequency of 24 hertz was intensified, and the assimilation range was expanded as a result of the 2.6- and 12-hertz frequencies.

The shift of the bioelectric activity spectrum to higher frequencies and intensification of the imposed rhythm assimilation reaction observed on exposure to a constant magnetic field is properly considered as predominance of the processes of stimulation and elevation of the lability of the nerve elements of the hypothalamus. In order to solve the problem of how these phenomena are felt in the hypothalamic regulatory mechanisms, studies were made of the effects of the high-frequency stimulation of the hypothalamus. On exposure to a constant magnetic field, the ordinary effects of the hypothalamus on the other formations of the central nervous system were maintained. During high-frequency stimulation of the hypothalamus in the background rhythmic of the cerebral cortex, the hippocampus and the reticular

formation of the mesencephalon, as a rule, predominance of the theta rhythm occurred. The frequency characteristic of the electrograms was quickly restored after cessation of the stimulation. During and after the exposure to the constant magnetic field (4,000 oersteds) the expression of the intracerebral activating effects of the hypothalamus did not change noticeably. On the other hand, exposure to a constant magnetic field led to a change in the reactions of the circulation and respiration apparatus to stimulation of the hypothalamus. Both in the presence of the constant magnetic field and immediately after the end of the exposure, the stimulation of the hypothalamus in rabbits could cause sharper increase in respiration frequency, more expressed bradycardia, and a stronger pressor reaction. Thus, whereas before exposure to the constant magnetic field the respiration frequency during stimulation of the hypothalamus increased on the average to 130 percent of the initial level, in the constant magnetic field it rose to 170 percent. The cardiac contraction rate during stimulation before exposure to the constant magnetic field dropped insignificantly (97 percent), and during exposure to 80 percent. In the rabbit with a stimulating electrode located in the dorsomedial nucleus of the hypothalamus, the bioelectric reaction in the form of the appearance of a regular theta rhythm in the electrograms of the cerebral cortex, the hippocampus and the reticular formation of the mesencephalon as a result of exposure to a 4,000-oersted constant magnetic field did not undergo significant changes, but the respiration reaction and the pressor effect were sharply intensified, and after exposure, noticeable bradycardia occurred, and the motor component of the reaction appeared. The intensification of the reaction to stimulation of the hypothalamus by a current of constant intensity observed on exposure to a constant magnetic field indicates elevation of excitability of the corresponding structures of the hypothalamus. The intensification of the hypothalamic effects on the vegetative functions, the shift of the bioelectric activity spectrum to higher frequencies, improvement of the assimilation of the imposed rhythms can indicate elevation of the functional activity of the hypothalamus in animals exposed to a constant high-intensity magnetic field. Even for a less intense constant magnetic field (300-520 oersteds) which has no significant effect on the central regulation of the cardiac activity and respiration, intensification of the vegetative effects of the stimulation of the posterior hypothalamus and ventral nuclei of the thalamus was noted in individual experiments [16]. Accordingly, the increased noradrenalin content detected in the hypothalamus in rabbits after 24 hours of exposure to a 1,000-oersted constant magnetic field is of interest [13]. Obviously, on exposure to a constant magnetic field both the purely nervous and the neuroendocrine hypothalamic mechanisms are affected. Under analogous experimental conditions to ours, data were obtained on the elevation of the neurosecretory function of the hypothalamus in rabbits for a field intensity of 1,000 oersteds, replaced by the exhaustion phase with significant increase in the exposure time or intensity [1].

The presented data suggest the conclusion that the change in functional state of the hypothalamus and its regulatory effects plays a significant role in the development of the vegetative shifts which occur on exposure to

a constant magnetic field. For identical effects of the constant magnetic field of sufficiently high intensity these shifts are of a transient functional nature and probably cannot be interpreted as the development of a pathological symptom complex. However, under the conditions of prolonged repeated exposures to a constant magnetic field it is possible to predict the development of deeper and more stable disturbances which can be classified as the manifestation of vegetative dystony.

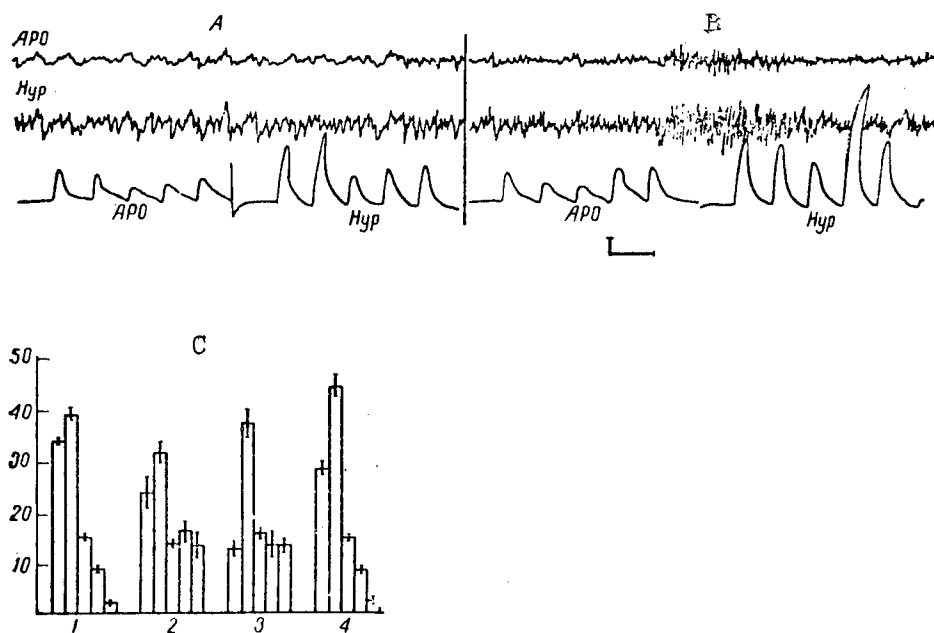


Figure 1. Effect of a constant magnetic field on the bioelectric activity of the hypothalamus. A and B--Electrophypothalamogram before and during exposure to a 3,000-oersted constant magnetic field. Lead from the medial preoptic region (APO) and the dorsomedial nucleus of the hypothalamus (Hyp). The calibration of amplification of 50 microvolts of time--1 second. C--Frequency characteristic of the EHG according to the average data. The content of the bio-currents of the corresponding frequency band is plotted on the y-axis in percentages of the total EHG power. On the x-axis we have: 1 and 4--before and after exposure to the constant magnetic field, respectively; 2 and 3--exposure to a 4,000-oersted constant magnetic field for 1 and 60 minutes, respectively. The columns denote five successive frequency bands--delta, theta, alpha, beta<sub>1</sub> and beta<sub>2</sub>.

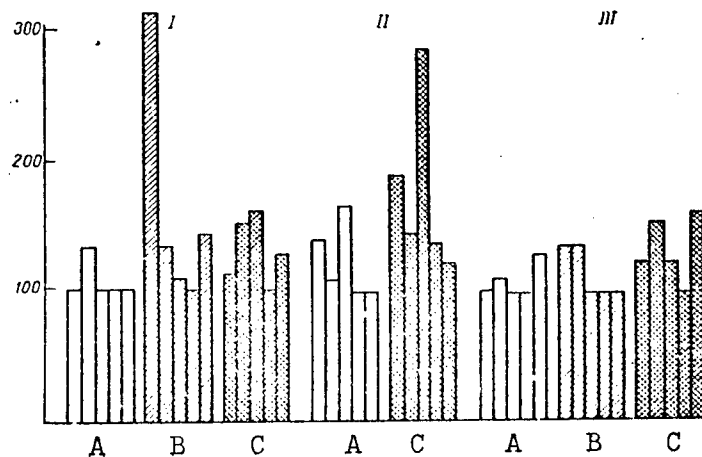


Figure 2. Effect of a constant magnetic field on photic rhythm assimilation by the hypothalamus (individual data). I--1,000 oersteds, exposure time 1 hour; II--1,000 oersteds, exposure time 24 hours; III--3,000 oersteds, exposure time 1 hour. A--Before exposure; B--during exposure; C--after exposure. The variation in the intensity of the biocurrents of the corresponding frequency band is plotted on the y-axis in percentages of the initial value taken as 100. The columns denote the five successive frequency bands--delta, theta, alpha, beta<sub>1</sub> and beta<sub>2</sub>.

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EFFECT OF LOW-INTENSITY MICROWAVES ON HEMODYNAMIC CHANGES IN ANIMALS WITH AN ACUTE INFLAMMATORY PROCESS IN ABDOMINAL CAVITY

Moscow PATOLOGICHESKAYA FIZIOLOGIYA I EKSPERIMENTAL'NAYA TERAPIYA in Russian No 3, 1978 pp 28-30

[Article by V. I. Bachurin, Department of Surgery (head of department--Prof S. M. Lutsenko) of Zaporozh'ye Medical Institute; submitted 26 October 1976]

[Text] The regional hemodynamics of the brain and extremities of rabbits with an acute inflammatory process in the abdominal cavity was studied in animals that had been first exposed to microwaves with a square of stream power of 10 milliwatts/cm<sup>2</sup> (exposure time 1 hour daily for 3 months). It was demonstrated that by the 7th day after an appendectomy, disturbance of the regional hemodynamics was observed in the form of vascular spasm and blood stasis, especially in the extremities. By the end of the 7th day the hemodynamics were in practice completely restored in the control group of animals.

There are 8 references and 1 table.

Among the extremal factors occurring under production conditions, microwave energy plays one of the leading roles. It has been proved [3-4, 7] that microwaves not only cause functional, but, under defined conditions, also morphological changes. There are reports on the results of observing the effects of microwaves on the course of a number of pathological processes [2, 8], the hemodynamics of the internal organs [1, 5], and so on. However, the nature of the variation of the regional hemodynamics in the presence of an acute inflammatory process in the organism previously exposed to microwaves, has not been discussed.

Procedure. Experiments were performed on 41 rabbits. Fifteen out of the 41 served as a control group, and 26 were exposed to irradiation by the GZ-10A generator at a frequency of 300 millihertz, lambda 10 cm, FFP 10 milliwatts/cm<sup>2</sup> with a daily exposure of 1 hour for 3 months.

A middle laparotomy was performed on all of the rabbits under hexenal narcosis (10-percent solution intraabdominally reckoning 1 ml/kg) with subsequent ligation at the base of the appendicular arterial process and a number of its vascular small intestinal anastomoses with the cranial mesenteric artery. Only one or two ramuli were left untied. One of them was at the base, and the other at the top of the process. Changes developed in the process similar to those in the presence of acute appendicitis, including its destructive forms [6]. A typical appendectomy was performed after 12-14 hours.

In the preoperation period and on the 1st, 3d and 7th days after the operation rheography was run on the brain and one of the rear extremities using the RG-1-01 rheograph. The electrodes were made of foil 0.5 x 1 cm in size.

To record the rheoencephalograms, the electrodes were placed in the masto-frontal position. To record the rheovasograms, one electrode was placed in the upper and the other in the lower third with respect to the outside surface of the rear extremity. The fur was removed by a depilator or 10-percent solution of sodium sulfide. The recording was made using the Elkar machine with a tape speed of 50 or 100 mm/sec. The EKG in the II standard lead was recorded synchronously. The following parameters of the rheograms were analyzed: 1) the pulse rate while recording the rheogram (T); 2) the change in vascular tonus with respect to the anacrotic phase in percentages (a percent); 3) the volumetric blood filling with respect to height of the base wave in ohms, that is, the product of the rheographic index times the calibration signal ( $A, \text{ohm} = [A, \text{mm/h, mm}] \times 0.1 \text{ ohm}$ ); 4) degree of blood-filling of the vessels, that is, the quotient from dividing the height of the base wave (in ohms) by the anacrotic phase expressed in percentages ( $K = [A, \text{ohm/a}\%] \times 100\%$ ).

Results and Discussion. When analyzing the rheograms, defined dynamics of the changes in activity of the cardiovascular system was noted under the effect of microwaves before the operation. The latter was expressed in a sharp elevation of vascular tonus in the irradiated animals, especially in the extremities. The volumetric bloodfilling was reduced not only in the extremities, but also the brain (see the table).

It is of interest that in the rabbits of the control group, after ligation of the vessels, but before the appendectomy, the vascular tonus of the brain rose by 15-16 percent ( $P < 0.05$ ), the height of the base wave had a tendency toward an insignificant reduction and, as a consequence, the blood-filling index did not change. In the extremities the vascular tonus did not exceed the normal. The base wave did not change, and in practice the degree of bloodfilling did not undergo any alterations.

After the appendectomy, a number of changes were observed on the part of the hemodynamics of the brain and the extremities. Thus, after 1 day a rise in vascular tonus of the brain by 20-25 percent ( $P < 0.05$ ) and in the lower extremities by no more than 10-15 percent ( $P < 0.05$ ) was noted against a background of mild reduction in the rheogram recording time (tachycardia). The

height of the base wave of the brain also decreased within the limits of 10-15 percent ( $P < 0.05$ ), and the lower extremities, within the limits of 20-22 percent ( $P < 0.05$ ). Accordingly, the blood-filling index of the brain decreased within the limits of 3-5 percent ( $P < 0.05$ ), and the lower extremities, 5-10 percent ( $P < 0.05$ ). On subsequent days, a tendency was noted toward normalization of all the hemodynamic indices. By the end of the 7th day the hemodynamics of the brain and the extremities in practice were completely restored.

Hemodynamic Indices ( $M \pm m$ )

Показатель реографии* (1)	(2) Облученные кролики		(5) Необлученные кролики	
	до перевязки сосудов	после перевязки сосудов	до перевязки сосудов	после перевязки сосудов
	(3)	(4)	(3)	(4)
T:				
головной мозг (5)	0,31±0,006	0,24±0,010	0,23±0,006	0,23±0,005
задняя конечность (6)	0,29±0,004	0,24±0,043	0,23±0,051	0,22±0,004
a%:				
головной мозг (5)	18,8±1,3	21,7±1,5	15,2±1,9	17,5±2,1
задняя конечность (6)	32,2±2,4	26,4±2,1	25,6±2,1	25,2±2,3
A, ohms:				
головной мозг (5)	0,10±0,003	0,09±0,041	0,31±0,017	0,25±0,015
задняя конечность (6)	0,13±0,021	0,22±0,023	0,13±0,016	0,12±0,014
K:				
головной мозг (5)	0,70±0,005	0,58±0,008	1,7±0,053	1,1±0,068
задняя конечность (6)	0,42±0,089	0,85±0,096	0,46±0,084	0,48±0,066

\*The notation is explained in the text.

- |                               |                         |
|-------------------------------|-------------------------|
| Key: 1. Rheographic index     | 5. Unirradiated rabbits |
| 2. Irradiated rabbits         | 6. Brain                |
| 3. Before ligation of vessels | 7. Rear extremity       |
| 4. After ligation of vessels  |                         |

The hemodynamics of the brain and the extremities has significant differences for the irradiated rabbits. After ligation of the appendicular vessels of the mesenteric branches, the tonus of the brain vessels rose by more than 11-15 percent ( $P < 0.05$ ). Simultaneously, the height of the base wave dropped within the limits of 10-12 percent ( $P < 0.05$ ). The degree of blood-filling decreased against the background of the noted tachycardia, but by no more than 18-20 percent ( $P < 0.05$ ) by comparison with the normal. The changes in the hemodynamics of the lower extremities were clearly determined. The vascular spasm tended toward a decrease by more than 12-15 percent ( $P < 0.05$ ). Simultaneously, the height of the base wave rose by 69-70 percent ( $P > 0.05$ ). The degree of bloodfilling increased, most probably as a result of stagnation. Twenty-four hours after the appendectomy the tachycardia continued to build which was indicated by a decrease in the rheogram recording time. The vascular tonus of the brain increased by more than 10-11 percent ( $P < 0.05$ ). Against this background the height of the basic wave was reduced by almost 50 percent ( $P < 0.05$ ). The degree of bloodfilling of the vessel also dropped by more than 40 percent ( $P < 0.05$ ). After 3 days the

changes on the part of the hemodynamics were expressed quite clearly. The vascular tonus of the brain rose by more than 44-45 percent ( $P < 0.05$ ) by comparison with the normal, but during this period the height of the base wave was equal to that before ligation of the vessels. This was immediately felt in the degree of bloodfilling, increasing by comparison with that during the previous 24 hours by 17-18 percent ( $P < 0.05$ ), but not reaching the normal. By the end of the 7th day the vascular tonus exceeded the normal by more than 27-30 percent ( $P < 0.05$ ). At the same time the height of the base wave was identical with normal. In spite of this fact, the degree of bloodfilling did not reach the initial level, remaining within the limits of 27-30 percent ( $P < 0.05$ ).

The hemodynamics of the extremities were characterized by tendencies toward a reduction in the vascular tonus 24 hours after the appendectomy within the limits of 19-20 percent ( $P < 0.05$ ), lowering of the base wave height by more than 50 percent ( $P < 0.05$ ). The degree of bloodfilling was also reduced within the limits of 35-36 percent ( $P < 0.05$ ). Maximum changes were observed by the end of the 3d day. During this period, the tachycardia was sharply expressed. The vascular tonus exceeded the initial tonus by 26-27 percent. The height of the base wave rose somewhat, but it was only 72 percent ( $P < 0.05$ ) of the initial value. Accordingly, the degree of bloodfilling reached 57-60 percent ( $P < 0.05$ ) of the initial value. By the end of the 7th day the vascular tonus exceeded the normal by no more than 5-8 percent ( $P < 0.05$ ). Simultaneously, the height of the base wave did not reach the normal level within the limits of 5-10 percent ( $P < 0.05$ ).

Thus, a nonequivalent response reaction was noted on the part of the cardiovascular system to the exposure to microwaves in the rabbits of both groups, especially against the background of an acute inflammatory process in the abdominal cavity. In the animals previously exposed to microwaves, disturbances of the regional hemodynamics in the form of vascular spasm and blood stasis of the extremities were expressed even 7 days after the appendectomy.

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EFFECT OF ELECTROMAGNETIC WAVES IN THE CENTIMETER RANGE ON BLOOD CLOTTING AND FIBRINOLYTIC SYSTEM (EXPERIMENTAL INVESTIGATION)

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[Text] As we know the physiological and therapeutic effects of natural and preformed factors are based on the same neurohumoral mechanism. The body's reaction is directed toward restoring equilibrium, which is impaired by disease, stimulating mechanisms of defense, adaptation and compensation. In view of the specificity of physical factors, one can specifically treat certain systems of the body, depending on their state and functional correlations.

The influence of physical factors on the hemostasis system is of particular interest from this standpoint. Disclosure of the principal patterns of changes therein and mechanisms of onset of the latter, distinctive features with regard to regulation of the state of this system under the influence of physiotherapeutic agents would increase the efficacy of therapy of diseases associated with impaired hemostasis.

The need for such studies is also due to the sparse and contradictory information on this score. Moreover, most studies in this direction were pursued under conditions that cannot be used in therapeutic practice.

Our main objectives here were to investigate the correlation between the coagulant effect of microwaves and conditions under which they are used, to determine the optimum parameters of energy of SHF fields in the centimeter range (12.6 cm) affecting hemocoagulation in animals, as well as to study the mechanism of action of electromagnetic waves on the system of hemostasis.

We studied the changes in some indices of the animal coagulogram under the influence of electromagnetic oscillations in the centimeter range (2375 MHz frequency). These studies were pursued with 50 healthy chinchilla rabbits kept under the usual vivarium conditions.

The animals were exposed to microwaves delivered by a Luch-2 using the contact method. The electrode was placed on the shaved skin in the region of the liver, in which most clotting factors are synthesized. A set of biochemical tests was used to describe the blood coagulating and anticoagulating systems: recalcification time, prothrombin and thrombin times, concentration of free heparin, heparin tolerance of plasma (Ye. P. Ivanov and I. I. Danilin), fibrinase activity (V. P. Baluda et al.), fibrinolytic activity (A. Sh. Byshevskiy) and fibrinogen content (R. A. Rutberg). The tests were conducted before exposure (control), immediately and 1, 2, 6 h after exposure. The obtained data were submitted to processing by the method of variational statistics (P. F. Rokitskiy).

Three series of experiments were conducted, in which exposure conditions were varied with regard to power and duration.

In the first series, we tested the effect on clotting of single exposure of animals to microwaves varying in energy (2.5 and 10 W) for 10 min. It was found electromagnetic oscillations have marked hypocoagulant properties. As a rule, the most significant changes in the coagulogram were observed 1-2 h after exposure. At this time, the state of the blood clotting system was related to intensity of irradiation. More significant changes, in the direction of slower clotting, were observed after exposure to 5 W microwaves. This was manifested by an increase in recalcification time ( $134.9 \pm 3.57$ , versus  $113.9 \pm 1.71$  s in the control;  $P < 0.001$ ), decreased plasma heparin tolerance ( $534.7 \pm 4.02$  and  $396.0 \pm 6.70$  s;  $P < 0.001$ ). Exposure at 2 and 10 W induced less and almost the same degree of hypocoagulation changes. Free heparin was an exception, and its level diminished ( $8.2 \pm 1.06$  and  $6.1 \pm 0.64$  s, respectively, versus  $11.3 \pm 0.16$  s in the control;  $P < 0.01$  and  $< 0.001$ ).

At all tested intensities, microwaves also influenced fibrinolysis, as indicated by increased activity of the fibrin-stabilizing factor and decreased fibrinolytic activity of blood. There was a decrease in amount of fibrinogen with the use of 2 and 5 W microwaves, whereas it fluctuated over the normal range at 10 W.

Virtually all indices of the coagulogram were close to base values 6 h after exposure. Only the concentration of free heparin and fibrinolytic activity of blood differed appreciably from the control.

In the second series of experiments, we investigated the changes in the coagulogram as function of exposure time (10 and 20 min) with a constant intensity of radiation (5 W). The obtained data revealed that longer single exposure of the rabbit liver region leads to a more significant decline of coagulating activity of blood. Maximum changes were observed in free heparin content of blood. As compared to 10-min exposure, this index tripled with 20-min exposure. With longer exposure periods, we observed a highly reliable increase in prothrombin and thrombin times, recalcification time, decrease in plasma heparin tolerance and fibrinolytic activity of blood.

In the third series of experiments, we studied the distinctions referable to delivery of a course of microwaves at 5 W lasting 10 min. Coagulation properties of blood were tested after 1, 5 and 10 exposures. With increase in number of sessions (particularly up to 5), there was intensification of the hypocoagulant effect of electromagnetic waves on the animal's body, as compared to single exposure. As in the preceding series of experiments, blood free heparin content underwent the most appreciable change. It showed a maximum increase after the 5th session ( $60.2 \pm 6.44$  s versus  $13.9 \pm 0.85$  s in the control;  $P < 0.001$ ) and decreased visibly after the 10th; however, it did not revert to the base level, even 6 h after exposure. A maximum increase in recalcification time and blood fibrinolytic activity was demonstrated after the 10th session and maximum decrease in heparin tolerance, after the 5th. In this group of animals, maximum changes in coagulogram indices were observed 1 h after exposure. Six h after a course (10 sessions) of microwaves most of the studied indices were close to the control level. The system of hemostasis reverted completely to normal 24-48 h after exposure to SHF electromagnetic waves.

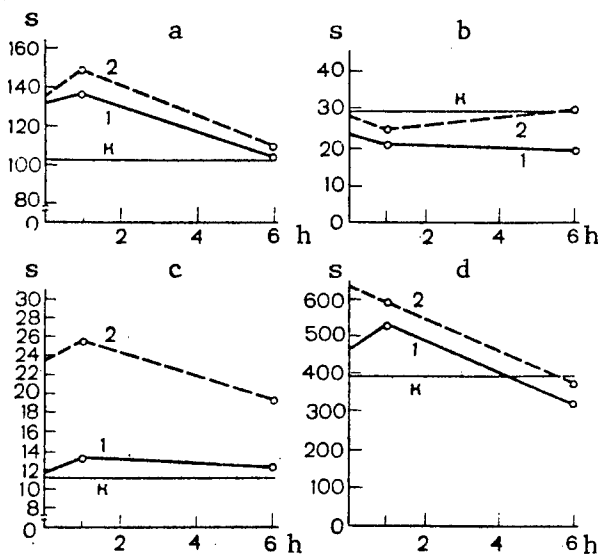
Effects of microwaves on plasma clotting properties in vitro ( $M \pm m$ )

Coagulogram index, s	Control	Experiment
Recalcification time	$111.0 \pm 2.45$	$140.0 \pm 2.40^*$
Prothrombin time	$28.2 \pm 0.23$	$26.1 \pm 1.28$
Thrombin time	$27.8 \pm 0.26$	$28.0 \pm 0.87$
Free heparin	$9.8 \pm 0.29$	$12.2 \pm 0.68^*$
Plasma heparin tolerance	$359.0 \pm 10.68$	$487.5 \pm 12.58^*$
Fibrinase	$27.1 \pm 0.79$	$26.6 \pm 1.63$

Note: Asterisks refer to reliable differences, as compared to control ( $P < 0.05$ ).

We could outline two possible routes of expression of the effects of microwaves on the blood clotting process. The first implies the direct influence of this physical agent on blood clotting factors. Identification of this mechanism may help in the study of the direct effects of waves in the centimeter range on blood clotting. For this purpose, we conducted a special series of in vitro experiments: samples of plasma stabilized with sodium oxalate (1:9) were exposed to electromagnetic waves delivered by a Luch-2 unit. The results of these experiments (see Table) revealed that microwaves retard clotting, as confirmed by the reliable decrease in plasma heparin tolerance, increase in recalcification time and free heparin content. Evidently, the anticoagulant effect of electromagnetic SHF waves in the in vitro experiments was attributable to the specific action of the physical factor. It is related to resonance absorption of energy of SHF waves by molecules of water and protein, associated with hydrophobic-hydrophilic fluctuations of the latter. This creates the conditions for changes in direction and rate of biochemical reactions upon which hemocoagulation is based.

The second possible mechanism of this action is a neuroreflex influence on regulation of hemostasis. Cutaneous receptors play an important role in neuroreflex reactions of the organism and transformation of energy of a physical factor into a physiological process. We conducted studies with exclusion of receptors to confirm involvement of the neuroreflex mechanism in the hemostatic action of microwaves. Demonstrating changes in clotting properties of blood under the influence of microwaves, against the background of blocked receptors on the skin surface exposed to these waves, we observed enhancement of the hypocoagulation effect (see Figure). Administration of agents that stimulate or depress the central nervous system (caffeine, barbamy) was also associated with a marked change in hypocoagulant effect of microwaves. The foregoing confirms convincingly the importance of the reflex mechanism in effects of microwaves on the blood clotting system of animals. At the same time, we do not rule out involvement of the adreno-sympathetic system, the functional state of which is of basic importance to hemostasis (B. A. Kudryashov; A. A. Markosyan; S. A. Georgiyeva, 1968, 1969, 1975; S. A. Georgiyeva et al.; P. V. Sergejev et al.; N. N. Petrishchev; Perlik and others).



Changes in some indices of blood clotting after exposure to microwaves against the background of anesthetized cutaneous receptors

- a) recalcification time
- b) prothrombin time
- c) free heparin
- d) plasma heparin tolerance
- K) control
- 1) microwaves
- 2) microwaves + anesthesia

The results of these studies revealed that a change in functional state of the adrenals (adrenalectomy, administration of ACTH) attenuates the anticoagulant effect of microwaves immediately after exposure, while blood clotting increases 1-2 h later. This unquestionably indicates that the adrenals play an important role in expression of the action of centimeter waves on hemocoagulation in animals.

Thus, SHF electromagnetic waves have marked activity, and when the region of the liver is submitted to local radiation they induce a decrease in blood

clotting. The hypocoagulant effect is substantially related to conditions of delivery of microwaves (intensity and duration of exposure, number of sessions). Maximum delay in clotting occurs with prolonged exposure at 5 W. The mechanism of the hypocoagulant effect of centimeter waves includes the influence thereof both directly on blood clotting factors and on neurohumoral regulation of hemostasis.

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