Possibilities of using numerical methods in assessing the impact of low-frequency pulsed magnetotherapy

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SUMMARY

The possibility of obtaining quantitative indicators that objectively characterize the therapeutic dose during therapy using a pulsed magnetic field has been investigated. Possibilities of numerical methods of theoretical dosimetry (program "SEMCAD") in assessing the therapeutic application of pulsed magnetic fields are shown.

Keywords: "SEMCAD ", pulsed magnetic fields, bioresonance therapy, exogenous bioresonance therapy, therapeutic dose, numerical methods.

RESUME

The possibility of obtaining quantitative evaluation describing the therapeutic dose for the treatment using a pulsed magnetic field is researched. The possibilities of numerical methods of theoretical dosimetry (software "SEMCAD") in the therapeutic application of pulsed magnetic fields are shown.

Keywords: "SEMCAD ", pulsed magnetic fields, exogenous bioresonance therapy, curative dose, numerical methods, bioresonance therapy.

The therapeutic use of physical factors is focused on obtaining one or several well-defined therapeutic effects and should not allow the formation of side, non-therapeutic effects in the patient both during treatment and in his later life. Low-frequency pulsed magnetic fields are one of these factors, since, along with high therapeutic efficacy, they are characterized by the absence of side effects and the possibility of adverse effects on the patient's body [1]. All this predetermined the use of magnetic fields in a pulsed mode in the method of exogenous bioresonance therapy with fixed frequencies. Recently, the field of application of variable magnetic fields has expanded significantly, the frequency range has shifted to a lower frequency region,

The nature of the reactions occurring in the patient's body depends on the parameters of the active signal (the shape of the pulses, their duration and repetition rate), as well as on the magnitude of the field induction, time and direction of the impact (area and spatial location) of magnetic fields [3]. The combination of these parameters forms a therapeutic effect (therapeutic dose). The correct selection of the dose is difficult due to the limited information on the quantitative ratios in the absorption and distribution of pulsed magnetic fields in the human body. It should be noted that, despite the sufficiently thoroughly studied therapeutic effect of magnetic fields, including pulsed ones, the issues of dosimetry, in relation to their therapeutic use, remain unresolved so far [4].

In the overwhelming majority, dosimetry of magnetic fields is predominantly focused on safety issues and forms the basis of all regulatory documents.

The therapeutic effects of a pulsed magnetic field during exogenous bioresonance therapy are not high-intensity and are not characterized by an excess of the energy they carry, the value of which is optimal for initiating the reactions in the body that underlie the therapeutic effect. Among all types of physical factors used in therapy, it is magnetic fields that do not allow the choice of dose, focusing on the patient's subjective sensations, for example, heat, as is used in ultra-high-frequency therapy [5]. It should be emphasized that the reason for this is not only low intensity, but also the absence of specific magnetoreceptors in the human body, which could cause subjective sensations in the patient, thereby allowing to create an idea of the magnitude of the dose of the acting magnetic field.

can serve as an objective criterion for choosing the optimal parameters and duration of the therapeutic effect of a pulsed magnetic field in exogenous bioresonance therapy. When conducting low-frequency pulsed magnetotherapy, it is advisable to assess the effectiveness and direction of the impact, as well as the duration of therapy.

Methods of electropunctural diagnostics make it possible to individually assess the influence of external therapeutic influences, including an alternating magnetic field, on the body based on the control of the adaptation reactions of the patient's autonomic nervous system (ANS). The assessment of the adaptive response of the ANS is carried out by measuring the electrical conductivity and registering the absolute indicators of the electrical conductivity of biologically active points (R. Voll's method) or by analyzing the dynamic state of the electrical conductivity of the reproduced biologically active point under functional load (the method of vegetative resonance test (ART)) [6, 7].

During electropuncture testing according to R. Voll's method, measurements are taken at points interconnected with organs and systems that require correction of their condition. In this case, the parameters of a low-frequency pulsed magnetotherapy effect are selected to achieve an adaptive response expressed in the normalization of BAP values.

In electropunctural testing by the ART method, the selection of the parameters of a low-frequency pulsed magnetotherapy effect is carried out upon achievement of the reaction of compensation of the functional load with ART test indicators, such as the determination of effective and tolerable therapeutic effects and the accompanying positive dynamics of integrative indicators.

For further research, justification efficiency and search new magnetotherapy impacts present practical interest research the spread of the magnetic field in the tissues of the human body and the magnitude of the eddy currents and electric fields caused by them. Since all tissues of the human body, with rare exceptions, are weak paras or diamagnets, a low-frequency alternating magnetic field in the frequency range from a few Hz to hundreds of kHz freely penetrates the body and induces an alternating electric field inside it, which leads to the appearance of electric currents. In accordance with Maxwell's equations, the density of the induced eddy current in the tissuesJ (A / m2) formed by an external sinusoidal magnetic field with a frequency f (Hz) and induction B (T), is equal to [eight]:

$$J = \pi r f \sigma B,$$

where r is the radius of the induction loop, m; σ - tissue electrical conductivity, cm / m.For a pulsed magnetic field, the following expression is valid:

$$J = 0{,}5\ r\ \sigma \frac{dB}{dt},$$

where dD / dt is the rate of change in the magnetic flux density.

Thus, in the most general case, the induced current density is proportional to the radius of the induction loop, tissue conductivity, and the rate of change in the magnetic flux density. Accordingly, more intense currents arise in tissues with a higher electrical conductivity.

The assumption that the current density induced in the tissues of the human body is J is the onea quantitative quantity that determines the biological effects of alternating magnetic fields was expressed by J. Bernhardt [9]. In particular, it was theoretically established that magnetic fields that can induce currents with a density of more than 1 mA / m in the nervous and muscle tissues2 are capable of producing adverse or hazardous effects to human health. At the same time, this value cannot be considered a threshold value for the implementation of starting (trigger) reactions, if only due to the fact that the tissues of the body have different electrical conductivity, and, consequently, different values of the currents induced in them [10]. The latter is especially important, since exogenous bioresonance therapy with fixed frequencies is characterized by the fact that a systemic therapeutic effect is realized at the level of the organism. The magnitude of the currents induced in tissues is an important factor for the biological action of alternating magnetic fields, which at the macroscopic (organismal) level can have a greater magnitude than at the microscopic (cellular) level. In this regard, one should not ignore the well-grounded proposal of K.

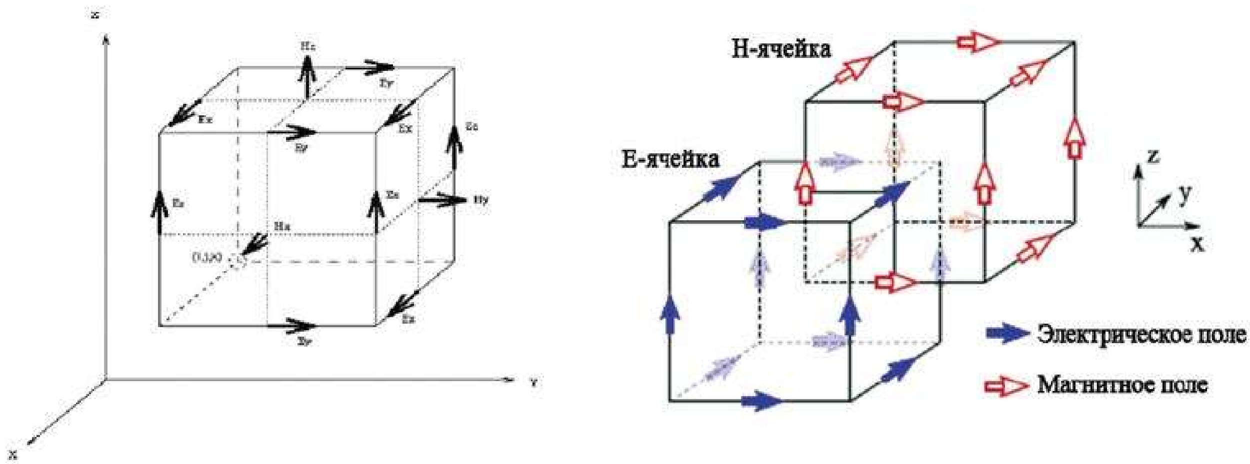
the basis of the formed biological response [11] (Fig. 1).

Much attention has been paid to engineering calculations of magnetic fields in the low frequency range created by elementary emitters, such as an induction coil (inductor) or a frame [1]. However, when exposed to magnetic fields in the case of exogenous bioresonance therapy, the complexity of the calculation lies in the fact that the pulsed magnetic field propagates in at least two media - air and tissues of the human body. Quantitative characteristics for the magnitude of the effective intensity of the pulsed magnetic field can be obtained only with the help of theoretical dosimetry. There are a large number of various numerical methods for dosimetry of electromagnetic fields as applied to biological objects, including humans, but none of them can be considered as universal and suitable for use in all situations.

Rice. 1. Schematic representation of the three-element structure of biological mechanisms interaction of variable H-fields: macrodosimetry, microdosimetry and the formation of a response reactions. According to [11] as amended.

The intensive development of the use of the numerical solution of Maxwell's equations for modeling electromagnetic fields in complex objects, including biological ones, began after the publication in 1966 of FS Yee's work [12]. In this article, the basic algorithm of the method was first proposed, which later became known as the method of finite differences in the time domain (English abbreviation - Finite Difference Time Domain, FDTD). The FDTD method is a numerical method for solving Maxwell's partial differential equations [13]. Since the FDTD method works in the time domain, it is applicable to solving problems of electrodynamics in a wide frequency range. The field of application of the FDTD method has especially expanded in recent years as a result of its application to a wide variety of problems, including dosimetry of electric and magnetic fields.

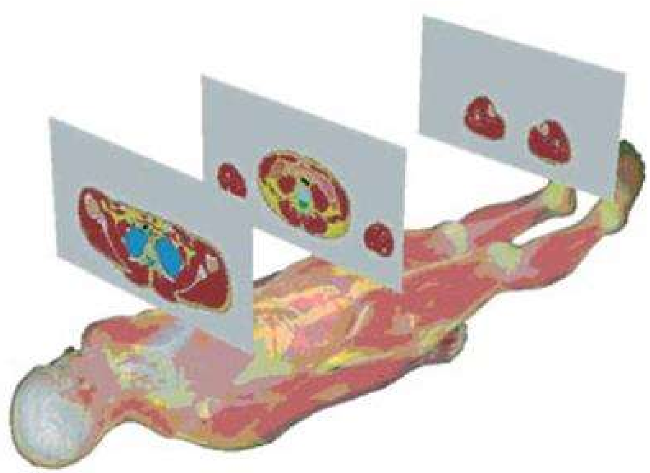
The FDTD method uses models divided into unit cells (voxel) of a certain shape, most often cubic, which, in principle, are suitable for the formation of any object (Fig. 2). It is assumed that the electrical properties (conductivity and capacitance) and the value of E or H-field in each cell are constant. For calculations, the electrical properties of each cell are selected in accordance with the electrical conductivity and dielectric constant of the simulated tissues (for example, blood, skin, bones, muscle and adipose tissue) at a specific frequency. The sizes of each cell depend on the tasks to be solved, and the smaller they are, the greater the spatial resolution, i.e. the accuracy of the method, with a simultaneous increase in the duration of the calculations.



Rice. 2. The nature of the distribution of E- and H-fields in the cells used in the methodFDTD.

In our studies, we used the SEMCAD program, which is based on the FDTD method, which allows us to simulate the structure and nature of the absorption of the energy of a pulsed magnetic field in the tissues of the human body in the frequency range used in exogenous bioresonance therapy - from 10 to 1000 Hz. The SEMCAD program was developed by Schmid & Partner Engineering AG, SPEAG, (Switzerland) [12] together with the IT'IS Foundation for Research on Information Technology in Society, Switzerland [15].

Using the "SEMCAD" program allows you to theoretically determine the value of currents induced in biological tissues when a pulsed magnetic field is applied to a certain area or zone of the patient's body. In our studies, we used a model with a cell size of 4 x 4 x 4 mm, which made it possible, with an optimal accuracy for the tasks being solved, to present the anatomy of the modeled area and to carry out calculations in a reasonable time and fully use the computational resources. The applied version of the model makes it possible to obtain an objective and complete anatomical picture of the section in any area of the human body (Fig. 3).



Rice. 3. Model of the human body, presented with three sections. By [fourteen].

During the simulation, a “loop” magnetic therapy device with localization in the neck and upper chest, which is one of the most commonly used in exogenous bioresonance therapy, was used. A pulsed magnetic field with a frequency of 465 Hz was used in the calculations.

The results obtained made it possible to obtain a qualitative characteristic of the impact in the form of the structure of the distribution of currents generated by a pulsed magnetic field in the cross section of the human body. A quantitative assessment was obtained in the form of the values of currents induced in various tissues. According to the data obtained, the theoretical values for the induced currents were in the range from 0.04 to 0.5 mA / m2... The obtained values do not exceed the maximum permissible values for this frequency range and signal structure, according to the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [16].

conclusions

The possibilities of the SEMCAD program for the use of numerical methods of theoretical dosimetry in the therapeutic application of pulsed magnetic fields, including for exogenous bioresonance therapy, are shown.

It was found that the maximum values of the induced currents do not exceed the values of the maximum permissible values for this frequency range and signal structure, according to the existing international recommendations of the International Commission on Protection against Non-Ionizing Radiation.

The authors are grateful to Prof. N. Kuster (IT'IS Foundation, Zurich) for providing the SEMCAD program for research.

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Gotovsky, M.Yu. Possibilities of using numerical methods in assessing the impact of low-frequency pulsed magnetotherapy / M.Yu. Gotovsky, S.Yu. Perov // Traditional medicine. - 2010. - No. 2 (21). - P.4-8.

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