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Research Article

Relief of Peripheral Neurogenic Chronic Pain by Exposure to Weak Magnetic Field

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Abstract

The study of increased neuron sensitivity to weak (up to 1 mT) alternating (70-200 Hz) external magnetic fields allows for the development of a new electromagnetic stimulation (EMS) method for relieving peripheral neurogenic chronic pain based on changing the firing activity of pain neurons. Clinical trials were approved by the Ethics Committee. The EMS was tested at the National Medical Research Center of Psychiatry and Neurology im. V. M. Bekhterev on a group of volunteers diagnosed with diffuse spine osteochondrosis, muscular tonic syndrome, and lumbodynia. Obtained results confirm that weak (up to 400 μT) external alternating magnetic field has the physical ability to affect conductivity of neurons which transmit the signal from the pain receptor and thus relieve pain. Magnetic field was applied topically to the pain point, and pain was relieved after one or several 20-30-minute sessions. The following ranges of alternating magnetic field were used to relieve peripheral neurogenic pain in specific regions of the spine: cervical – 70-80 Hz, thoracic – 110-130 Hz, and lumbar – 80-130 Hz. The main advantages of the EMS method include its noninvasiveness, selective effect, ability to account for patients' individual characteristics, and the absence of side effects.

Keywords: Neurogenic chronic pain, Magnetic field

Acronyms: MBE – Magnetobiological effect; EMS – Electomagnetic stimulation; Hz – Unit of frequency that measures alternating magnetic field; μT, mT – units that measure magnetic field induction

Introduction

When studying the impact of weak (up to 1 mT) magnetic fields on the peripheral nerve system, the authors detected super sensitivity of nerve cells to alternating magnetic fields of certain frequencies exhibited by a change in neuron conductivity during the transmission of input signals. Conductivity of some neurons dropped sharply under exposure to certain frequencies of alternating magnetic fields, which resulted in a change in characteristics of the transmitted signal. The authors assumed that the detected effect could be used to block signals transmitted by neurons within specific subsystems, e.g. signals from pain receptors. The authors conducted studies in order to determine more precise characteristics of applied magnetic fields capable of blocking neuron signals. They chose to focus on the pain signal [1,2] which reflected an acute pain sensation that allowed for better tracking of changes caused by the application of the EMS method.

Background

Chronic pain relief is among the most important issues for applied medicine [3]. According to the definition of the International Association for the Study of Pain [4], "chronic pain is defined as pain that lasts or recurs for more than three months". Chronic pain is currently perceived not as a symptom, but as a disease in itself which requires special attention and complex etiopathogenic treatment. Pursuant to the "Survey of chronic pain in Europe" [5], "Chronic pain of moderate to severe intensity occurs in 19% of adult Europeans, seriously affecting the quality of their social and working lives". According to the Russian Association for the Study of Pain (RASP) [6], the share of people suffering from chronic pain in Russia varies between 13.8% and 56.7%, the average being 34.3 cases per 100 people, and the number continues to increase.

Disorders which affect the generation and conductivity of nociceptive signals in nerve fibers and disrupt processes that control the excitability of nociceptive neurons in the brain and spinal cord [7] serve as the physiopathological source of neuropathic pain syndromes. Conventional approaches to chronic pain relief either eliminate the source of pain or inhibit the transmission of pain signal along the nerve fibers. The latter is typically achieved by chemical means at the level of synaptic modulation of pain neurons. Main disadvantages of such solutions include their invasiveness, the need to determine the dosage of prescribed pain relievers and duration of their effect, and the lack in the selectivity in inhibiting pain transmission pathways.

The use of strong permanent external magnetic fields for chronic pain relief allows for partial resolution of the aforementioned disadvantages as they pertain to invasiveness and the use of pain relievers, but strong magnetic fields with tens and hundreds of mT induction may have hidden and delayed side effects. The problem with selective inhibition of nerve fibers has not been addressed, possibly due to the lack of knowledge about possible mechanisms of magnetic fields' effect on neurons.

Alternating magnetic fields with relatively high induction (20–50 mT and higher) are also used for chronic pain relief [8,9]. Under these methods, magnetic fields are applied to large body areas (e.g. general magnetic therapy affects the entire human body) and, therefore, affect not only afferent nerve fibers which transmit pain, but also efferent fibers which ensure motor activity, which is not always acceptable. Moreover, topical magnetic therapy commonly uses several magnetic sources. In this case, pain relief takes several days, and it takes anywhere between 10 days and 1 month to cure pain completely.

It is important to point out that the aforementioned applications of magnetic fields in pain treatment have virtually exhausted the ability to adjust the field's parameters, and modern magnetotherapy relies on devices which operate within strictly set and pre-determined intervals. But the study of and careful impact on subtler mechanisms responsible for the emergence and transmission of chronic pain could eliminate main disadvantages of modern magnetotherapy [10,11].

Objectives

The main objectives of this study were as follows:

1. Show the possibility of weak alternating magnetic field to impact on pain-transmitting neurons;
2. Establish that EMS is strictly selective and does not affect other neuronal chains;

3. Determine frequency ranges of weak alternating magnetic fields that provide chronic pain relief;
4. Test the EMS method on patients suffering from chronic pain;

Materials and methods

The method was developed in collaboration with the Department of Neurological Surgery of the National Medical Research Center of Psychiatry and Neurology im. V. M. Bekhterev (3 Bekhterev St., St. Petersburg 192019, Russia) pursuant to Protocol No.4 of the Center's Independent Ethics Committee of April 28, 2016 (28.04.2016, №ЭК-И-34-а/16). Testing was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Informed consent was obtained for experimentation with human subjects. The privacy of human subjects was strictly observed.

The proposed method for chronic pain relief used SFG-2004 (manufactured in China) standard small-size generator of specific signals and a copper wire solenoid inductor (D_1=10sm, d_2=4sm, h=4sm) with maximum magnetic induction of 400 μT (manufactured in Russia). Magnetic induction was measured with a three-coordinate magnetometer HB0305.1A (manufactured in Russia). It is possible to use any other equipment with appropriate parameters of signals and magnetic field.

Peripheral neurogenic chronic pain relief was achieved through the application of a solenoid inductor to a patient's pain point. The inductor generated 10-180 Hz alternating magnetic field adjusted individually pursuant to patient feedback on a reduction in the pain sensation. The inductor impacted the first neuron, caused a change in its firing activity, and changed the pain sensation. The average session lasted for 20-30 minutes. Where one session was insufficient, a patient underwent several sessions.

Procedures for chronic pain relief may be accompanied by magnetic and other types of diagnostics conducted before and after treatment as a way to measure its efficiency.

As part of physical therapy, magnetotherapy has the following contraindications: pregnancy; blood disorders, atherosclerosis, and stage 3 hypertension; and the need to exercise care when treating cancer patients.

Testing

Testing was performed on 56 patients (28.6% male, 71.4% female; aged 41-65, average age 53). Main diagnoses: diffuse spine osteochondrosis, predominantly in lumbar (69.7%) and sacral (21.2%) spine; symptoms: muscular tonic syndrome and lumbodynia. Other diagnoses included osteochondrosis in the cervical spine (21.2%) with cervicalgia, thoracic spine (9.1%).

Patients were selected based on the main criteria of having the following diagnosed disorders: diffuse spine osteochondrosis (mainly loin), muscular-tonic syndrome, and lumbodynia. 45 patients from the sampling, before the EMS, underwent conventional treatment: medication therapy (e.g. pentoxyphilline, sulfuric magnesia, potassium chloride, intravenous physiological saline; ketoprofen, intramuscular combilipen, mydocalm, ranitidine) and physical therapy (e.g. electrophoresis with novocaine paravertebral block of the lumbosacral region daily; massage of the lumbosacral region daily; reflexotherapy daily). Conventional methods provided only short-time (2-5 hours) pain relief. 11 patients did not undergo conventional treatment.

The following ranges of alternating magnetic field were used to relieve peripheral neurogenic pain in regions of the spine: cervical - 70-80 Hz, thoracic - 110-130 Hz, lumbar - 80-130 Hz.

Treatment efficiency was determined based on the time period during which pain was significantly reduced or relieved completely. The effect of one session lasted from 8-10 hours to 3-5 days. Repeat treatment exhibited higher efficiency. Cases when results were reported after 1-2 sessions can be tentatively explained by patients having only the muscular-tonic syndrome in the absence of chronic physical irritation of pain receptors.

The extent of the analgesic effect was different for all patients. Long-term and consistent (up to 1 month) analgesic effect was reported for 76% of patients.

Discussion

Over the course of their research on the effect of weak magnetic fields on biological objects [12-16], the authors noticed that several studies [17,18] mentioned unusually high sensitivity of neural

cells to electromagnetic fields compared against other cell types. Experiments confirmed the possibility of achieving magnetobiological effect (MBE) on neurons as a result of using weak external magnetic fields with 200–300 μT induction.

Furthermore, there exists a dependence between the parameters (frequency, intensity, change over time, etc.) of applied alternating magnetic field and the nature of MBE on neurons. In other words, some neurons respond exclusively to magnetic fields with specific parameters, and exceeding certain threshold values cancels the MBE. This peculiarity in magnetic fields' effect on neurons was used to ensure magneto-parametric selectivity when out of all neurons affected by a specific magnetic field only certain neurons respond to an external physical stimulus. Moreover, the use of such weak magnetic fields, along with their selective effect, eliminated the possibility of side effects. Proposed pain relief mechanism relies on the electromagnetic impact on the processes responsible for the formation of pain neurons' action potential, which allows for changing the firing activity of pain neurons to the point where they do not conform to the typically created pain sensation.

In order to assess the efficiency of the EMS method compared with modern methods for chronic pain relief, we should determine the criteria for such comparison that would allow for answering the following major questions: what is used to achieve the desired effect, what does the method target; how the effect is achieved; and what are the side effects?

Table 1 contains data for virtually all currently used methods for treating chronic pain syndromes and includes the assessment of their efficiency, side effects, complications, relapse and cost. In addition, the bottom row of Table 1 provides relevant information on the EMS method. Based on all parameters under consideration, the EMS method matches or even surpasses the methods that are currently being used.

The physical method for peripheral neurogenic chronic pain relief relies on the application of external weak alternating magnetic field (electromagnetic induction) with particular characteristics (80-180 Hz, induction up to 400 μT) which affect the formation of action potential on a specific neuron's axon and elicit a change in its firing activity and spectrum. Spectral changes in pain transmission channel necessarily cause changes in the formation of pain sensation in relevant areas of cerebral cortex, which allows for pain relief [19,20]. These modified signals evoke sensations that are different from pain, which ensures the inhibition of the pain syndrome. It is also important to point out that parameters of applied weak alternating magnetic field are adjusted so as to affect only certain neurons [7] and not disturb neighboring neurons and cells, which allows for requisite selectivity.

Thereby, based on observed high magneto-parametric selectivity of neurons that transmit pain signals, the authors developed and successfully tested a new method for peripheral neurogenic chronic pain relief reliant on weak alternating magnetic field with induction not exceeding 200 – 300 μT. They tested the method at the National Medical Research Center of Psychiatry and Neurology im. V. M. Bekhterev on a group of volunteers diagnosed with backbone osteochondrosis. Tests complied with all standards of subjects' informed consent.

The research showed that the effectiveness of the electromagnetic method for chronic pain relief mainly depends on applied frequency ranges and, to a lesser extent, on the intensity of the alternating magnetic field. The Testing section provides specific frequency ranges for certain sections of the backbone, which confirms the authors' hypothesis about the difference in frequency characteristic of various neurons that transmit pain signals from pain receptors located in various parts of the vertebral column. In their opinion, the intensity of applied alternating magnetic field is important only once frequency ranges for certain pain-transmitting neurons are established. In the absence of such data, pain will either not be relieved, or the intensity of applied magnetic field will have to increase dramatically with lower effectiveness due to potential magneto-biological side effects exhibited by other neural structures.

The method is non-invasive, pain-free, and has no side effects. Individual characteristics, i.e. minor variations in neural perception of frequency ranges and intensity of the external magnetic field, can be easily accounted for through certain adjustments. Magnetic field is applied topically to the pain point, and pain is relieved after one 20-30-minute session. In order to ensure a lasting effect, the

Table 1: Comparison of modern methods for chronic pain relief.

Method	Efficiency	Side effects	Complications	Relapse	Cost
Drug therapy	Low, often non-effective	Present	Frequent	Requires constant use of medicine	High (due to duration)
Drug-free conservative therapy	Medium, low. Non-effective for acute pain	Rare	Rare	Requires frequent repeated courses	High (due to duration)
Blocks	Cannot be used for central pains; low efficiency for acute and chronic pain	Present	Not rare	Requires frequent repeated courses	Not very high
Intervention therapy that applies catheter technique	High. Limited to very vertebrogenic pain	-	-	Rare (new catamnesis method~7 years)	Medium
Neurostimulation	High, for all neurogenic pains	None	Rare, technogenic	Very rare	High
Intrathecal analgesic application	High	Possible	Rare	Rare	Rather high
Electromagnetic stimulation (EMS)	**High**	**None**	**None**	**Very rare if patients complete treatment course**	**Rather low**

Source: Isaguyan, E.D., Shabalov, V.A. Modern methods for chronic pain syndromes treatment – neurostimulation. N.N. Burdenko NMIC for neurosurgery. http://www.painstudy.ru/matls/treat/isagulyan.htm

authors recommend a course comprised of several sessions.

The closest method to the EMS is neurostimulation, but it requires the application of electrodes (internal or external) with an electric current between them, which limits possible points of impact and may have side effects.

The possibility of changing the intensity and frequency of applied alternating magnetic field by using a three-component magnetometer to adjust the generator of strandard signlas allows for desired selectivity in choosing the impact on a specific neuron and provides the option of making adjustments during application based on a patient's individual characteristics. Drug therapy is deprived of such possibilities.

High selectivity of the EMS impact also determines the virtual absence of side effects and complications. The EMS method for chronic pain relief is rather universal because it affects only the characteristics of the pain transmission channel and, consequently, could be used for relieving different types of pain. The cost of EMS is rather low due to the simplicity of equipment.

Results

The results of the authors' study show that pain relief can be obtained not only by prescribing medication, but also by changing the formation of neurons' action potential through the application of external alternating magnetic fields. The induction value of such fields may not exceed 400 μT. An added bonus for using magnetic fields for pain relief is the noninvasive nature of impact, the possibility of adjusting impact parameters in real time, and the absence of side effects due to the high degree of selectivity.

The authors demonstrated the selective impact of weak alternating magnetic fields on neurons which transmit neurogenic pain; detected that such impact does not affect other neuron chains; established frequency ranges of weak alternating magnetic fields that can ensure chronic pain relief; successfully tested the EMS method on patients suffering from chronic pain.

Conclusion

Research results confirmed that external weak (up to 400 μT) alternating magnetic fields are physically capable of affecting the

conductivity of neurons which transmit signals from the pain receptor to cortical neurons. It is shown that EMS is strictly selective and does not affect other neuronal chains. The main parameter which affects impact efficient is the frequency of applied magnetic field. EMS treatment exhibited high efficiency for the patients suffering from chronic pain. It is important to point out that efficient frequency ranges vary for different pain receptors in various sections of the spine, which can be explained by the difference in pain receptors' operations frequency ranges.

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