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ORIGINAL ARTICLE

Electromagnetic fields in medicine – the state of art

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Abstract

Introduction: Intense development of methods belonging to physical medicine has been noted recently. There are treatment methods, which in many cases lead to reduction treatment time and positively influence on quality of life treatment patients. *Research implications*: The present physical medicine systematically extends their therapeutic possibilities. This above applies to illnesses and injuries of locomotor system, diseases affecting of soft tissues, as well as chronic wounds. *The aim of the study*: The evidence on this are the results of basic and clinical examinations relating the practical use of electromagnetic fields in medicine. *Originality*: In this work the authors introduced the procedure using the current knowledge relating to physical characteristic and biological effects of the magnetic fields. In the work the following methods were used: static magnetic fields, spatial magnetic fields, the variable magnetic fields both with laser therapy (magnetolaserotherapy) and variable magnetic fields both with light optical non-laser (magnetoledtherapy) talked.

Keywords

Electromagnetic fields, physical medicine, treatment

History

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Introduction

In recent years, the number of scientific publications concerning new possibilities and clinical applications connected with the use of magnetic fields of extremely low frequency (MF-ELF) in the treatment has been ever on the increase. In medicine, magnetic fields are used in diagnostics as well as in therapy. In therapy, magnetic fields of low frequency are used in magnetic induction range, between some and several militesla (mT). In case of diagnostics (MRI – magnetic resonance imaging, TMS – transcranial magnetic stimulation) those values reach even up to 8 T (Adey, 2004; Barnes et al., 2006).

The nomenclature of magnetic fields used in therapy depends upon physical parameters of those fields, in particular, upon which the value and shape of magnetic flux density changes, as well as the frequency of those changes. Such research has been conducted on all levels (laboratory experiments, sub-molecular studies, up to research with the use of experimental animals). Clinical studies, however, demonstrate the highest dynamics (Adey, 2004; Bawin et al., 1975; Cosimo, 2007).

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Magnetic fields in medicine

Physical medicine equals first of all well-considered diagnostics and targeted treatment. Since its introduction, the experience developed over the years, various ways of therapies and diagnostics began to be the subject to irrevocably becoming the objective. Also the fact that modern technologies have been introduced to physical medicine, allowing for reduction of costs related to therapy and treatment cannot be underestimated (Cosimo, 2007; Eccles, 2005). So far, in physical medicine, the most often applied procedures have been slow-changing and changing magnetic fields (i.e. magneto-therapy and magneto-stimulation). Magnetic fields applied in magneto-therapy, in line with the criteria generally accepted in physical medicine, have the frequency below 100 Hz and magnetic flux density in the range between 0.1 mT and 30 mT. Those densities are 2–3 times greater than the induction of terrestrial magnetic field, which amounts to 30–70 μT. Magnetic fields used in magnetostimulation usually have higher frequency of the basic course, which is in the range of 80 to 3000 Hz. Values of the magnetic flux density amount from 1 pT to 100 μT. Basic courses used in magnetostimulation are modulated in such a way, that their envelopes have the shape of wave having the frequency of several to 100 Hz (Gmitrov, 2010; Janicki, 2008).

Among the new possibilities provided by physical medicine, one should mention the application of constant and spatial magnetic field. Constant magnetic fields are the fields

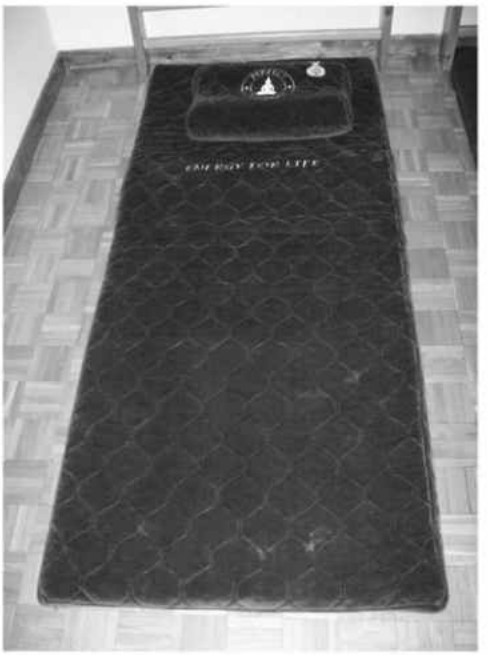

Figure 1. The large applicator (maternal) to magnetostimulation procedure.

Figure 2. Applicator to spatial magnetic fields.

Figure 3. The apparatus to magnetolaserotherapy Viofor JPS Classic.

which in a given point in space do not change their value or direction in time. Such fields can be obtained by applying immovable permanent magnets or magneto-generators, powered with direct current (DC) (Figure 1). The frequency of the constant magnetic field is maximum of 1000 Hz. To provide extra safety in longer exposures of the entire body to constant magnetic fields, the permissible [flux] value was determined to be 200 mT. The physical influence of stable magnetic fields upon the body results mainly from the influence upon the uncompensated electron spins, diamagnetic molecules (comprising liquid crystals contained in tissues), as well as moving electric charges. In case of application of constant magnetic fields, one should also consider the forces affecting the liquid biological structures with diversified magnetic properties: diamagnetic, paramagnetic, and ferromagnetic structures (Laali et al., 2011; Marko and Markov, 2009).

Spatial magnetic field is generated in the system of three pairs of spatially-oriented pairs, mutually coupled field applicators (the so-called coils for inducing magnetic fields), the planes of which form the angle of 90° between one another. When one of the two pairs of applicators is powered, it enables the generation of rotating the magnetic fields (Figure 2) (Opalko, 2009). This method is particularly useful in the treatment of degenerative joint diseases (affecting shoulder, hip, knee joints), as well as inflammatory lesions, Parkinson's disease, cerebral stroke, depression conditions, or skin lesions located in lower extremity area. At present, spatial magnetic fields demonstrate benevolent regenerative activity in case of peripheral nerve lesions (Opalko, 2009; Sieroń et al., 2007a).

Discussing the issue of magnetic fields, one should mention the procedures comprising combined therapy, in which the methods applied are based on simultaneous effects on the patient's body achieved by – most often two – physical factors with similar or mutually complementary therapeutic mechanisms (Pasek et al., 2011a). The examples of such methods are the magneto-laser-therapy and magneto-led-therapy procedures. The magneto-laser procedures consist of simultaneous application and subjecting the body to weak alternating magnetic field of low frequency, together with laser radiation (Figure 3) (Pasek et al., 2008a).

Magneto-led-therapy, in turn, is joint application of low frequency changing magnetic field, together with non-laser optic radiation – (led-therapy) by means of innovative magnetism and light applicators (Figure 4) (Sieroń et al., 2007b).

The procedures of magneto-laser-therapy and magneto-led-therapy are particularly recommended in case of chronic diseases, related to locomotor organs, and diseases occurring within soft tissues. The energy of light affects tissues mainly locally. Its ability to penetrate deeper into the body depends upon the length of the light wave emitted. The efficiency of energy absorption in the tissues is influenced mainly by: the thickness of individual layers of the tissue, blood supply and blood flow value, water content, and the presence of pigments. However, the influence of changing magnetic fields is observed at the cellular and tissue level. Depending on the individual properties when applying those methods, one can expect synergistic effects of both the types of electromagnetic radiation (Pasek et al., 2006a; Pasek et al., 2006b; Pasek et al., 2008b, Sieroń et al., 2007b).

Figure 4. The apparatus to magnetoledotherapy Viofor JPS Light.

Biological effects of magnetic fields

The biological activity of magnetic fields is a consequence of the effect those fields have on ion currents, as well as upon particles having a specific magnetic moment. This interaction causes certain orientations of physical stimuli, which influence the properties of cell membranes, electrolyte systems, sensitivity threshold for free nerve endings or cell capable of contracting. The general reaction to stimuli modulates complex reactions at various levels of the nervous system (Adey, 2004; Polk et al., 1996).

Magnetic fields, influencing the ions moving within the body by means of Lorentz forces, applied perpendicularly to the direction of ion streams and the direction of magnetic field forces' lines, cause deflexion of the ion stream, as well as the direction of lines of magnetic field forces, thus causing the phenomenon of deflexion of paths along which negative and positive ions move, in opposite directions. Moreover, ions gather in the vicinity of biological barriers, e.g. cell membranes in magnetic field, as a result of which ion polarization occurs (in accordance with the phenomenon of ion cyclotrone resonance – ICR) and change in the ion diffusion rate between the inside area of the cell and the intercellular space. A consequence of the above-mentioned phenomena is a change in intercellular concentration of ion, sodium, and potassium ions, among others, which has significant influence upon the intensity of numerous metabolic processes and the speed of nerve conductivity (Pasek et al., 2006a; Sieroń et al., 2002). Proven biological effects of magnetic fields comprise of vasodilatation, angiogenesis, anticoagulation activity, intensification of the processes of repair and regeneration of soft tissues, anti-oedematic, as well as analgesic activity, etc.

Clinical examinations about the use of magnetic fields

Methods of physical medicine are methods which are most promising in the near future, as regards their clinical application. It has been proven, in the research published so far, that the application of magnetic fields – in a statistically significant number of cases – results in reduction of pain complaints which in connection with their regenerative activity makes such application widely used in diseases of the hearing organ. Such ailments comprise, ossification disturbances, osteoporosis, degenerative affections of peripheral joints, diseases with rheumatoid background (rheumatoid arthritis, ankylosing spondylitis), pain suffered in the spinal cord, etc. (Pasek et al., 2011a; Shupak et al., 2006; Sieroń et al., 1989; Sieroń et al., 2002). It has been demonstrated in the research that magnetic fields cause increased secretion of endogenous opiates from the group of beta-endorphins, which are substances responsible for increasing the pain threshold. It has also been proven that the analgesic effect evoked by those fields is manifested not only directly during their application, but can be also observed after the exposure to the field stopped. The time of reduced pain sensation extends for the period of up to 4 weeks after completion of the therapy. This biological hysteresis of the magnetic field activity has substantial therapeutic significance (Pasek et al., 2006a; Yamaguchi-Sekino et al., 2011).

It is also worth mentioning that indications for the application of magnetic fields also include diseases of the nervous system (patients who had undergone cerebral stroke, multiple sclerosis, neuralgia, paresis of nerves, Parkinson's disease, lesions of peripheral nerves, as well as consequences of disruption of the nerve fiber in the spinal medulla), as well as some diseases of the visionary organ (Bawin et al., 1975; Pasek et al., 2007a; Sandyk, 1996; Wang et al., 2010).

The treatment of the wounds that are difficult to heal still poses a serious medical problem, of interdisciplinary character. However, it does not mean that wounds that are difficult to heal would not heal at all. Other published studies indicate that the application of low-frequency magnetic fields is conducive to the regeneration of tissues damaged in accidents, thermal traumas, or due to other factors that impair the continuity of the tissues. They may be chronic infections, scalds, bedsores, diabetic foot, or trophic ulceration of the lower leg. This initiated the use of magnetic fields in dermatology and surgery. The mechanism of the therapeutic action of magnetic fields is based, in such cases, on the stimulation of regeneration of the destroyed blood vessels responsible for microcirculation, enhancing the local blood supply to tissues. Those procedures not only reduce the inflammatory process, speeding up healing and visible development of granulation tissue, but also demonstrate action that provides better oxygen supply. In addition to that, they contribute to the reduction of pain complaints. It is also possible to use magnetic field therapy in combination with classic therapy and, what is important, it is not necessary to remove the dressing for procedures (with the exception of magneto-led-therapy and magneto-laser-therapy procedures) (Gmitrov, 2010; Pasek et al., 2010e; Sieroń and Pasek, 2011).

Recently, due to upcoming technologies, new possibilities arose for the generation of magnetic fields by means of small elliptic applicators, or point applicators, which is of importance in case of treating stomatological ailments. Low-frequency magnetic fields have beneficial influence upon densification of osseous structure in osteolysis spots, reduce sensitivity to pain, and influence saliva pH changes. Also, joint application of low power light and magnetic fields, in the form of magneto-laser-therapy is useful in complications after tooth extraction, including alveolar osteitis. First reports

also indicate beneficial effects of magneto-led-therapy procedures in the treatment of temporo-mandibular joint dysfunctions. The application of changing magnetic fields in implantology is also worth noting. Both the above-mentioned methods accelerate the healing process, thus reducing the time required to finish the intervention and crowning teeth (Opalko, 2009; Pasek et al., 2008b; Pasek et al., 2010a).

An exceptionally important issue is the influence of magnetic fields upon ailments affecting the circulatory system. Research results demonstrate that magnetic fields induce hypotension actions in case of arterial hypertension treatment, reduce cholesterol level, initiating de-coagulation processes. They also reduce the degree of blood vessel calcification. First reports have also been published on the assessment of influence exerted by magnetic fields upon the parameters of variability of averaged sinus rhythm, detected on high amplification electrocardiography, in patients with diagnosed arterial hypertension. The results obtained indicate that a therapy that makes use of magnetic fields may have protective influence, as regards the process of tissue degradation under the influence of metalloproteinases, being one of the pathogenic factors of inflammatory process (Gmitrov, 2010; Laali et al., 2011; Pasek et al., 2006c).

It is also known already that the action of magnetic fields causes the regression of mental and physical fatigue symptoms, reduces irritability, as well as is effective in the treatment of depression manifestations (Pasek et al., 2006b). The application of magnetic fields may also prove to be a useful method for the treatment of some diseases of the respiratory system. An example is provided in the study by Pasek et al. The application of constant magnetic field demonstrated significant increase of the forced expiratory volume in 1 s (FEV1) in the study group, which improved their quality of life (Pasek et al., 2010b).

Therapeutic effectiveness of constant magnetic fields has also been stressed in case of diseases of neurological background. It turns out that constant magnetic field causes stimulation of conduction between the nerve cells. This improves the metabolism of neurons and influences the regeneration of nervous tissue by intensification of the processes of branching and differentiation of axons, which leads to quicker restoration of the abandoned functions of injured nerves (Bawin et al., 1975; Sieroń et al., 2002; Wang et al., 2010).

Procedures with the use of magnetic fields (regardless their type) do not appear to have significant side effects. They are well tolerated by the patients. Having the knowledge we have at present, there are no scientific proofs that would indicate life or health threats connected with the application of constant magnetic fields, both in cases of short-term exposure and over a longer time. Nevertheless, the list of contraindications resulting from clinical observations comprises of pregnancy, neoplastic diseases (not applicable for constant magnetic fields), active form of tuberculosis, electronic implants (e.g. pacemakers), metal implants (with the exception of magnetostimulation procedures), and acute infectious diseases like viral, bacterial, as well as mycotic ones. On the other hand, among the possible moderate side effects include: transient intensification of pain manifestations, particularly in the early stage of therapy, fatigue sensation, excessive sweating, itching, or tingling sensation, as well as unstable level of arterial blood pressure. Those manifestations are usually moderately intensified, and are transient in most of the cases (Marko and Markov, 2009; Sieroń et al., 2002, Sieroń et al., 2006).

Conclusions

Physical methods using magnetic fields – regardless their type – provide completely new possibilities. Extending their application depends upon close co-operation of specialists in various fields of medicine, namely, physical medicine, balneo-climatology, and physiotherapy. In every specific clinical case one should find the correct physical parameters of the magnetic fields applied, as is the case with dosage of medicines. To define correctly the parameters meeting the required clinical as well as therapeutic criteria usually takes years of work, both in the laboratory and in the clinical practice.

Taking into the account the potentially multi-directional mechanisms of biological action of magnetic fields, it should be stressed that they require further clinical studies on representative groups of patients. Only this way the therapy can assure a deserving place for itself among the available methods of physical therapy.

Declaration of interest

Declaration of interest The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

References

Adey, W. R. (2004). Potential therapeutic application of non-thermal electromagnetic fields: ensemble organization of cells in tissue as a factor in biological field sensing. *Bioelectromagn. Med.* 8:1–12.

Barnes, F., Greenebaum, S., Handbook, B. (2006). *Bioengineering and Biophysical Aspects of Electromagnetic Fields – third edition*. Boca Raton: CRC Press.

Bawin, S. M., Kaczmarek, L. K., Adey, W. R. (1975). Effects of modulated VHF fields on the central nervous system. *Ann. NY Acad. Sci.* 247:74–91.

Cosimo, C., Pogliacomi, F., Passera, F., Concari, G. (2007). Treatment of wrist and hand fractures with natura magnets: Preliminary report. *Acta. Biomed.* 78:198–203.

Eccles, N. K. (2005). A critical review of randomized controlled trial of static magnets field for pain relief. *J. Complement. Med.* 11:495–509.

Gmitrov, J. (2010). Static magnetic field blood pressure buffering, baroreflex vs. vascular blood pressure control mechanism. *Int. J. Radiat. Biol.* 86:89–101.

Janicki, J. S. (2008). *The Use of Magnetic Fields in Therapy*. Poznań: Instytut Badań Fizykomedycznych.

Laali, M., Flécher, E., Nogarede, B., et al. (2011). First experimental use of magnets in cardiac valve repair. *J. Heart Valve Dis.* 20:70–74.

Marko, S., Markov T. (2009). What need to be known abort the therapy with static magnetic fields? *Environmentalist.* 29:169–176.

Opalko, K. (2009). *The Treatment of Electromagnetic Fields*. Wrocław: Wydawnictwo Med. Pharm Polska.

Pasek, J., Budziosz, J., Pasek, T., Sieroń, A. (2010a). Magnetoledtherapy in the treatment of clinical dysfunction temporal-mandibula joint – Case report. *Twój Przegląd Stomatologiczny*. 10:48–52.

Pasek, J., Budziosz, J., Szajkowski, S., Sieroń, A. (2010b). The influence of static magnetic fields on the chosen spirometric parameter in patients with chronic obturative pulmonary disease. In: Taradaj, J., Sieroń, A., Jarzębski, M. *''Fizykoterapia w praktyce''*. Katowice: ELAMED. pp. 231–237.

Pasek, J., Cieślar, G., Budziosz, J., et al. (2010c). Static magnetic field in physical medicine''. In: Taradaj, J., Sieroń, A., Jarzębski, M. *Fizykoterapia w praktyce''*. Katowice: ELAMED. pp. 227–231.

Pasek, J., Cieślar, G., Pasek, T., Sieroń, A. (2010d). Magnetoledtherapy – Adjunctive physical methods in the skin transplant treatment from Burns – Case report. *Przegląd Flebologiczny*. 18:61–64.

Pasek, J., Misiak, A., Mucha, R., et al. (2008a). New possibility in physics therapy – Magnetolaserotherapy. *Fizjoterapia Polska*. 1:1–10.

Pasek, J., Mucha, R., Sieroń, A. (2006a). Magnetostimulation – The modern form therapy in medicine and rehabilitation. *Fizjoterapia*. 14: 3–8.

Pasek, J., Mucha, R., Sieroń A. (2006b). Variable magnetic fields in the treatment of drug-resistance depression – Case report. *Balneologia Polska*. 8:235–238.

Pasek, J., Mucha, R., Gmyrek, J., Sieroń, A. (2006c). The influence of variable magnetic fileds on blood pressure conservation in patients with hypertension. *Balneologia Polska*. 3:95–101.

Pasek, J., Pasek, T., Sieroń, A. (2011a). Associated therapy in the treatment of pain – The chosen physiotherapeutic procedures. *Wiadomości Lekarskie*. 64:122–126.

Pasek, J., Pasek, T., Sieroń, A. (2008b). Magnetolaserotherapy in the treatment of dryness alveolar – Case report. *Leczenie Ran*. 5:21–24.

Pasek, J., Pasek, T., Sieroń, A. (2007a). Some practical recommendation in use magnetic fields and light in physical medicine. *Acta Bio – Optica et Informatica Medica*. 14:284–285.

Pasek, J., Pasek, T., Kniażewska, M., et al. (2008c). Magnetostimulation in the treament of periphery nerve paralysis. *Neurologia Dziecięca*. 17:71–74.

Pasek, J., Pasek, T., Sieroń A. (2010e). The efficacy of magnetic fields in the treatment of leukocytoclastic vessels inflammation. *Acta Angiol*. 16:93–98.

Pasek, J., Szajkowski, S., Zięba, A., et al. (2011b). Variable and static magnetic fields in the treatment of arthrosis. *J. Ecol. Heath*. 2:79–82.

Pasek, J., Pasek, T., Sieroń A. (2007b). Home therapy with use variable magnetic fields and light. *Rehabilitacja w Praktyce*. 3:50–53.

Polk, Ch., Postow, E., Handbook, B. (1996). *Biological Effects of Electromagnetic Fields –Second edition*. Boca Raton: CRC Press. pp. 149–184.

Sandyk, R. (1996). Treatment with electromagnetic field alters the clinical course of chronic progressive multiple sclerosis. *Int. J. Neurosci*. 88:75–82.

Shupak, N. M., McKay, J. C., Nielson, W. R. (2006). Exposure to a specific pulsed low-frequency magnetic field: A double-blind placebo-controlled study of effects on pain ratings in rheumatoid arthritis and fibromyalgia patients. *Pain Res. Manag*. 11:85–90.

Sieroń, A., Cieślar, G., Krawczyk-Krupka, A. (2002). *The Use of Magnetic Fields in Medicine*. Wydanie II. Bielsko – Biała: α – Medica Press.

Sieroń, A., Pasek J. (2011). Magnetic fields in the treatment of wounds. *Rehabilitacja w Praktyce*. 4:48–51.

Sieroń, A., Pasek, J., Mucha R. (2006). Magnetotherapy. *Rehabilitacja w Praktyce*. 3:29–32.

Sieroń, A., Pasek, J., Biniszkiewicz T. (2007a). Spatial magnetic fields – New form of therapy? *Balneologia Polska*. 1:8–10.

Sieroń, A., Pasek, J., Mucha R. (2007b). Magnetic fields and light energy in medicine and rehabilitation – Magnetoledtherapy. *Balneologia Polska*. 1:1–7.

Sieroń, A., Żmudziński, J., Cieślar G. (1989). The problem of use magnetic fields on human organism. *Post Fiz Med*. 24:75–79.

Wang, Z., Che, P. L., Du, J., et al. (2010). Static magnetic field exposure reproduces cellular effects of the Parkinson's disease drug candidate. *PLoS One*. 5:13–18.

Yamaguchi-Sekino, S., Sekino, M., Ueno, S. (2011). Biological effects of electromagnetic fields and recently updated safety guidelines for strong static magnetic fields. *Magn. Reson. Med. Sci*. 10: 1–10.