
INVITED LECTURE

**ELECTROMAGNET THERAPY IN PHYSICAL MEDICINE
AND REHABILITATION**

INTRODUCTION**Milica LAZOVIĆ¹**
VM LAZOVIĆ²¹*Institute for rehabilitation,
Belgrade*²*Clinic for Cardiovascular diseases,
Niš**Serbia*

Electromagnet therapy (EMT) in contemporary medicine is irreplaceable and harmless method in treatment of many disorders in rehabilitation. EMT involves application of various types of magnetic field, which inducted on patient tissue various therapeutic effects. Contemporary science achievements offer various types of magnetic fields which aim is to reach positive therapeutically results by various biological effects

In medicine magnetic field (MF) have been used from the age of ancient Greece. 800 years B.C. was discovered in MAGNESIA (GREECE) PHENOMENON of magnetic force, between grits on ground, if you walk across. This magical pebbles found application in medicine very soon. Until 18th century there weren't significant developments on electromagnetic field and application and magnets in medicine unpretentious. Although magneto therapy is probably the oldest method of physical therapy, biological ef-

fects of magnetic field were scientifically investigated from 60's of the XX century.

First serial apparatus for application of magnetic field were produced in seventies of 20th century, and extraordinary therapeutic effects were inspired a lot of physicians to investigate induction mechanism.^{3,4}

MAGNETIC FIELD MECHANISM

There are various types of criteria for differentiation of magnet field from the view of biological effects. Induction variability differentiates two types of magnet field: stationary and changeable (unstable).

STATIONARY FIELDS are used for stimulation acupunctural or biologically active points by using a lot of small permanent magnets on human scion.^{6,7} Induction of this magnets is approximately 0,1 – 10mT.^{8,9}

UNSTABLE (changeable) magnet fields are generated in inductors where electric energy of changeable power is passed. Therapeutically application of these magnets is bigger and varied. Various parameters of magnetic fields have various biological effects.

Induction is criteria for differentiation of these subgroups:

INDUCTION FIELDS pT (pico T = 10^{-12}) and nT (nano T = 10^{-9}) are everywhere around us as consequence of electric energy flow through various home apparatus and instruments or installations.

INDUCTION FIELDS (100nT – 1mT) - STACIONAR FIELDS of these magnets nearby weak permanent magnets. Induction of earth magnet field is in this range and arises from equator toward polls. Changeable magnet fields in this range are nearby electric installation or surrounding high voltage wires.

INDUCTION FIELDS (1mT – 100mT) are almost therapeutically used. Frequency range is 1-100 Hz and these fields of induction are used for simulative effects as increase of tissue oxygenation and ATP production, normalization of membrane and additional cells potential and others biological effects.^{3,11}

INDUCTION FIELDS over 100mT. These apparatus, witch produce magnet induction in these ranges are not present long ago, and operate as pulse magnet stimulator with high level of magnet induction. Extremely high electromagnet field's density can stimulate muscle contraction. Patients with slow callus healing, osteoporosis, all pain syndromes, and post-traumatic status are indication field.

MAGNET FIELD TYPES ACCORDING TO FREQUENCY

Magnet field frequency is number of cyclic field changes which happen in one second. Various frequencies produce various biological effects.

MAGNET FIELD FREQUENCIES up to 1000Hz – Purpose is neuro magnetic stimulation and bio simulative effects. Low frequency and small induction of these fields in treated tissue provoke very low current induction, and do not have expressed thermal effects.

MAGNET FIELD FREQUENCIES range 1 kHz to 30 kHz – Warming effects are not possible. Inducted current of these frequencies are still able to provoke action potential of neural and muscle cells. These frequencies stimulate production some cytokines as is interleukin 1 and 2, tumor necrosis factor (TNF).¹¹

MAGNET FIELD FREQUENCIES 30 kHz to 300 kHz - completely lose ability to provoke stimulated cells action potential but these fields are not suitable for thermal effect production.

MAGNET FIELD FREQUENCIES 300 kHz to 30 kHz Correspondent to frequencies of medium (300 kHz-3MHz) and short (3-30MHz) electromagnetic waves. These frequencies can depolarize cells up to induction currents of these frequencies, suitable for application in diathermal purposes. For deep tissue heating in most cases is used frequency 27,12MHz (shortwave diathermia). As thermal effects are emphasized in this region, bio stimulated effects are obtained by pulse stimulated MF where medium power is significantly decrease related to continual work regime.

BIOLOGICAL EFFECTS

Biological effects that took place under electromagnetic field activity can be divided on bio modulated, thermal and neuro stimulate. According to the type of MF can provoke all or only some of counted effects.

BIOMODULATING EFFECTS

Bio modulating effects develop as a direct after effect of MF on bio molecules. Though precise biophysical acting mechanisms are not found yet, it is possible to assort bio modulating effects in next groups:

Facilitation of energetic and metabolite mechanisms – it is well known that MF by fast flow of energy and by increased oxygenation influence even on increased production of energy which is reflected in increased synthesis of ATP. Increased synthesis of ATP further carry on to increased entry of glucose which enters the cells by secondary active transport

on count of normalized cell membrane potential.^{1,11}

David Hood found 1989 year, that chronic stimulation (30 and more days), has tripled value of two critical enzymes, citrate synthesis and cytochrom c oxidize by frequency of 10Hz at the finishing cell aspiration faze.¹⁴

Increasing activity cytochrom c oxidizes in the beginning responded modification on the level of mRNA. Meanwhile, multiple stimulation (over 14 days), increasing cytochrom c oxidize activity exceeded double level mRNA.

Examining oxygen consumption through aspiration-test system since 2005 we have found routine improvements in as little as 2-3 days. Cell's burn oxygen more efficiently, drawing oxygen from blood slower, producing more energy and less waste from every breath; thus you are able to hold your breath up to 20% longer the first week or two; 2/3rds longer after a year or two and up to 100% longer after several years. Sleep on Command™ inventors (9+years nightly use) breath hold is 2:46 (baseline 1:20) and he smokes cigarettes; only takes the test once every 18 months so practice is not a factor. Since 2005 it brought to the routine improvement only after 2 or 3 days. Cells oxygen burning is efficiently, oxygen extraction from blood is slower, energy production is increased, whereas waste from every breath is reduced, so it is breath hold possible up to 20% longer first week or 2/3rds longer after year or two, and up to 100% longer, after few years.

In 2003 NASA-Goodwin it was found that 10Hz square wave stimulation cause nerve tissue regeneration four times faster, better 3-D orientation: cell DNK prescription (more then 100 set nuclein DNA) returne from maturation into the growth.¹⁵

In 2007 James Tong did triplicate nerve synapsis and energy by stimulation whereas he doubled consistency (density) mitochondria on nerve synapsis. Almost six decades researching of pulse electromagnetic field points out that IEMF, appropriate frequency, intensity and duration offers opportunity effects in different cells processes and mechanism. As we know that ATP is main source of energy for the most cells functions, as well as for macromolecule synthesis, including the role in macromolecule transport across cells membrane.¹⁶

Cells proliferation stimulation and cells matrix building – recently issued research points out possibility of massive electron flow within DNK chain so executed conclusions indicate that action of MF on gene expression and transcription stimulation take role under the direct influence of field on DNK.^{17,18} Even mechanism of proliferation stimulation of some cells lines are not clear yet, increased cells proliferation under the MF influence, as well as increased ATP production are documented by multiple investigations.¹⁸

It is great importance for patients with osteoporosis stimulation osteo-cells line TE-85 growth, which together with facilitation of calcium and phosphorous metabolism carry out to the growth of bone density.^{1,16} The nature of such electro mechanic signals is not fully known. Inside bones, mechanical and electrical signals may regulate synthesis extra-cellular matrix by the way of synthesized signalization on cells membrane.¹⁹ In soft tissue alternating current of electric field, induce protein redistribution of integrated cell membrane, which hypothetically can initiate transduction cascades signal and cause cytoskeleton structure reorganization.^{19,20} However, hypothesis that electric signals may be responsible for information transfer inside or on cells, have never been proved or disproved.

Immunology action of MF reflect in stimulation or inhibition some of the branches immune system related to received type of the field and dose applied. MF has stimulating effect on immune cells proliferation as on their migration to the place of inflammation. It also stimulates secretion of mediator inflammation reaction which influence on further flow immune response. All investigated mediators including internucleins IL-1 and IL-2, tumor necroses factor TNF, prostaglandine and leukotriane have showed changes in concentration under the action of MF (11,19,20). Because of different results obtained from investigations there is no possibility to conclude yet which frequency and induction frame brings to stimulation or inhibition of mediators.

Increase of partial oxygen pressure lead to enhanced tissue oxygenation, which together with stimulation stress protein production; grow by acting MF in the range 1-1000Hz and 1-100mT. This enables faster and better quality recovery at numerous cerebral and heart anoxic and ischemic states. Increased oxygenation also lead to metabolic activity acceleration and acceleration of bioenergetics process.²¹

Increased exchange of matter in tissue – lead to faster entry nutritive matters and faster removing bad metabolic products or mediators inflammatory reactions which could lead to appearing fatigue and pain. Because of increased exchange of matter between intra and extra cellular space lead to normalized sugar in blood as well. It is obvious that increased entry of calcium ions from extracellular media, lead to inhibition of apoptosis at some types of cells and to prolonged cell life. Even it is well known that MF is not mutable, apoptosis inhibition and prolonged damaged cells life can enhance mutation effects.²²

THERMAL EFFECT

Magneto therapy thermal effects are reached only with

MF which inducts current in tissue sufficiently high to provoke tissue heating. MF frequencies over 300 kHz are used for obtaining thermal effects (depolarization of cells is not happening because of high frequencies).^{3,21}

NEUROMAGNET STIMULATION

Neuromagnet stimulation imply MF use in current induction purposes in treated part of the body which further lead to excitation nerve fibrous and provoke action potential. Related to the acting target, magnet stimulation may be peripheral or transcranial. Transcranial stimulation is used for recording motor evoke potential for the purpose of check nerve path functionality from center in brain along to the periphery.^{1,11} MF application has advantage in transcranial stimulation because brain bones are not barrier for MF penetration. Peripheral magnet stimulation is used for excitation peripheral nerves in diagnostic and therapeuticall purposes. For the peripheral nerve stimulation instead magneto stimulation usually is used electrical stimulation, because of application simplicity.²¹

PULSE ELECTRO MAGNETIC FIELD THERAPY

Therapy by pulse electromagnetic field (PEMF) in human medicine is most widely accepted in fracture therapy. Even the procedures are not yet fully completed, a few studies talk that PEMF stimulate biological processes which relate to osteogenesis.^{11,12} United States Food and Drug Administration in USA approved this type of therapy of bone fracture with slow callus generating and open bone fracture. A lot of double blind studies approved effectiveness of support treatment.²² Selected low energy PEMF is used in last 20 years in bone fracture treatment with slow callus regeneration medium part fractures of long bones, with destruction of tendon (soft) tissue. Prolonged without load immobilization (orthopedic or in bed), decrease bone mass. In other hand, bone mass raises if load increases correctly. Results of biomechanical and histological investigations improved that PEMF don't decrease bone mass, but regenerate it. Program was implemented on McGill University of Montreal; they found that PEMF decrease bone resorption.¹¹ Bone resorption is reduced and new bone regeneration is increased when we implement electromagnetic field with lower frequencies than 100Hz.¹³ Dosemetric studies demonstrate show that cortical bones react on frequencies from 199 to 200Hz.^{11,16}

Hawaiian University School of Medicine study gave concrete data related to bone mass regeneration at post-menopause in female. All 20 examinee (age be-

tween 57 and 75 years), which had decreased bone density diagnose by bone densitometer, have been treated 12 weeks. Bone density was increased by around 5,6%, after 6 weeks period.^{11,16} By treatment with PEMF in time of 60 minutes per day, it was noticed osteogenic effect by using PEMF between 0.01 and 0,04T. Maximal osteogenic response was reflected in decrease intracortical transformation level, by decrease endoaxis resorption as well as stimulation per axis and endoaxis bone forming. This data point out that exposing wit PEMF in short daily periods is possible to realize beneficial effects on cell population, which are responsible for regenerating bone. Numerous studies documented beneficial PEMF action at soft tissue injury, in chronic ischemic wound treatment.¹¹ In accelerated regeneration damaged nerves^{24,25,26} and in many other multiple injuries with lesion different tissue structure.^{27,28}

PEMF can modify biological behavior around and inside cells. The key for rational PEMF using lays in possibility in defining certain parameters of treatment (amplitude, frequency, orientation and time). Right accepted PEMF, adequately used on the whole body, results with clear clinical successfulness in bone diseases treatment and pain decrease, which are often caused with micro-traumas. Associative pain caused with used-up gristle layers, can be successfully treated across electromagnetic stimulation,^{29,30} by increasing partly oxygen pressure which result with increased calcium transport. Recovery and growth gristle is on that way stimulated.^{16,30}

CONTRAINDICATIONS

PEMF application is contraindicated in all kind of tumor because of direct action of MF on cell growth, and because promoting thermal effect on proliferation of many malign cells. Application of MF absolutely is contraindicated at patients with pacemaker, because interference in work with other electrical devices. Pregnant woman treatment with MF is not recommended because of possibility to influence on embryonic tissue, and because of changes in blood inflow.

Although treatment of rheumatoid arthritis gives good results in case of application with MF by low frequencies (1-1000Hz) and induction (1-100mT), treatment by strong, high frequencies fields (3-30MHz) bring up to deep tissue heating and collagenasa enzymes activation which influence on gristle retrogression at joint treatment. Implanted metals represent relative contraindication in MF treatment. Metal is contraindicated at applications with high induction because of strong magnetic power which could act on implanted metal, and at field application in thermal purposes because of higher possibility tissue heating

in the vicinity of implanted metal. MF therapy can lead to complication and in case of application no adequate dose at acute infection and inflammations, serious circulation problems which include arthrosclerosis and thrombosis, as well as in many heart work disorders.

CONCLUSION

Biological actions stated in text are approved in many word laboratories which work on this mater, but still there are some dilemmas related to precisely defined aim of magnetic field action and cause of existing of frequent, inductive and time window within which comes to enhanced positive effects, and out of it reduction of negative effects of magneto therapy.

Further investigations related to effects of magnetic field, should be directed on biophysical investigations which imply electromagnetic field detection mechanism in biological structures, protein molecular dynamics and exposition in EMF, as well as micro dosimetry.

In vitro investigations are necessary with a special point on cell membrane function effects and cell transport, and on biochemical reaction effects and effect on cell cycle and proliferation. Further in vivo investigations are important using more sensible methods for even smallest abnormality detection and genetic and tumor studies because there are no confident proofs for gentotoksic cancer action of magnetic field.

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