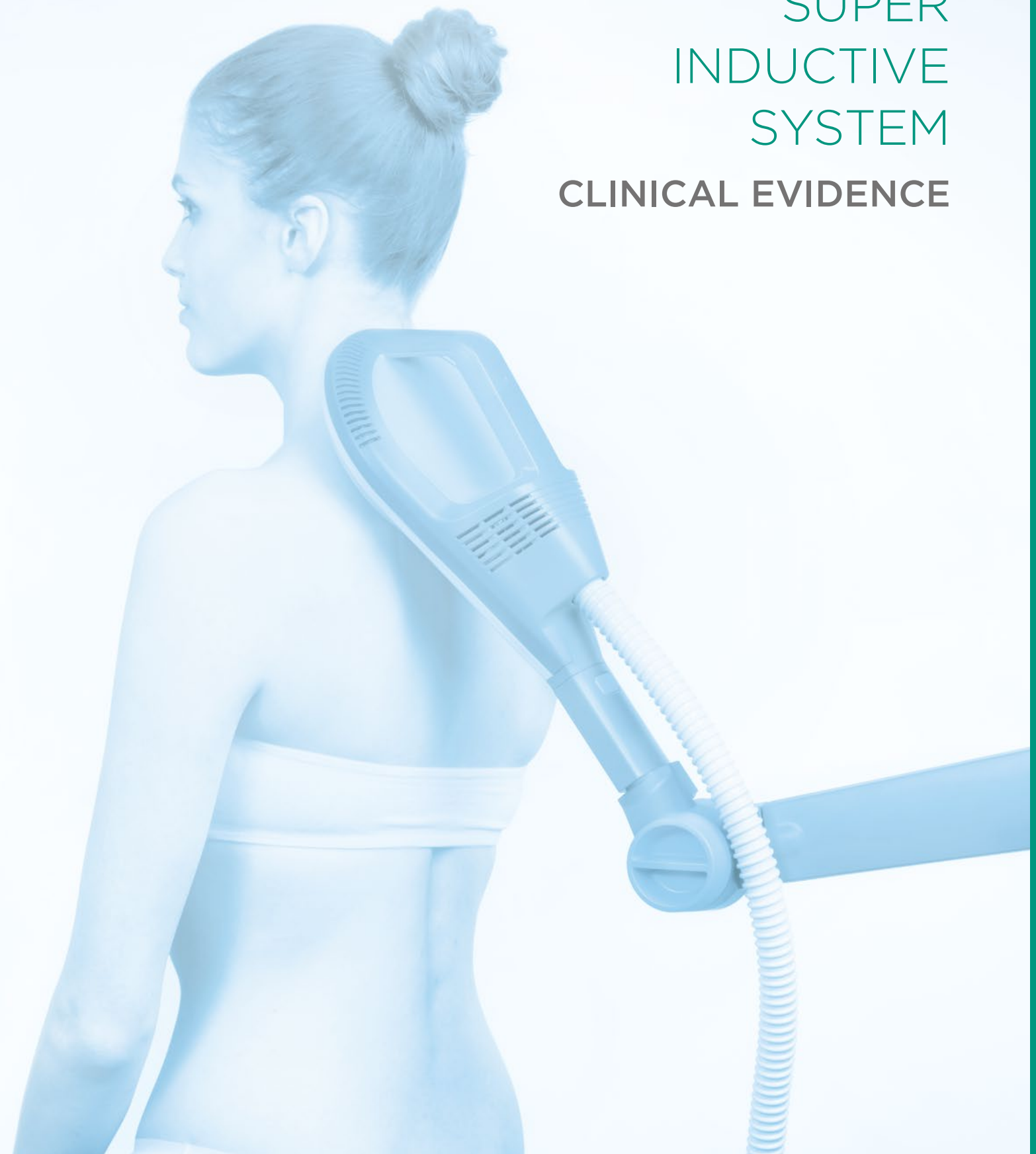
SUPER INDUCTIVE SYSTEM

CLINICAL EVIDENCE



CONTENT

1. ANALGESIC EFFECT

TITLE: REPETITIVE PERIPHERAL MAGNETIC STIMULATION AS PAIN MANAGEMENT SOLUTION IN MUSCULOSKELETAL AND NEUROLOGICAL DISORDERS – A PILOT STUDY

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Published: International Journal of Physiotherapy, 2016, Vol. 3(6), p. 671–675

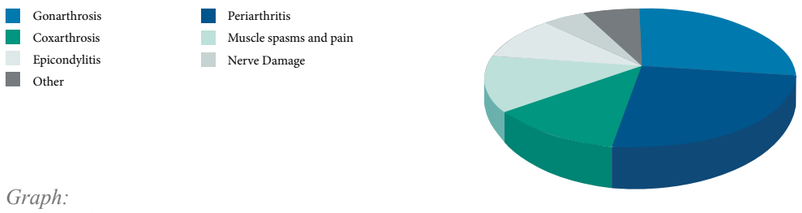
ABSTRACT:

Background and Objectives:
Non-invasive therapeutic approaches without negative side-effects are desirable in pain condition treatment where the mobility limiting factor is also there. Repetitive peripheral magnetic stimulation (rPMS) is considered a promising curative method from different perspectives. Because of wide range of therapeutic effects, therapy is mainly indicated in musculoskeletal and neurological disorders. Aim of this study was to investigate pain relief effect and improving of the difficulties in performing Activities of Daily Living (ADL) achieved by rPMS among patients with acute and chronic conditions assosiated with musculoskeletal and neurological painful disorders.

Methods:
40 patients (n = 23 women, n = 17 men) with acute and chronic painful condition and difficulty to perform ADL accompanying musculoskeletal or neurological disorders were comprised in the study. All patients were treated with rPMS. The therapy parameters were adjusted to patient´s condition. Patients with acute pain underwent daily treatments (n = 5). Patients with chronic pain underwent treatments three times per week (n = 10). The pain presence was evaluated by a 10-point Visual Analog Scale (VAS) for Pain Presence. Difficulties to perform ADL were evaluated by Patient Functional Assessment Questionnaire (PFAQ) for ADL. A three-month follow-up was completed. All collected data were further evaluated.

Results:
There was a statistically significant difference in the before/after condition comparison. Majority of participants described pain decrease (87.33 %) on VAS for Pain and improvement (41.33 %) in ability to perform ADL after the course of treatment. A three-month follow up showed persisting improvement (to 42.04 % (vs. before treatment condition)) in ADL performing abilities.

Conclusions:
Similar results proved that rPMS therapy can be used as an effective and non-invasive treatment of painful condition with ADL limiting factor accompanying musculoskeletal and neurological disorders. Persisting pain relief effect and ameliorating patient quality of life were observed.



Graph:
Clinical diagnoses

TITLE: CLINICAL STUDY OF APPLIED HIGH-INDUCTION ELECTROMAGNETIC FIELD ON PAINFUL CONDITIONS

Authors: Šťastný E[1]., Prouza O.[2]
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[2]Charles University in Prague, Faculty of Sport and Physical Education, Prague, Czech republic
Published: Rehabilitace a fyzikální lékařství, 2016, Vol. 3(23), p. 142–148

ABSTRACT:

Background:
A new approach to pain management appeared in a physical therapy. It is technology based on the effect of strong pulsed electromagnetic field in human tissue (the value of induction is in the order of units of tesla). This pilot study examines the analgesic effect of this technology with different diagnoses.

Objective:
Verification of an analgesic effect of a strong pulsed electromagnetic field on a sufficient statistical sample in a clinical practice.

Methods:
The therapy was performed with 57 randomly selected patients with chronic and acute pain of musculoskeletal system. Patients had 6 therapies in average, 1-2 times per week, 10-15 minutes according to the selected protocol. We used the combination of the Visual Analog Scale (VAS) and the Verbal Numerical Rating Scale (VNRS) to determine the analgesic effect.

Results:
Regardless of diagnoses the overall decrease of pain was 37.5%. There was significant release of pain at 46 patients. There was neither improvement nor worsening of pain in 4 of the 50 patients. Seven patients were excluded from the study.

Conclusion:
We have demonstrated the analgesic effect of a strong pulsed electromagnetic field on musculoskeletal pain.

Keywords:
FMS, electromagnetic induction, analgesic effect, musculoskeletal system

TITLE: REPETITIVE PERIPHERAL INDUCTIVE STIMULATION IN MUSCULOSKELETAL PAIN MANAGEMENT – A PILOT STUDY

Authors: Pětioký J.[1] ,Váňa Z.[1], Šubert D.[1], Žarković D.[2], Prouza O.[2], Bittner V.[3]
Affiliations: [1]Rehabilitation Center Kladruby, Kladruby, Czech republic;
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Published: Rehabilitace a fyzikální lékařství, 2016, Vol. 4(23), p. 195-200

ABSTRACT:

Background:
Repetitive peripheral inductive stimulation is a solution in musculoskeletal pain management in medical branches such as neurology, orthopaedics, rehabilitation and physical medicine. Therapy is based on the principle of time-varying electromagnetic field passing through neural and muscular tissue, in which electric currents are induced. By affecting conductive tissue, a chain reaction including changes in action potential and leading to muscle contraction is performed.

Aim:
Aim of the pilot study was to investigate immediate pain relief effect of the repetitive peripheral inductive stimulation device BTL-6000 Super Inductive System (BTL Industries Ltd.) in musculoskeletal diseases.

Methods:
31 subjects from Rehabilitation Center Kladruby were comprised in the pilot study. Subjects underwent approx. 7 therapies individually. A hand-held applicator type „focus field“ was used. Pulse repetition rates matching with gate theory and peripheral pattern theory were applied to achieve pain relief effect. A Visual Analog Scale (VAS) was used to evaluate pain before and after each therapy. Results: Immediate pain relief effect of the repetitive peripheral inductive stimulation in 62% patients with musculoskeletal diseases was observed.

Conclusion:
Despite small number of subjects, decrease of painful perception and pain relief effect were achieved. Although, the study design does not allow comparison with placebo effect, statistically significant ($\alpha = 0.2$) immediate pain relief effect in 50 - 74 % of subjects might be expected.

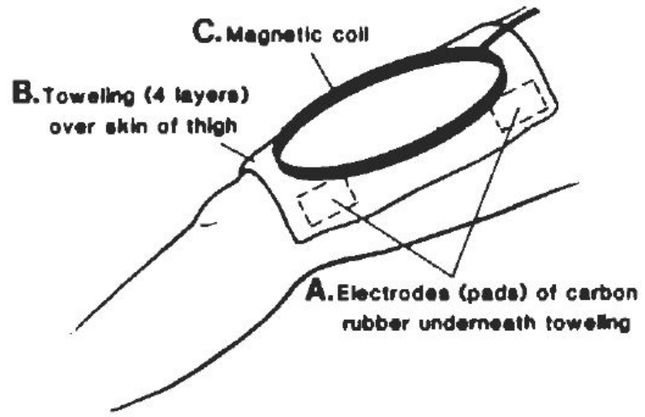
Key words:
pain, pain relief effect, gate control theory, peripheral pattern theory, repetitive peripheral inductive stimulation, vertebrogenic algic syndrome, visual analog scale

TITLE: EFFECTS OF ELECTRICAL AND ELECTROMAGNETIC STIMULATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Authors: Currier D.P.[1], Ray J.M., Nyland J., Rooney J.G., Noteboom J.T., Kellogg R.
Affiliations: [1]Division of Physical Therapy, University of Kentucky Medical Center, Annex I, Lexington, KY
Published: Journal of Orthopaedic & Sports Physical Therapy, 1993, April; 17 (4), 177-184

ABSTRACT:

A need exists to develop new methods of neuromuscular electrical stimulation (NMES) that are both effective and relatively pain-free. The purpose of this pilot study was to determine the effects of both NMES and a new method of electromagnetic (NMES/PEMF) stimulation for reducing girth loss and for reducing pain and muscle weakness of the knee extensor muscles in patients during the first 6 weeks after reconstructive surgery of the anterior cruciate ligament (ACL). Seventeen patients receiving ACL reconstructive surgery participated as a control group (n = 3), as an NMES group (n = 7), and with combined NMES and magnetic field stimulation (NMES/PEMF), (n = 7). Patients receiving NMES/PEMF rated each type of stimulation for perceived pain and were measured for their torque. Torque results revealed a mean decrease of 13.1 % for NMES/PEMF patients. The mean percent of thigh girth decreased 8.3 % for controls, 0.5 % for NMES, and 2.3 % for NMES/PEMF patients. The NMES/PEMF patients rated NMES as causing about twice the pain intensity as NMES/PEMF during treatments. As a result of this data, the authors conclude that both NMES and NMES/PEMF are effective in reducing girth loss and that NMES/PEMF is less painful than NMES alone in treating patients after ACL reconstruction.



Picture:
Procedure for inducing muscle contractions

TITLE: CLINICAL STUDY OF HIGH-INDUCTIVE ELECTROMAGNETIC STIMULATOR SALUS TALENT

Authors: Poděbradský J.[1], Poděbradská R.
Affiliations: [1]Lázně Dolní Lipová, Lipová-lázně 248, 790 61, Czech republic
Published: Rehabilitation and Physical Medicine, 2010, 17 (3), 95-100

ABSTRACT:

This is a pilot study for clinical tests of analgesic effect of electromagnetic stimulator SALUS Talent in pain of locomotive organs. It is the first magneto-therapeutic device, with which can be subjective intensity during the application achieved, as well as magnetic induction of 2.5 Tesla. The statistical sample consisted of 89 patients, both rehabilitation clinic and patients undergoing treatment at Spa Dolní Lipová with cutaneous indications. In terms of the locomotor system the problem was mainly a structural failure. Most patients recorded a distinctive, early, long-lasting analgesic effect. As a dominant is the effect of this therapy, which appears to be dispersed, directly and also through the activation of the sympathetic in spinal storey, with following improvements of thixotropic properties of tissue in the area of application.

Results :
The overview provides a basic diagnosis of patients treated, the number of patients and changes in pain sensitivity converted to mm VAS (Visual Analogue Scale).

Representation of diagnoses:	Number of patients:	Pain sensitivity decrease on VAS (mm):
Gonarthrosis (M17.*)	19	24
Coxarthrosis (M16.*)	15	43
Other arthrosis (M19.*)	16	23
Syndrom of stubbed shoulder (M75.4)	9	27
Vertebral alg.sy. LS (54.9)	9	27
Psoriatic arthropathy (M07.*)	8	12*
Other enthesopathia (M77.*)	6	25
Vertebral alg. sy. CB	4	12
Reumathoides artrithis (M05.9)	1	16
Other determined arthropathy (M12.8)	1	-8**
Polyarthrosis (M15.9)	1	3

* 3 patients had subjective and objective deterioration. All this was primarily an acute exacerbation with typical signs of inflammation - swelling, local temperature increase, redness.
** Problems with understanding of VAS.

Conclusion :
Despite the well-known opinion of the author on the use of physical therapy at the structural (especially degenerative) diseases of the musculoskeletal system, in the interest of objectivity it must be conceded that in case of tested device the situation is different. Retreat of pain, swelling, improving mobility and consequently the quality of life, often even after the first application, lasting for weeks is a phenomenon, which existence in the physical therapy is unrecorded. Obviously, it will be necessary to verify the individual effects on other workplaces and selectively compiled files. However, already these first clinical tests lead to the conclusion that the initial sizeable investment in equipment is returned as a significant therapeutic effect.

TITLE: EFFECTS OF PARA-SPINAL REPETITIVE MAGNETIC STIMULATION ON MULTIPLE SCLEROSIS RELATED SPASTICITY

Authors: Serag H.[1], Abdelgawad D., Emara T., Moustafa R., El-Nahas N., Haroun M.
Affiliations: [1]Neurology Department, Ain Shams University, Cairo, Egypt
Published: International Journal of Physical Medicine & Rehabilitation, 2014, 2:242

ABSTRACT:

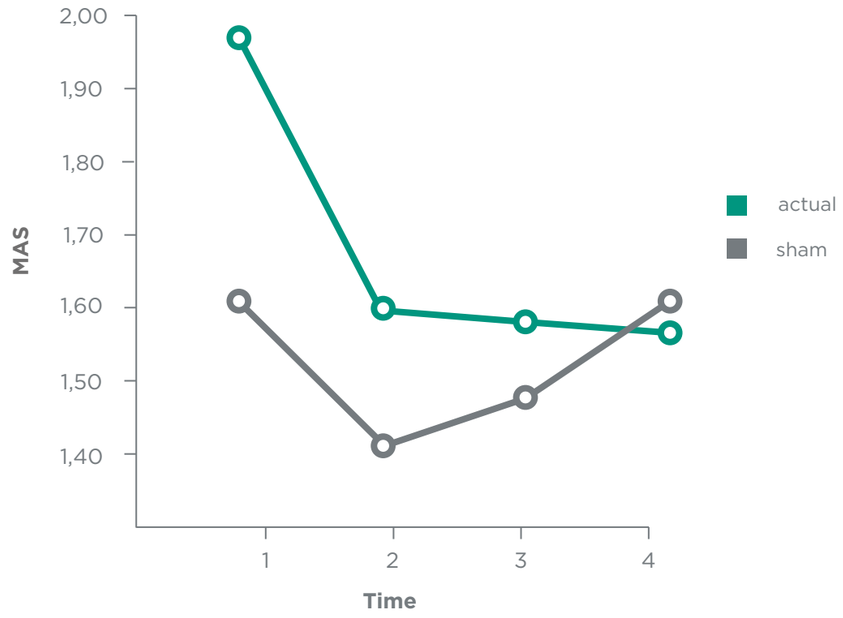
Introduction:
Spasticity is a major problem in multiple sclerosis (MS) patients directly affecting their quality of life. Despite having many treatment modalities, the clinical effectiveness of these modalities is at best modest.

Aim of the Study:
The aim of this study was to test the effectiveness of repetitive peripheral magnetic stimulation (rpms) in decreasing spasticity and painful cramps in the lower extremities of MS patients.
A secondary objective was to know whether this postulated improvement would result in an increase in the speed of walking of these patients.

Patients and Methods:
Twenty six MS cases were randomly assigned either to 6 sessions of active 1 Hz rpms over the paravertebral region bilaterally (Group 1; n = 18) or to sham stimulation (Group 2; n = 8). Outcome measures included the Modified Ashworth Scale (MAS) for spasticity, self-reported spasm frequency and degree of pain associated with it, generalized body pains and 25 feet walking test. All measures were examined at baseline, after the end of treatment, and 2 and 4 weeks later. EDSS (Expanded Disability Status Scale) of all study patients did not exceed 6.5.

Results:
There was no significant difference between the two studied groups at baseline. There was a significant difference between the two study groups in terms of muscle spasticity tested by MAS ($p = 0.05$), and spasm frequency and intensity ($p<0.0001$ for both). There was no significant difference between the two study groups in terms of duration taken to complete the 25 feet test or generalized body pain. There was no significant difference between relapsing remitting and secondary progressive MS cases receiving active stimulation.

Conclusions:
Rpms helps ameliorating MS related spasticity and muscle spasms. Further studies are needed to look into the effects of this improvement on the quality of life and the activities of daily living of those patients.



Graph:
MAS in the two treatment groups across all time points. A persistent improvement in the active treatment group is clearly shown.

TITLE: LUMBAR REPETITIVE MAGNETIC STIMULATION REDUCES SPASTIC TONE INCREASE OF THE LOWER LIMBS

Authors: Krause P.[1], Edrich T., Straube A.
Affiliations: [1]Department of Neurology, University of Munich, Klinikum Grosshadern, Munich, Germany
Published: Spinal Cord, 2004, February, 42 (2), 67–72

ABSTRACT:

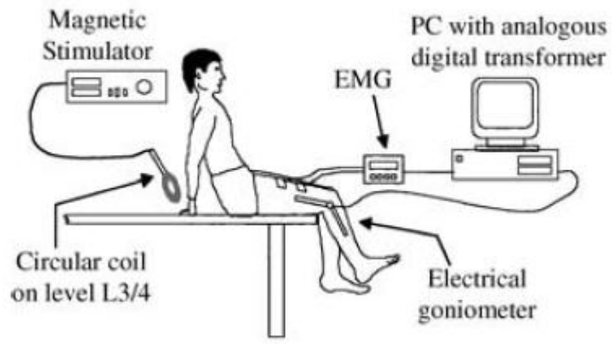
Study Design:
Comparison of spinal lesion subjects and normal subjects.

Objective:
To investigate the effects of a paravertebral repetitive magnetic stimulation on spastic tone increase of the lower limbs.

Methods:
We compared the effects in 15 patients with different spinal lesions and in 16 healthy subjects. The spastic tone increase was evaluated clinically with the Ashworth scale and apparatively with the pendulum test, both at fixed times before and after stimulation. Unilateral stimulation was applied to the lumbar nerve roots L3 and L4 of the clinically more spastic leg.

Results:
The spastic tone decreased significantly in the interval between 4 and 24 h after stimulation. This effect was slightly more pronounced in the contralateral extremity. Furthermore, the stimulation motor threshold of the patients was significantly raised.

Conclusion:
Repetitive magnetic unilateral stimulation has a positive effect on spastic tone increase due to spinal lesions, causing a decrease that lasts for about 1 day not only on the ipsilateral but also on the contralateral side.



Picture:
Setup of the stimulation and pendulum test recording

TITLE: PERIPHERAL MAGNETIC STIMULATION TO DECREASE SPASTICITY IN CEREBRAL PALSY

Authors: Flamand V.H.[1,2,3], Beaulieu L.-D., Nadeau L., Schneider C.
Affiliations: [1]Laboratoire de neuroStimulation et Neurosciences Cliniques, Axe Neurosciences Centre de Recherche du Centre Hospitalier Universitaire de Québec; [2]Département de Réadaptation, Université Laval; Quebec City, Quebec, Canada; [3]Centre Interdisciplinaire de Recherche en Réadaptation et Intégration Sociale, Institut de Réadaptation en Déficience Physique de Québec, Quebec City, Quebec, Canada
Published: Pediatric Neurology, 2012, November, 47 (5), 345–348

ABSTRACT:

Muscle spasticity in pediatric cerebral palsy limits movement and disrupts motor performance, thus its reduction is important in rehabilitation to optimize functional motor development. Our pilot study used repetitive peripheral magnetic stimulation, because this emerging technology influences spinal and cerebral synaptic transmission, and its antispastic effects were reported in adult neurologic populations. We tested whether five sessions of tibial and common peroneal nerve stimulation exerted acute and long-term effects on spasticity of the ankle plantar flexor muscles in five spastic diparetic children (mean age, 8 years and 3 months; standard deviation, 1 year and 10 months). Muscle resistance to fast stretching was measured with a manual dynamometer as a spasticity indicator. A progressive decrease was observed for the more impaired leg, reaching significance at the third session. This sustained reduction of spasticity may reflect that the peripheral stimulation improved the controls over the spinal circuitry. It thus suggests that a massive stimulation-induced recruitment of sensory afferents may be able to influence central nervous system plasticity in pediatric cerebral palsy.

TITLE: TREATMENT OF SPASTICITY WITH REPETITIVE MAGNETIC STIMULATION; A DOUBLE-BLIND PLACEBO-CONTROLLED STUDY

Authors: Nielsen J.F.[1], Sinkjaer T., Jakobsen J.
Affiliations: [1]Departmentof Neurology, Aarhus University Hospital, Denmark
Published: Multiple Sclerois, 1996, December, 2 (5), 227–232

ABSTRACT:

The effect of repetitive magnetic stimulation on spasticity was evaluated in 38 patients with multiple sclerosis in a double-blind placebo-controlled study. One group treated with repetitive magnetic stimulation (n = 21) and the other group with sham stimulation (n = 17). Both groups were treated twice daily for 7 consecutive days. Primary end-points of the study were changes in the patient self-score, in clinical spasticity score, and in the stretch reflex treshold. The self-score of ease of daily day activities improved by 22 % (p = 0.007) after treatment and by 29 % (p = 0.004) after sham application. The clinical spasticity score improved – 3.3 ± 4.7 arbitrary unit (AU) in treated patients and 0.7 ± 2.5 AU in sham stimulation (p = 0.003). The stretch reflex treshold increased 4.3 ± 7.5 deg/s in treated patients and – 3.8 ± 9.7 des/s in sham stimulation (p = 0.001). The data presented in this study supports the idea that repetitive magnetic stimulation has an antispastic effect in multiple sclerosis. Future studies should clarify the optimal treatment regimen.

TITLE: REPETITIVE PERIPHERAL INDUCTIVE STIMULATION IN COMPREHENSIVE PHYSIOTHERAPEUTIC APPROACH – A CASE STUDY

Authors: Žarković D.[1]
Affiliations: [1]Charles University in Prague, Faculty of Sport and Physical Education, Prague, Czech republic
Presented at the XXIII. Meeting of Society of Rehabilitation and Physical Medicine, May, 2016, Luhačovice, Czech republic

ABSTRACT:

Background:
Repetitive peripheral inductive stimulation (rPIS) uses high-intensity electromagnetic field, which passes through neural tissue in which, electric current causing change in action potential is induced. As the currents are carrying an electric signal to the muscle, muscle contraction is achived. rPIS is a method covering multiple therapeutic effects in various medical branches. By affecting neuromuscular tissue, rPIS is indicated in treatment of various conditions of musculoskeletal and neural system.

Aim:
Aim of this case study was to integrate rPIS in comprehensive physiotherapeutic approach in treatment of patient with postraumatic respiratory and musculoskeletal disease. Device Super Inductive System (SIS; BTL Industries Ltd.) was used to achieve pain relief, myorelaxative and breathing enhancement effect.

Methods:
A 29-year-old male patient underwent a 4-week comprehensive therapeutic protocol comprised of total 16 therapies. Spirometry and kinesiology evaluation were used to compare the patient´s condition ´before and after´. In therapy, a hand-held applicator type „focused field“ was used to treat affected areas. As the device allows setting wide range of therapeutic parameters, various stimulation frequencies were used to achieve different therapeutic effects.

Results:
The 4-week protocol with SIS resulted into improvement of spirometric parameters. Statistically significant changes in SVC, FVC and MVV profile were observed. A positive effect was also observed in his musculoskeletal system, where numerous painful muscle spasms, leading to scoliotic trunk assymetry were eliminated.

Conclusion:
This case study suggest that rPIS can be effectively integrated in comprehensive physiotherapy treatment and covers various therapeutic effects. Although, the study represents only one case, statistically significant changes in respiratory and musculoskeletal system were observed.

Key words:
repetitive peripheral inductive stimulation, spirometry, kinesiology, physiotherapy

TITLE: FORCE–PAIN RELATIONSHIP IN FUNCTIONAL MAGNETIC AND ELECTRICAL STIMULATION OF SUBJECTS WITH PARESIS AND PRESERVED SENSATION

Authors: Szecsi J.[1,2], Götz S., Pöllmann W., Straube A.
Affiliations: [1]Center for Sensorimotor Research, Department of Neurology, Ludwig-Maximilians University, Munich, Germany
[2]Technische Universität München, Munich, Germany

ABSTRACT:

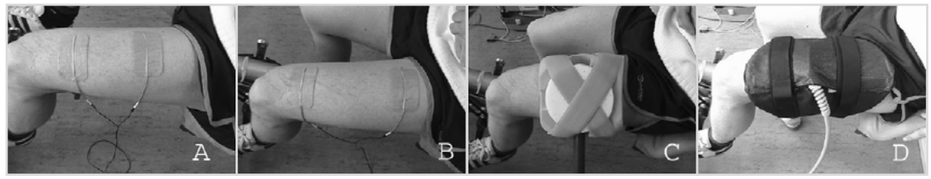
Objective:
Using “painless” magnetic stimulation (FMS) to support the cycling of paretic subjects with preserved sensation is possible and potentially superior to electrical stimulation (FES). We investigated the dependence of the torque and the pain evoked by FMS and FES on stimulation conditions in order to optimize magnetic stimulation.

Methods:
Torque and pain induced by quadriceps stimulation in 13 subjects with paresis and preserved sensation (due to multiple sclerosis) were compared under the conditions: (1) small versus large stimulated surfaces of the thigh, (2) varying contraction velocities of the muscle (isometric versus 15 and 30 rpm isokinetic speed), (3) FMS versus FES modalities, and (4) varying magnetic coil locations.

Results:
Torque and pain significantly depended on the amount of surface and location of stimulation during FMS, on the stimulation modality, and on the muscle contraction velocity during FES and FMS. FMS with a saddle-shaped coil produced more torque ($p < 0.05$) than any other stimulation modality, even at 30 rpm velocity.

Conclusions:
To support leg cycling of subjects with preserved sensation, the application of FMS stimulation with a large-surface saddle-shaped coil and the focusing of stimulation on the lateral-frontal surface of the thigh produces greater torque and less pain than FES.

Significance:
Optimized magnetic stimulation is a superior alternative to electrical stimulation in the rehabilitation of subjects with preserved sensation.



Picture:
Location of the electrodes and the coils during small-separation FES (A) and standard-separation FES (B), FMS with annular-round coil (C) and saddle coil (D)

TITLE: MUSCLE TRAINING WITH REPETITIVE MAGNETIC STIMULATION OF THE QUADRICEPS IN SEVERE COPD PATIENTS

Authors: V. Bustamante V.[1], Lopez de Santa Maria E., Gorostiza A., Jimenez U., Galdiz J.B.
Affiliations: [1]Pneumology Department, Hospital de Basurto, Osakidetza, Basque Country, Spain
Published: Respiratory Medicine, 2010, February, 104 (2), 237-245

ABSTRACT:

Background:
Previous studies have used electrical neuromuscular stimulation as a physical training method in patients with severe COPD (Chronic obstructive pulmonary disease). We introduce the use of the more tolerable magnetic stimulation for the same purpose, investigating the effectiveness of an eight-week protocol.

Methods:
Eighteen patients with severe COPD were randomly assigned to a magnetic stimulation training protocol, n = 10, FEV_1 = 30 % (SD: 7) or to parallel clinical monitoring, control group, n = 8, FEV_1 = 35 % (SD: 8). During eight weeks, patients were stimulated for 15 min on each quadriceps femoris, three times per week. Quadriceps muscle strength and endurance measurements, quality-of-life questionnaires (SF36, SGRQ) and a six-minute walking test were all carried out before and after the training period in the stimulated and control subjects.

Results:
All patients completed the training with increasing intensity of stimulation, displaying a significant improvement in voluntary quadriceps strength (17.5 % of the baseline value) and exercise capacity, with a mean increase of 23 m in the six-minute walking test. The questionnaire scores showed greater increases in quality-of-life scores in the trained subjects compared to the controls, particularly in the physical function areas: mean increments in SF36 in "physical function": +26, "role limitations due to physical problems": +40 and "vitality": +17.5, while +13, -4 and +1, respectively in controls. Saint George's "Activity" score improved by 19.6 points, for 11.5 in controls.

Conclusions:
An rMS (repetitive magnetic stimulation) programme has demonstrated improvements in muscle function parameters, effort capacity and quality of life in severe COPD patients. It can be postulated that this stimulation method might be an alternative for patients incapable of engaging in conventional rehabilitation exercise. It is also a well tolerated, promising option for patients debilitated due to an intercurrent acute disease, bedridden or in intensive care units, in which respiratory rehabilitation is not appropriate or may even have negative effects.

TITLE: DIFFERENTIAL ACTIVATION OF NERVE FIBERS WITH MAGNETIC STIMULATION IN HUMANS

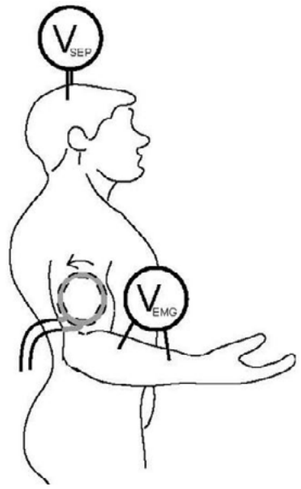
Authors: Tuday E.C.[1], Olree K.S., Horch K.W.
Affiliations: [1]Department of Bioengineering, University of Utah, Salt Lake City, Utah, USA
Published: BMC Neuroscience, 2006, July, 24, 7:58

ABSTRACT:

Background:
Earlier observations in our lab had indicated that large, time-varying magnetic fields could elicit action potentials that travel in only one direction in at least some of the myelinated axons in peripheral nerves. The objective of this study was to collect quantitative evidence for magnetically induced unidirectional action potentials in peripheral nerves of human subjects. A magnetic coil was maneuvered to a location on the upper arm where physical effects consistent with the creation of unidirectional action potentials were observed. Electromyographic (EMG) and somatosensory evoked potential (SEP) recordings were then made from a total of 20 subjects during stimulation with the magnetic coil.

Results:
The relative amplitudes of the EMG and SEP signals changed oppositely when the current direction in the magnetic coil was reversed. This effect was consistent with current direction in the coil relative to the arm for all subjects.

Conclusion:
A differential evocation of motor and sensory fibers was demonstrated and indicates that it may be possible to induce unidirectional action potentials in myelinated peripheral nerve fibers with magnetic stimulation.



Picture:
Sketch of electrode and coil placement. The coil was placed on the medial side of the right arm. The arrow indicates CW current flow in the coil.

TITLE: FUNCTIONAL MAGNETIC STIMULATION SYSTEM AND PULSED MAGNETIC-FIELD EFFECT ON PERIPHERAL NERVE

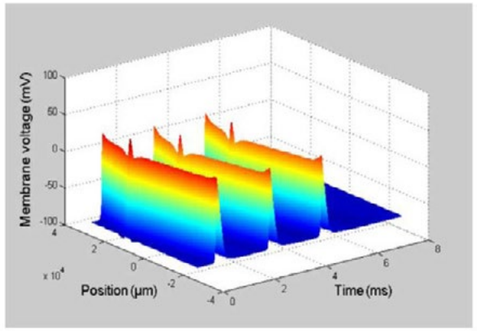
Authors: Liu Ch.[1], Zhu J., Li J., Wang S., Qiu J., Shi Q., Liu J., Zhong L., Zhu J.
Affiliations: [1]Faculty of Electrical Engineering, Xi'an Jiaotong University, State Key Laboratory of Electrical Insulation and Power Equipment, China
Published: IEEE Transactions On Magnetics, 2013, May, 49 (5), 1853-1856

ABSTRACT:

In recent decades, the biological effects of pulsed magnetic field on nerve tissue have attracted more attention. Through experiments, some useful knowledge is summarized. However, the intrinsic mechanisms are not fully understood. The pulsed magnetic-field generator is one of the crucial devices in nerve stimulation. The current waveform produced by the generator, the repeated frequency of the current, and coil form of the device all affect the experimental results. Thus, the development of a magnetic stimulation system, which is suitable for peripheral nerve function recovery, is necessary. In this paper, referring to some studies of magnetic stimulation systems and peripheral nerve properties, a prototype of a pulsed magnetic-field generator is designed and realized. The device can generate damped sinusoidal current flowing through a stimulation coil with appropriate frequency to achieve a pulsed magnetic field for peripheral nerve function recovery. In order to obtain enough induced electric field in nerve tissue, the parameters of stimulation coil are analyzed and designed. Neural response to the magnetic stimulation is simulated based on the Schwarz model, a circuit model of neural, which is helpful to predict the threshold of induced electric field and the effect of magnetic stimulation.

Nerve Fibre Model:
The Schwarz model is used to simulate nerve response. Referring to the work of Roth and Basser, the induced electric field is considered. The nerve membrane voltage can be calculated. The action potential propagation is determined by the induced electric field. If the induced electric field does not exceed the threshold value, the nerve fiber shows a subthreshold. With repeated stimulus acting on nerve fiber, the action potentials are evoked repeatedly.

Conclusion:
In order to study the magnetic stimulation effects on the peripheral nerve, a prototype of the pulsed magnetic-field generator is designed and established. The comparison of simulated and experimental performances of the generator proves the feasibility of this device. The simulation of neural response to pulsed magnetic stimulation is applied to predict an induced electric-field threshold.



Picture:
Repeated stimulus on nerve fibre

TITLE: UNILATERAL MAGNETIC STIMULATION OF THE PHRENIC NERVE

Authors: Mills G.H.[1], Kyroussis D., Hamnegard C.-H., Wragg S., Moxham J., Green M.
Affiliations: [1]Department of Respiratory Medicine, Royal Brompton Hospital, London, United Kingdom
Published: Thorax, 1995, November, 50 (11), 1162-1172

ABSTRACT:

Background:
Electrical stimulation of the phrenic nerve is a useful non-volitional method of assessing diaphragm contractility. During the assessment of hemidiaphragm contractility with electrical stimulation, low twitch transdiaphragmatic pressures may result from difficulty in locating and stimulating the phrenic nerve. Cervical magnetic stimulation overcomes some of these problems, but this technique may not be absolutely specific and does not allow the contractility of one hemidiaphragm to be assessed. This study assesses both the best means of producing supramaximal unilateral magnetic phrenic stimulation and its reproducibility. This technique is then applied to patients.

Methods:
The ability of four different magnetic coils to produce unilateral phrenic stimulation in five normal subjects was assessed from twitch transdiaphragmatic pressure (TwPdi) measurements and diaphragmatic electromyogram (EMG) recordings. The results from magnetic stimulation were compared with those from electrical stimulation. To determine whether the magnetic field affects the contralateral phrenic nerve as well as the intended phrenic nerve, EMG recordings from each hemidiaphragm were compared during stimulation on the same side and the opposite side relative to the recording electrodes. The EMG recordings were made from skin surface electrodes in five normal subjects and from needle electrodes placed in the diaphragm during cardiac surgery in six patients. Similarly, the direction of hemidiaphragm movement was evaluated by ultrasonography. To determine the usefulness of the technique in patients the 43 mm mean diameter double coil was used in 54 patients referred for assessment of possible respiratory muscle weakness. These results were compared with unilateral electrical phrenic stimulation, maximum sniff PDI, and TwPdi during cervical magnetic stimulation.

Conclusions:
Unilateral magnetic phrenic nerve stimulation is easy to apply and is a reproducible technique in the assessment of hemidiaphragm contractility. It is well tolerated and allows hemidiaphragm contractility to be rapidly and reliably assessed because precise positioning of the coils is not necessary. This may be particularly useful in patients. In addition, the anterolateral positioning of the coil allows the use of the magnet in the supine patient such as in the operating theatre or intensive care unit.

TITLE: FUNCTIONAL MAGNETIC STIMULATION FOR CONDITIONING OF EXPIRATORY MUSCLES IN PATIENTS WITH SPINAL CORD INJURY

Authors: Lin V.W.[1], Hsiao I.N., Zhu E., Perkash I.
Affiliations: [1]The Functional Magnetic Stimulation Laboratory of the SCI Health Care Group, VA Long Beach Health Care System
Published: Archives of physical medicine and rehabilitation, 2001, February, 82 (2), 162-166

ABSTRACT:

Objective:
To evaluate the effectiveness of functional magnetic stimulation (FMS) in conditioning expiratory muscles patients with spinal cord injury (SCI).

Participants:
Eight men with tetraplegia.

Intervention:
Expiratory muscle training was achieved by placing a magnetic stimulator with a round magnetic coil along subjects' lower thoracic spine.

Main Outcome Measures:
Measures taken were the maximal expired pressure at total lung capacity (MEP-TLC) and at functional residual capacity (MEP-FRC), expiratory reserve volume (ERV), and the forced expiratory flow rate at TLC (FEF-TLC) and at FRC (FEF-FRC) by subjects' voluntary maximal efforts.

Conclusion:
A 4-week protocol of FMS of the expiratory muscles improves voluntary expiratory muscle strength significantly, indicating that FMS can be a noninvasive therapeutic technology in respiratory muscle training for persons with tetraplegia.

TITLE: FUNCTIONAL MAGNETIC STIMULATION FOR RESTORING COUGH IN PATIENTS WITH TETRAPLEGIA

Authors: Lin W.H.[1], Singh H., Chitkara R.K., Perkash I.
Affiliations: [1]Functional Magnetic Stimulation Laboratory, Spinal Cord Injury Service, VA Palo Alto Health Care System, CA 94304, USA
Published: Archives of physical medicine and rehabilitation, 1998, May, 79 (5), 517-522

ABSTRACT:

Objective:
To evaluate the usefulness of functional magnetic stimulation (FMS) as a noninvasive method for assisting cough in patients with tetraplegia.

Participants:
Thirteen male SCI (spinal cord injury) patients, with injury levels between C4 and C7.

Intervention:
A commercially available magnetic stimulator with a round magnetic coil (MC) was used. Expiratory muscle activation was achieved by placing the MC along the lower thoracic spine.

Main Outcome Measure:
The planned major outcome measures were the maximal expired pressure (MEP), expiratory reserve volume (ERV), and forced expiratory flow rate (FEF) by FMS compared with voluntary maximal efforts. Another outcome was the optimal MC placement and stimulation intensity that would result in highest expired pressure.

Conclusion:
FMS of the expiratory muscles produced significant expired pressures, volumes, and flow rates when compared with voluntary maximum efforts; therefore, FMS can be used as an effective method to restore cough in tetraplegic patients.

TITLE: FUNCTIONAL MAGNETIC STIMULATION OF THE ABDOMINAL MUSCLES IN HUMANS

Authors: Polkey M.I.[1], Luo Y., Guleria R., Hamnegård C.H., Green M., Moxham J.
Affiliations: [1]Respiratory Muscle Laboratory, King's College School of Medicine & Dentistry and Respiratory Muscle Laboratory, Royal Brompton Hospital, London, United Kingdom
Published: American Journal of Respiratory and Critical Care Medicine, 1999, August, 160 (2), 513-522

ABSTRACT:

Functional magnetic stimulation (FMS) of the thoracic nerve roots to simulate cough has been suggested as a treatment approach in patients unable to voluntarily activate the abdominal muscles. However, factors that could influence the efficacy of FMS in clinical use have not been evaluated. In the present investigation we studied train length, posture, and frequency to determine the optimal stimulation protocol. We also evaluated the use of a valve at the mouth to enhance glottic function and investigated whether lung volume at the time of stimulation would influence the tension generated by the abdominal muscles. Studies were performed using a Magstim Rapid stimulator augmented by four booster packs in nine healthy subjects; we measured the change in gastric (ΔPga_{FMS}), esophageal (ΔPes_{FMS}), and mouth pressure and expiratory flow. With our apparatus pressure generation was maximized by having a train length of at least 300 ms and a frequency of 25 Hz. Posture and valve use were not important determinants of ΔPga_{FMS} or ΔPes_{FMS}. Lung volume exerted only a minor influence on ΔPga_{FMS}, but the ratio ΔPes_{FMS}: ΔPga_{FMS} was increased at TLC (relaxation after inspiration) compared with FRC (relaxed end-expiration). Expiratory flow was increased by adopting a seated posture and using an occlusion valve with an opening threshold close to the maximum ΔPes_{FMS} generated by the stimulus train; however, expiratory flow was susceptible to interference from glottic incoordination. Representative results (with train length 600 ms, 25 Hz, and 100 % power, seated) were mean ΔPga_{FMS}, 166 cm H_2O; mean ΔPes_{FMS}, 108 cm H_2O; and mean expiratory flow, 311 l/min. We confirm that FMS of the abdominal muscles can generate a substantial positive intra-abdominal and intrathoracic pressure and, consequently, expiratory flow in normal subjects.

TITLE: FUNCTIONAL MAGNETIC STIMULATION OF EXPIRATORY MUSCLES: A NONINVASIVE AND NEW METHOD FOR RESTORING COUGH

Authors: Lin V.W.[1], Hsieh C., Hsiao I.N., Canfield J.
Affiliations: [1]Spinal Cord Injury Service, Stanford University School of Medicine, Palo Alto, California 94304, USA
Published: Journal of Applied Physiology Published, 1998, April, 84 (4), 1144-1150

ABSTRACT:

The purpose of this study was to assess the effectiveness of functional magnetic stimulation (FMS) for producing expiratory function in normal human subjects. Twelve able-bodied normal subjects were recruited for this study. FMS of the expiratory muscles was performed by using a magnetic stimulator and placing the magnetic coil along the lower thoracic spine. Results showed that peak expired pressure, volume, and flow rate generated by FMS at the end of normal were comparable to their voluntary maximal levels ($p > 0.1$). The optimal coil placement was between T7 and T11, and the optimal stimulation parameters were a frequency of 25 Hz and 70–80 % of maximal intensity. We conclude that 1) FMS of the lower thoracic nerves in normal subjects resulted in a significant expiratory function comparable to their voluntary maximum; 2) FMS was noninvasive and was well tolerated by all subjects; and 3) FMS may be useful to produce cough in patients in critical care or perioperative settings, or in patients with neurological disorders.

TITLE: SIMULATION OF COUGH IN MAN BY MAGNETIC STIMULATION OF THE THORACIC NERVE ROOTS

Authors: Kyroussis D.[1], Polkey M.I. Mills G.H., Hughes P.D., Moxham J., Green M.
Affiliations: [1]Department of Thoracic Medicine, King's College School of Medicine, London, United Kingdom
Published: American Journal of Respiratory and Critical Care Medicine, 1997, November, 156 (5), 1696-1699

ABSTRACT:

Normal cough requires abdominal muscle contraction. We have previously reported contraction of the abdominal muscles elicited by a single percutaneous magnetic stimulation of the thoracic nerve roots. We hypothesized that paired magnetic twitches could generate sufficient tension in the abdominal muscles to simulate cough. Therefore, six normal subjects were stimulated at the T10 intervertebral level in the seated position. We measured the gastric pressure elicited by paired magnetic stimuli (pTw Pga) with interstimulus intervals in the range of 10 ms (100 Hz) to 999 ms (1 Hz). In the second part of the study we evaluated paired stimuli (at the frequency found to produce the greatest response) using a valve to simulate the function of the glottis; the valve was arranged such that it opened once mouth pressure exceeded a predetermined threshold. Mean pTw Pga during stimulation for the 6 subjects was 74 cm H_2O (range, 30–109), and mean peak flow was 209 l/min (range, 128–345 l/min). These values were increased if the subject took a prior inspiration or had previously made a vigorous expiratory effort. Comparable values for a maximal natural cough were 212 cm H_2O and 649 l/min. We conclude that paired magnetic thoracic nerve root stimulation produces gastric pressure and expiratory flow of an order of magnitude comparable to a natural cough.

TITLE: FUNCTIONAL MAGNETIC STIMULATION FACILITATES GASTRIC EMPTYING

Authors: Lin V.W.[1], Kim K.H., Hsiao I., Brown W.
Affiliations: [1]Functional Magnetic Stimulation Laboratory, Spinal Cord Injury/Disorder Health Care Group, VA Long Beach Health Care System, Long Beach, CA 90822, USA
Published: Archives of Physical Medicine and Rehabilitation, 2002, June, 83 (6), 806-810

ABSTRACT:

Objective:
To evaluate the effect of functional magnetic stimulation (FMS) on gastric emptying in able-bodied and spinal cord injury (SCI) subjects.

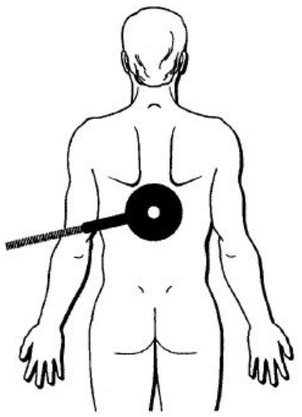
Participants:
Five healthy, able-bodied subjects and four subjects with SCI.

Intervention:
A commercially available magnetic stimulator was used; a round magnetic coil was placed along the T9 spinous process. The intensity of the magnetic stimulation was 60 %, with a frequency of 20 Hz, and a burst length of 2 seconds for the gastric emptying protocol.

Main Outcome Measures:
Rate of gastric emptying and time required to reach gastric emptying half-time ($GE_{t1/2}$) with and without FMS. Data fit into linear regression curve.

Results:
Accelerated gastric emptying was achieved in both able-bodied and SCI subjects. The mean standard error of mean of the $GE_{t1/2}$ at baseline and with FMS was 36 ± 2.9 minutes and 33 ± 3.1 minutes, respectively, for able-bodied subjects, and 84 ± 11.1 minutes and 59 ± 12.7 minutes, respectively, for SCI subjects.

Conclusion:
Gastric emptying was enhanced by FMS in able-bodied subjects and was greatly enhanced in SCI subjects. FMS can be a useful noninvasive therapeutic tool to facilitate gastric emptying in humans.



Picture:
Human subject lying supine with a 12.5-cm, round magnetic coil placed at T9 of the spinal processes

TITLE: PERIPHERAL APPLICATION OF REPETITIVE PULSE MAGNETIC STIMULATION ON JOINT CONTRACTURE FOR MOBILITY RESTORATION

Authors: Kouloulas E.[1,2]
Affiliations: [1]Rehabilitation Unit "Physiatriki", Athens, Greece
[2]2nd Neurosurgery Dpt, National Kapodistrian University of Athens "Attikon" University Hospital Athens, Greece
Published: International Journal of Physiotherapy, 2016, 3(5), 519-524

ABSTRACT:

Background and Objectives:
Joint contracture is a limitation in the passive or active range of motion (ROM) of a joint, where in addition to the mobility limiting factor the pain is also present. Repetitive pulsed Magnetic Stimulation (rPMS) appears to be an effective, non-invasive and safety solution for treating this condition. Therefore aim of this study was to evaluate the effect of rPMS in treating joint contracture.

Materials and Methods:
30 subjects with joint contracture in the knee were enrolled in this study and divided respectively into Treatment and Control group. The treatment group were delivered with rPMS therapy. The control group were delivered with conventional physiotherapy method (ultrasound). The primary outcome measurements were: 1. Mobility evaluation by goniometry (ROM in degrees while performing flexion) and Patient Functional Assessment Questionnaire (PFAQ) for ability to perform Activities of Daily Living (ADL) and 2. Pain evaluation by 10-point Visual Analog Scale (VAS) for pain perception. Absence of adverse events was set as a secondary measure.

Results:
The results of the study show statistical difference between the levels of improvement of all studied parameters while comparing between both groups. The results suggest greater mobility restoration and pain relieving effect of the rPMS in comparison to conventional physiotherapy method.

Conclusion:
rPMS is an effective and safe non-invasive method for mobility restoration and pain relief in case of joint contractures. This study suggests the method as beneficial and quality of life ameliorating among patients suffering from immobilized joints accompanied by pain.

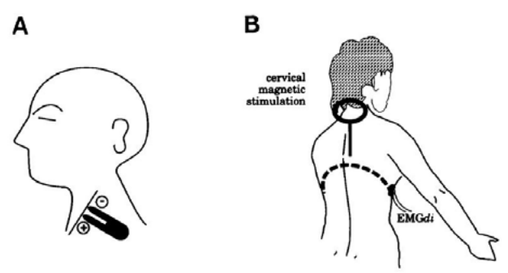
TITLE: COMPARISON OF MAGNETIC AND ELECTRICAL PHRENIC NERVE STIMULATION IN ASSESSMENT OF PHRENIC NERVE CONDUCTION TIME

Authors: Similowski T.[1], Mehiri S., Duguet A., Attali V., Straus Ch., Derenne J.P.
Affiliations: [1]Service de Pneumologie et Re´animation and Laboratoire de Physiopathologie Respiratoire, Groupe Hospitalier Pitie-Salpetriere
Published: Journal of Applied Physiology, 1997, April, 82 (4), 1190-1199

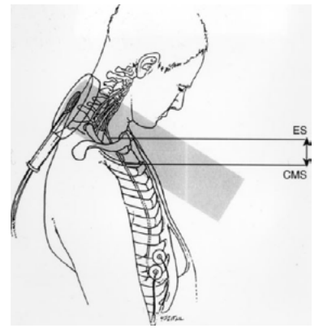
ABSTRACT:

Cervical magnetic stimulation (CMS), a nonvolitional test of diaphragm function, is an easy means for measuring the latency of the diaphragm motor response to phrenic nerve stimulation, namely, phrenic nerve conduction time (PNCT). In this application, CMS has some practical advantages over electrical stimulation of the phrenic nerve in the neck (ES). Although normal ES-PNCTs have been consistently reported between 7 and 8 ms, data are less homogeneous for CMS-PNCTs, with some reports suggesting lower values. This study systematically compares ES- and CMS-PNCTs for the same subjects. Surface recordings of diaphragmatic electromyographic activity were obtained for seven healthy volunteers during ES and CMS of varying intensities. On average, ES-PNCTs amounted to 6.41 ± 0.84 ms and were little influenced by stimulation intensity. With CMS, PNCTs were significantly lower (average difference 1.05 ms), showing a marked increase as CMS intensity lessened. ES and CMS values became comparable for a CMS intensity 65 % of the maximal possible intensity of 2.5 Tesla. These findings may be the result of phrenic nerve depolarization occurring more distally than expected with CMS, which may have clinical implications regarding the diagnosis and follow-up of phrenic nerve lesions.

Discussion:
The salient finding of this study is that PNCTs measured with CMS can be significantly shorter than PNCTs measured by using transcutaneous ES.



Picture:
Schematic representation of techniques used for transcutaneous electrical stimulation of phrenic nerve (ES;A) and cervical magnetic stimulation (CMS;B).



Picture:
Anatomic drawing of cervical origin and intrathoracic pathway of phrenic nerve. Magnetic field produced when CMS is applied according to technique generally used for phrenic nerve stimulation intersects with trunk of phrenic nerve in thorax, approximately between 1st and 2nd rib.

TITLE: MAGNETIC VERSUS ELECTRICAL STIMULATION IN THE INTERPOLATION TWITCH TECHNIQUE OF ELBOW FLEXORS

Authors: Lampropoulou S.I.[1], Nowicky A.V. , Marston L.
Affiliations: [1]School of Health Sciences and Social Care, Centre for Rehabilitation Research, Brunel University, Uxbridge, UK
Published: Journal of Sports Science and Medicine, 2012, December, 11 (4), 709-718

ABSTRACT:

The study compared peripheral magnetic with electrical stimulation of the biceps brachii m. (BB) in the single pulse Interpolation Twitch Technique (ITT). 14 healthy participants (31 ± 7 years) participated in a within-subjects repeated-measures design study. Single, constant-current electrical and magnetic stimuli were delivered over the motor point of BB with supramaximal intensity (20 % above maximum) at rest and at various levels of voluntary contraction. Force measurements from right elbow isometric flexion and muscle electromyograms (EMG) from the BB, the triceps brachii m. (TB) and the abductor pollicis brevis m. (APB) were obtained. The twitch forces at rest and maximal contractions, the twitch force-voluntary force relationship, the M-waves and the voluntary activation (VA) of BB between magnetic and electrical stimulation were compared. The mean amplitude of the twitches evoked at MVC (maximal voluntary contraction) was not significantly different between electrical (0.62 ± 0.49 N) and magnetic (0.81 ± 0.49 N) stimulation ($p > 0.05$), and the maximum VA of BB was comparable between electrical (95 %) and magnetic (93 %) stimulation ($p > 0.05$). No differences ($p > 0.05$) were revealed in the BB M-waves between electrical (13.47 ± 0.49 mV.ms) and magnetic (12.61 ± 0.58 mV.ms) stimulation. The TB M-waves were also similar ($p > 0.05$) but electrically evoked APB M-waves were significantly larger than those evoked by magnetic stimulation ($p < 0.05$). The twitch voluntary force relationship over the range of MVCs was best described by non-linear functions for both electrical and magnetic stimulation. The electrically evoked resting twitches were consistently larger in amplitude than the magnetically evoked ones (mean difference 3.1 ± 3.34 N, $p < 0.05$). Reduction of the inter-electrodes distance reduced the twitch amplitude by 6.5 ± 6.2 N ($p < 0.05$). The fundamental similarities in voluntary activation assessment of BB with peripheral electrical and magnetic stimulation point towards a promising new application of peripheral magnetic stimulation as an alternative to the conventional ITT for the assessment of BB voluntary activation.

Results:
All participants reported that magnetic stimulation caused much less discomfort than electrical stimulation and that it was well tolerated even at supramaximal intensities.

Conclusion:
Overall, the results of the study have shown that there are key similarities between magnetic and electrical stimulation in the assessment of voluntary activation with the single pulse Twitch Interpolation Technique. The twitch responses at maximal contractions and the M-waves for agonist BB were comparable. The activation for the antagonist TB was minimal and the curve-fitting for the twitch force-voluntary force relationship was non linear for both electrical and magnetic stimulation. The closeness of BB voluntary activation between electrical and magnetic stimulation at maximal contractions indicate that the use of magnetic stimulation in the single twitch interpolation technique may be an appropriate method of estimating the activation level of BB, despite the factors which contribute to the resting twitch differences and the different curve fitting observed here. The larger resting twitches evoked by electrical stimulation and the different curve fitting may not be significant when investigating the use of peripheral magnetic stimulation with an array of coils and stimulators. Thus, the similar sensitivity of magnetic stimulation to electrical stimulation in assessing voluntary activation and the absence of discomfort from magnetic stimulation offer significant advantages for the assessment of voluntary activation in the clinical environment.

TITLE: A COMPACT THEORY OF MAGNETIC NERVE STIMULATION: PREDICTING HOW TO AIM

Authors: Babbs Ch.F.[1]
Affiliations: [1]Purdue University, Weldon School of Biomedical Engineering, West Lafayette, Indiana, USA
Published: BioMedical Engineering OnLine, 2014, 13:53

ABSTRACT:

Background:
A compact theory that predicts quantitatively when and where magnetic neurostimulation will occur is needed as a guide to therapy, ideally providing a single equation that defines the target volume of tissue excited by single or dual coils.

Methods:
A first-principles analysis of magnetic stimulation incorporating a simplified description of electromagnetic fields and a simplified cable theory of the axon yields a mathematical synthesis predicting how to aim.

Results:
Nerve stimulation produced by a single circular coil having one or more closely packed turns occurs in donut shaped volume of tissue beneath the coil. Axons spanning several millimeters are the sites of magnetic stimulation. The sites of maximal transmembrane depolarization in nerve fibers correspond to points where the axons enter or exit this volume of magnetically induced voltage and current. The axonal membrane at one end is depolarized locally during the rising phase of current in the coil. The axonal membrane at the opposite end is depolarized locally during the falling phase of current in the coil. Penetration depths of several centimeters from the skin surface or approximately one to two coil radii are practical. With two coils placed in a figure-of-eight configuration the separate clockwise and counterclockwise currents generate magnetic fields that add, producing maximal stimulation of a spindle shaped volume, centered at a depth of one-third to one-half coil radius from the body surface.

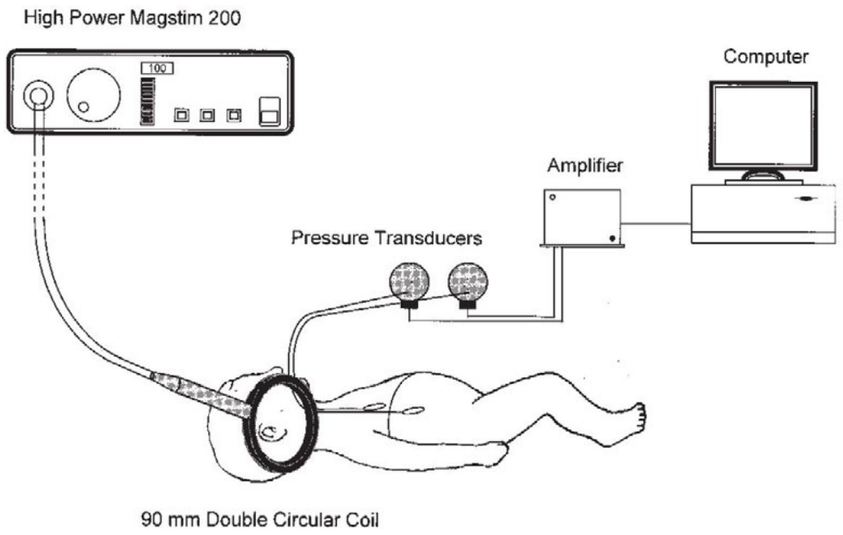
Conclusions:
This condensed synthesis of electromagnetic theory and cable theories of axon physiology provides a partial solution to the targeting problem in peripheral and in transcranial magnetic stimulation.

TITLE: ASSESSMENT OF NEONATAL DIAPHRAGM FUNCTION USING MAGNETIC STIMULATION OF THE PHRENIC NERVES

Authors: Rafferty G.F.[1], Greenough A., Dimitriou G., Kavadia V., Laubscher B., Polkey M.I., Harris M.L., Moxham J.
Affiliations: [1]Department of Child Health, Guy's, King's and St Thomas' School of Medicine, King's College Hospital, London, United Kingdom
Published: American Journal of Respiratory and Critical Care Medicine, 2000, December, 162 (6), 2337-2340

ABSTRACT:

A nonvolitional test to assess diaphragm strength in neonates has not been previously described. Our aim was to assess the feasibility of cervical (CMS) and anterior (AMS) magnetic stimulation of the phrenic nerves in neonates. Double circular stimulating coils (90-mm) were used. For CMS, one coil was placed over the cervical spine to bilaterally stimulate the phrenic nerve roots, whereas for AMS the coils were placed on the anterolateral aspect of the neck to allow unilateral and bilateral stimulation. Diaphragm contractility was assessed as transdiaphragmatic pressure (Pdi) measured with balloon catheters positioned in the midesophagus and stomach. Stimulus supramaximality was assessed by examining diaphragm twitch Pdi (TwPdi) across a range of stimulator outputs; 85, 90, 95, and 100 % of maximum. Pressure signals were measured by differential pressure transducer and displayed in real time on a computer. Patients were studied supine during sleep. CMS was performed on seven neonates (mean gestational age [GA] 38 weeks, range 33 to 40 weeks) and AMS on 18 neonates (mean GA 37 weeks, range 32 to 41 weeks). The mean (SD) TwPdi with CMS was 2.5 (0.8) cm H_2O. CMS was not supramaximal; reducing the stimulator output below 100 % caused marked reductions in TwPdi, also the shape of the pressure waveforms suggested that CMS may not have activated the diaphragm alone. Mean (SD) TwPdi with AMS was 4.5 (1.3) cm H_2O on the left, 4.1 (0.9) cm H_2O on the right, and 8.7 (3.9) cm H_2O for bilateral stimulation. The shape of the pressure waveforms suggested that AMS was more specific and a plateau in TwPdi at higher stimulator outputs indicated supramaximality. We conclude that AMS may provide a useful technique to assess diaphragm function in the neonate.



Picture:
Diagrammatic representation of the apparatus used with the magnetic coil positioned for unilateral AMS of the phrenic nerve

TITLE: MAGNETIC STIMULATION FOR THE MEASUREMENT OF RESPIRATORY AND SKELETAL MUSCLE FUNCTION

Authors: Man W.D-C.[1], Moxham J., Polkey M.I.
Affiliations: [1]Respiratory Muscle Laboratory, Guy's, King's and St Thomas' School of Medicine, King's College Hospital, London, United Kingdom
Published: European Respiratory Journal, 2004, November, 24 (5), 846-860

ABSTRACT:

Respiratory and skeletal muscle function is of interest in many areas of pulmonary and critical care medicine. The capacity of the respiratory muscle pump to respond to the load imposed by disease is the basis of an understanding of ventilatory failure. Over the last four decades, considerable progress has been made in quantifying the capacity of the respiratory muscles, in terms of strength, endurance and fatigue. With the development of magnetic stimulation, it has recently become possible to nonvolitionally assess the respiratory muscles in a clinically acceptable way. This is of particular interest in the investigation of patients receiving critical care, those with neuromuscular disease, and in children where volitional efforts are either not possible or likely to be sub-maximal. Furthermore, the adaptation of these techniques to quantify the strength of peripheral muscles, such as the quadriceps, has allowed the effects of muscle training or rehabilitation, uninfluenced by learning effect, to be assessed. This article focuses on the physiological basis of magnetic nerve stimulation, and reviews how the technique has been applied to measure muscle strength and fatigue, with particular emphasis upon the diaphragm. The translation of magnetic stimulation into a clinical tool is described, and how it may be of diagnostic, prognostic and therapeutic value in several areas of pulmonary medicine. In particular, the use of magnetic stimulation in neuromuscular disease, the intensive care setting, chronic obstructive pulmonary disease and paediatrics will be discussed.

TITLE: ADDUCTOR POLLICIS TWITCH TENSION ASSESSED BY MAGNETIC STIMULATION OF THE ULNAR NERVE

Authors: Harris M.L.[1], Luo Y.M., Watson A.C., Rafferty G.F., Polkey M.I., Green M., Moxham J.
Affiliations: [1]Department of Respiratory Medicine, King's College and Royal Brompton Hospitals, London, United Kingdom
Published: Am J Respir Crit Care Med. American Journal of Respiratory and Critical Care Medicine, 2000, July, 162 (1), 240-245

ABSTRACT:

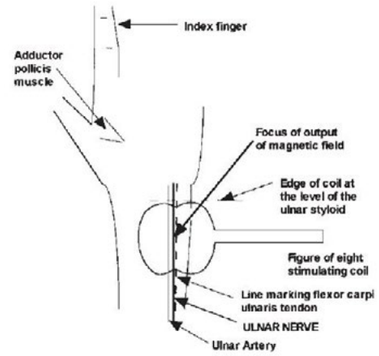
Many critically ill patients develop significant skeletal muscle weakness in the Intensive Care Unit (ICU), which ultimately may cause difficulties in weaning from mechanical ventilation and a protracted, expensive ICU stay. Reliable monitoring of muscle strength in this environment is difficult. The purpose of this study was to develop a reproducible, nonvolitional method of measuring adductor pollicis (AP) muscle function by magnetic stimulation of the ulnar nerve (MSUN) that could be applied to patients in the ICU and operating theater (OT).

Subjects:
We studied a total of 50 subjects who were divided into three groups (Table 1). In addition, to compare young normal subjects with healthy elderly subjects we divided Group 1 into subgroups 1a (20 young control subjects) and 1b (12 elderly control subjects).

Stimulation Technique:
Electrical stimulation (ES): The ulnar nerve was stimulated with squarewave impulses of 0.1 ms duration from a bipolar surface stimulating electrode powered by an electrical stimulator (Medelec Ltd., Old Woking, Surrey, UK). The cathode position was standardized and placed distal to the anode at the intersection of the two marked lines marking the flexor carpi ulnaris tendon and the ulnar styloid. With this position maintained the active EMG recording electrode over the thenar eminence was at least 5 cm from the stimulating electrode. Magentic stimulation (MS): A 43-mm figure of eight coil (P/N 8459) powered by a Magstim 200 stimulator (Magstim Co. Ltd., Whitland, Dyfed, Wales) was used. The coil was positioned firmly against the skin with the focus of the output of the magnetic field over the ulnar nerve at the same point as for electrical stimulation (Picture 1). Optimum position and orientation of the coil head were examined. Maximum voluntary contraction (MVC): Subjects were asked to perform a maximum voluntary contraction without flexing their thumb and the ratio between MVC and Tw AP (AP twitch tension) was calculated. During the MVC a superimposed supramaximal stimulation (interpolated twitch) was delivered to the ulnar nerve when force reached a plateau, to assess the level of voluntary activation. This maneuver was repeated three time and the MVC was accepted for comparison with resting twitch tension if the interpolated twitch was less than 5 % of the potentiated Tw AP.

Protocols:
MSUN was performed on all subjects. Group 1a (20 young control subjects): A comparison was made between ESUN (electrical stimulation of the ulnar nerve) and MSUN in 12 of the control subjects and in six of these control subjects the comparison was repeated on three to five occasions. Measurement of MVC was made in 10 control subjects. In five control subjects the spread of the MSUN was compared to ESUN. Group 1b (12 elderly control subjects): Twitch force and CMAP (compound muscle action potential) amplitude was recorded in all subjects. Six subjects performed an MVC. Group 2 (12 ICU patients): Twitch force was measured in all patients and CMAP amplitude was measured in seven patients. Only two patients were able to attempt an MVC. Group 3 (six OT patients): MSUN was performed and the twitch force was measured in these patients prior to the induction of anesthesia.

Discussion:
The main finding of this study is that it is possible to achieve supramaximal activation of the AP muscle by MSUN. The twitch response elicited is reproducible and the technique can be successfully employed in the ICU and OT.



Picture 1:
The position of a magnetic stimulating coil in relation to anatomical landmarks

Group	No.	Age
1a	20 young control subjects	Mean (range) 30 yr (16–39)
1b	12 elderly control subjects	Mean (range) 77 yr (65–86)
2	12 ICU patients	Mean (range) 46 yr (24–73)
3	6 OT patients	Mean (range) 42 yr (33–47)

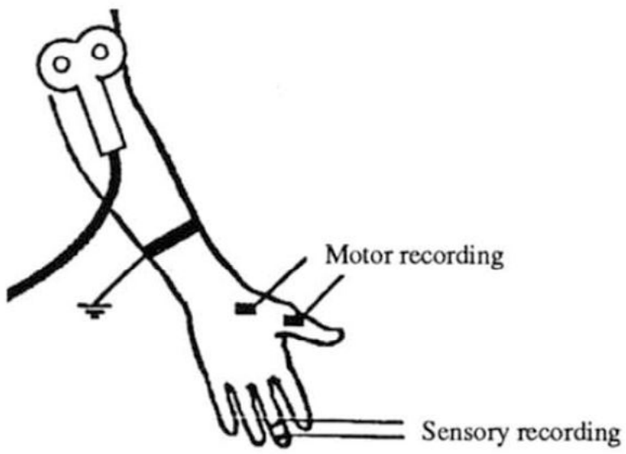
Table 1:
Subjects and age range in the four groups

TITLE: DETERMINING THE SITE OF STIMULATION DURING MAGNETIC STIMULATION OF A PERIPHERAL NERVE

Authors: Nilsson J.[1], Panizza M., Roth B.J., Basser P.J., Cohen L.G., Caruso G., Hallett M.
Affiliations: [1]Laboratory of Clinical Neurophysiology, Fondazione Clinica del Lavoro, Castel Goffredo, (MN) Italy
Published: Electroencephalography and Clinical Neurophysiology, 1992, August, 85 (4), 253-264

ABSTRACT:

Magnetic stimulation has not been routinely used for studies of peripheral nerve conduction primarily because of uncertainty about the location of the stimulation site. We performed several experiments to locate the site of nerve stimulation. Uniform latency shifts, similar to those that can be obtained during electrical stimulation, were observed when a magnetic coil was moved along the median nerve in the region of the elbow, thereby ensuring that the properties of the nerve and surrounding volume conductor were uniform. By evoking muscle responses both electrically and magnetically and matching their latencies, amplitudes and shapes, the site of stimulation was determined to be 3.0 + 0.5 cm from the center of an 8-shaped coil toward the coil handle. When the polarity of the current was reversed by rotating the coil, the latency of the evoked response shifted by 0.65 + 0.05 msec, which implies that the site of stimulation was displaced 4.1 + 0.5 cm. Additional evidence of cathode- and anode-like behavior during magnetic stimulation comes from observations of preferential activation of motor responses over H-reflexes with stimulation of a distal site, and of preferential activation of H-reflexes over motor responses with stimulation of a proximal site. Analogous behavior is observed with electrical stimulation. These experiments were motivated by, and are qualitatively consistent with, a mathematical model of magnetic stimulation of an axon.



Picture:
Positioning of the coil and recording electrodes on the arm and hand