Pulsed Magnetic Therapy Nerve Regeneration – PEMF Spinal Cord Injury Bibliography

A classic 'red-herring' study done at 72 Hz –>
J Peripher Nerv Syst. 2009 Dec;14(4):285-93.
PEMF fails to enhance nerve regeneration after sciatic nerve crush lesion.
Baptista AF, Goes BT, Menezes D, Gomes FC, Zugaib J, Stipursky J, Gomes JR, Oliveira JT, Vannier-Santos MA, Martinez AM.
Universidade Federal da Bahia, Biomorphology Department, Health Sciences Institute, Salvador, BA, Brazil.

Int J Surg. 2014 Dec;12(12):1278-85. doi: 10.1016/j.ijsu.2014.11.004. Epub 2014 Nov 11.
Pulsed electromagnetic fields accelerate functional recovery of transected sciatic nerve bridged by chitosan conduit: An animal model study.
Mohammadi R1, Faraji D2, Alemi H2, Mokarizadeh A3.

Int J Neurosci. 2014 Oct 31. [Epub ahead of print]
Co-treatment effect of pulsed electromagnetic field (PEMF) with human dental pulp stromal cells and FK506 on the regeneration of crush injured rat sciatic nerve.
Kim YT1, Hei WH, Kim S, Seo YK, Kim SM, Jahng JW, Lee JH.

Electromagn Biol Med. 2014 Sep;33(3):198-205. doi: 10.3109/15368378.2013.801351. Epub 2013 Jun 19.
Variable spatial magnetic field influences peripheral nerves regeneration in rats.
Suszyński K1, Marcol W, Szajkowski S, Pietrucha-Dutczak M, Cieślar G, Sieroń A, Lewin-Kowalik J.

J Phys Ther Sci. 2014 Sep;26(9):1355-61. doi: 10.1589/jpts.26.1355. Epub 2014 Sep 17.
Effects of pulsed electromagnetic field and swimming exercise on rats with experimental sciatic nerve injury.
Kavlak E1, Belge F2, Unsal C2, Uner AG2, Cavlak U1, Cömlekçi S3.

J Mol Neurosci. 2012 Sep;48(1):144-53. doi: 10.1007/s12031-012-9791-8. Epub 2012 May 17.
Electromagnetic field stimulation potentiates endogenous myelin repair by recruiting subventricular neural stem cells in an experimental model of white matter demyelination.
Sherafat MA, Heibatollahi M, Mongabadi S, Moradi F, Javan M, Ahmadiani A.

J Head Trauma Rehabil. 2012 Jul-Aug;27(4):274-92. doi: 10.1097/HTR.0b013e318217df55. Review.
Noninvasive brain stimulation in traumatic brain injury.
Demirtas-Tatlidede A, Vahabzadeh-Hagh AM, Bernabeu M, Tormos JM, Pascual-Leone A.

Int Rev Neurobiol. 2012;105:19-38. doi: 10.1016/B978-0-12-398309-1.00003-2. Review
Role of electrical activity of neurons for neuroprotection.
Morimoto T.

Brain Res Bull. 2011 Mar 10;84(4-5):343-57. doi: 10.1016/j.brainresbull.2010.08.007. Epub 2010 Aug 20.
Development of quantitative and sensitive assessments of physiological and functional outcome during recovery from spinal cord injury: a clinical initiative.
Ellaway PH, Kuppuswamy A, Balasubramaniam AV, Maksimovic R, Gall A, Craggs MD, Mathias CJ, Bacon M, Prochazka A, Kowalczewski J, Conway BA, Galen S, Catton CJ, Allan DB, Curt A, Wirth B, van Hedel HJ.

Below on-point 1989 study done at just 2 Hz showing 22% enhanced regeneration (10 Hz should have shown 400% if in-line withNASA/Goodwin) –>and still there is no good published research in this area. Definitely this therapy is being swept under the carpet by the BigPharma cartel.

Brain Res. 1989 Apr 24;485(2):309-16.
Stimulation of rat sciatic nerve regeneration with pulsed electromagnetic fields.
Sisken BF, Kanje M, Lundborg G, Herbst E, Kurtz W.

..And this too; they're obviously keeping this from the public–>>
Clin Orthop Relat Res. 1983 Dec;(181):283-90.
Effect of weak, pulsing electromagnetic fields on neural regeneration in the rat.
Ito H, Bassett CA.
Center for Biomedical Engineering, University of Kentucky, Lexington 40506.

Then you have this study done at power frequency (50Hz) and remarkably showed benefit (i saw 50 Hz and thought it'd be another red-herring)
Effect of Whole Body Magnetic Field Exposure on the Sensori-Motor Recovery in Spinalised Rats

---

Neurorehabil Neural Repair. 2010 Jun;24(5):435-41. Epub 2010 Jan 6.
Reduction of spasticity with repetitive transcranial magnetic stimulation in patients with spinal cord injury.
Kumru H, Murillo N, Samso JV, Valls-Sole J, Edwards D, Pelayo R, Valero-Cabre A, Tormos JM, Pascual-Leone A.

Source
Hospital de Neurorehabilitación Institut Guttmann, Barcelona, Spain

---

Exp Neurol. 2010 Apr;222(2):211-8. Epub 2010 Jan 6.
Functional electrical stimulation helps replenish progenitor cells in the injured spinal cord of adult rats.
Becker D, Gary DS, Rosenzweig ES, Grill WM, McDonald JW.
International Center, for Spinal Cord Injury, Hugo Moser Research Institute, Department of Neurology, Johns Hopkins School of Medicine and Kennedy Krieger Institute, Baltimore, MD 21205, USA.

Clin Neurophysiol. 2010 Feb;121(2):248-54. Epub 2009 Dec 29.
Increased motor cortical excitability after whole-hand electrical stimulation: a TMS study.
Golaszewski SM, Bergmann J, Christova M, Nardone R, Kronbichler M, Rafolt D, Gallasch E, Staffen W, Ladurner G, Beisteiner R.
Department of Neurology and Neuroscience Institute, Christian Doppler Clinic, Paracelsus Medical University Salzburg, Salzburg, Austria.

Electromagn Biol Med. 2007;26(1):1-23. Review.
Magnetic field therapy: a review.
Markov MS.

Altern Ther Health Med. 2006 Sep-Oct;12(5):42-9.
Regenerative effects of pulsed magnetic field on injured peripheral nerves.
Mert T, Gunay I, Gocmen C, Kaya M, Polat S.
Department of Biophysics, University of Cukurova School of Medicine, Adana, Turkey.

Previous studies confirm that pulsed magnetic field (PMF) accelerates functional recovery after a nerve crush lesion. The contention that PMF enhances the regeneration is still controversial, however. The influence of a new PMF application protocol (trained PMF) on nerve regeneration was studied in a model of crush injury of the sciatic nerve of rats. To determine if exposure to PMF influences regeneration, we used electrophysiological recordings and ultrastructural examinations. After the measurements of conduction velocity, the sucrose-gap method was used to record compound action potentials (CAPs) from sciatic nerves. PMF treatment during the 38 days following the crush injury enhanced the regeneration. Although the axonal ultrastructures were generally normal, slight to moderate myelin sheath degeneration was noted at the lesion site. PMF application for 38 days accelerated nerve conduction velocity, increased CAP amplitude and decreased the time to peak of the CAP. Furthermore, corrective effects of PMF on. the abnormal characteristics of sensory nerve fibers were determined. Consequently, long-periodic trained-PMF may promote both morphological and electrophysiological properties of the injured nerves. In addition, corrective effects of PMF on sensory fibers may be considered an important finding for neuropathic pain therapy.

Clin Orthop Relat Res. 1983 Dec;(181):283-90.
Effect of weak, pulsing electromagnetic fields on neural regeneration in the rat.
Ito H, Bassett CA.

BASSETT PREDATES ROBERT O. BECKER IN THIS FIELD OF WORK; HIS RESEARCH ON BONE AND ELECTRIC CURRENTS DATE BACK TO THE 1960'S (EMPASIS ADDED)

The short- and long-term effects of pulsed electromagnetic fields (PEMFs) on the rate and quality of peripheral nerve regeneration were studied. High bilateral transections of rat sciatic nerves were surgically approximated (a 1-mm gap was left) and shielded with a Silastic sleeve. Animals were exposed to PEMFs for two to 14 weeks after operation. Three groups of 20 rats each (control rats and rats undergoing 12- and 24-hour/day PEMF exposure) were killed at two weeks. Histologically, regenerating axons had penetrated the distal stump nearly twice as far in the PEMF-exposed animals as in the control animals. Return of motor function was judged two to 14 weeks after operation by the load cell-measured, plantar-flexion force produced by neural stimulation proximal to the transection site. Motor function returned earlier in experimental rats and to significantly higher load levels than in control rats. Nerves from animals functioning 12-14 weeks after operation had less interaxonal collagen, more fiber-containing axis cylinders, and larger fiber diameters in the PEMF-exposed group than in the control rats. Histologic and functional data indicate that PEMFs improve the rate and quality of peripheral nerve regeneration in the severed rat sciatic nerve by a factor of approximately two.

Plast Reconstr Surg. 1984 Feb;73(2):173-83.
Pulsing electromagnetic field therapy in nerve regeneration: an experimental study in the cat.
Orgel MG, O'Brien WJ, Murray HM.

A multidisciplinary approach to the study of peripheral nerve regeneration in the cat has been presented. The purpose of this work has been to determine if pulsing electromagnetic field (PEMF) therapy can enhance peripheral nerve regeneration after injury. In equal groups of animals, two types of pulsing electromagnetic field treatment were compared with untreated controls. All animals underwent quantitative electrophysiologic and morphologic assessment at the area of injury. In addition, muscle fiber sizing in the periphery and retrograde labeling of anterior horn motoneurons with horseradish peroxidase were studied. Results have shown no statistical differences between the groups in electrophysiologic or morphologic parameters. However, in animals treated with a pulse-burst electromagnetic field there was a statistically significant improvement in the labeling and localization of anterior horn cells in the central nervous system. These results indicate that pulse-burst electromagnetic radiation can increase the numbers of motor neurons that reestablish appropriate connections to the periphery after nerve injury. It remains to be seen if this improved spinal cord organization can translate to improved peripheral functional return.

J Neurosci Res. 2004 Jan 15;75(2):253-61.
Repetitive transcranial magnetic stimulation improves open field locomotor recovery after low but not high thoracic spinal cord compression-injury in adult rats.
Poirrier AL, Nyssen Y, Scholtes F, Multon S, Rinkin C, Weber G, Bouhy D, Brook G, Franzen R, Schoenen J.
Source

Research Centre for Cellular and Molecular Neurobiology, Neuroanatomy Laboratory, University of Liege, Belgium.

Bioelectromagnetics. 2005 Jan;26(1):20-7.
Pulsed electromagnetic fields induce peripheral nerve regeneration and endplate enzymatic changes.
De Pedro JA, Pérez-Caballer AJ, Dominguez J, Collía F, Blanco J, Salvado M.
Department of Orthopaedics, University Hospital of Salamanca, Salamanca, Spain. jpedrom@usal.es

An experimental study was carried out in rats with the purpose of demonstrating the capacity of pulsed electromagnetic fields (PEMFs) to stimulate regeneration of the peripheral nervous system (PNS). Wistar and Brown Norway (BN) rats were used. Direct sciatic nerve anastomoses were performed after section or allograft interposition. Treatment groups then received 4 weeks of PEMFs. Control groups received no stimulation. The evaluation of the results was carried out by quantitative morphometric analysis, demonstrating a statistically significant increase in regeneration indices ($P < 0.05$) in the stimulated groups (9000 +/- 5000 and 4000 +/- 6000) compared to the non-stimulated groups (2000 +/- 4000 and 700 +/- 200). An increase of NAD specific isocitrate dehydrogenase (IDH) activity was found along with an increase in the activity of acetyl cholinesterase at the motor plate. The present study might lead to the search for new alternatives in the stimulation of axonal regenerative processes in the PNS and other possible clinical applications. 2004 Wiley-Liss, Inc.

Spine. 2003 Dec 15;28(24):2660-6.
Exposure to pulsed magnetic fields enhances motor recovery in cats after spinal cord injury.
Crowe MJ, Sun ZP, Battocletti JH, Macias MY, Pintar FA, Maiman DJ.
Neuroscience Research Laboratories, The Clement J. Zablocki VA Medical Center, Milwaukee, WI 53295, USA. mcrowe@mcw.edu

STUDY DESIGN: Animal model study of eight healthy commercial cats was conducted.

OBJECTIVE: To determine whether pulsed electromagnetic field (PMF) stimulation results in improvement of function after contusive spinal cord injury in cats.

SUMMARY OF BACKGROUND DATA: PMF stimulation has been shown to enhance nerve growth, regeneration, and functional recovery of peripheral nerves. Little research has been performed examining the effects of PMF stimulation on the central nervous system and no studies of PMF effects on in vivo spinal cord injury (SCI) models have been reported.

MATERIALS AND METHODS: PMF stimulation was noninvasively applied for up to 12 weeks to the midthoracic spine of cats with acute contusive spinal cord injury. The injury was produced using a weight-drop apparatus. Motor functions were evaluated with the modified Tarlov assessment scale. Morphologic analyses of the injury sites and somatosensory-evoked potential measurements were conducted to compare results between PMF-stimulated and control groups.

RESULTS: There was a significant difference in locomotor recovery between the PMF-stimulated and control groups. Although not statistically significant, PMF-stimulated spinal cords demonstrated greater sparing of peripheral white matter and smaller lesion volumes compared to controls. Somatosensory-

evoked potential measurements indicated that the PMF-stimulated group had better recovery of preinjury waveforms than the control group; however, this observation also was not statistically significant because of the small sample size.

CONCLUSIONS: This preliminary study indicates that pulsed magnetic fields may have beneficial effects on motor function recovery and lesion volume size after acute spinal cord injury.

Exp Mol Med. 2002 Mar 31;34(1):53-9.
Enhanced expression of neuronal nitric oxide synthase and phospholipase C-gamma1 in regenerating murine neuronal cells by pulsed electromagnetic field.
Kim SS, Shin HJ, Eom DW, Huh JR, Woo Y, Kim H, Ryu SH, Suh PG, Kim MJ, Kim JY, Koo TW, Cho YH, Chung SM.
Source
Department of Pathology, Ulsan University College of Medicine, Korea.

J Reconstr Microsurg. 1999 Aug;15(6):427-31.
Using a direct current electrical field to promote spinal-cord regeneration.
Shen NJ, Wang SC.
Department of Orthopedics, People's Hospital of Hainan Province, Haikou, China.

The authors used a direct current electrical field to promote spinal-cord regeneration in a canine model. Thirty-two dogs were randomly divided into four groups. Complete spinal-cord injury was induced, and electrical stimulators were then placed in the animals. Group 1 served as controls; Groups 2 to 4 were experimental groups, with varying stimulator voltages: 0V in Group 1, 12V in Groups 2 and 4, and 6V in Group 3, with the stimulator implanted 6 hr after spinal-cord injury in Group 4. Functional, electrophysiologic and morphometric assessments were carried out 1 to 3 months postoperatively. Results showed that spinal-cord function, cortical somatosensory evoked potentials, number of neurons, sectional area of neurons, and Nissl body density in the experimental groups were much better than those in the control group. In addition, all the indices in Group 2 were better than those in Groups 3 and 4. This indicated that direct current electrical stimulation could effectively promote spinal-cord regeneration and functional recovery in this model. The 12V voltage was safe for the animals. The stimulator was not rejected by the host for a relatively long period of time.

J Neurosci Res. 1999 Jan 15;55(2):230-7.
Electromagnetic fields influence NGF activity and levels following sciatic nerve transection.
Longo FM, Yang T, Hamilton S, Hyde JF, Walker J, Jennes L, Stach R, Sisken BF.
Department of Neurology, UCSF/VAMC, San Francisco, California, USA.

Plast Reconstr Surg. 1984 Feb;73(2):173-83.
Pulsing electromagnetic field therapy in nerve regeneration: an experimental study in the cat.
Orgel MG, O'Brien WJ, Murray HM.

A multidisciplinary approach to the study of peripheral nerve regeneration in the cat has been presented. The purpose of this work has been to determine if pulsing electromagnetic field (PEMF) therapy can enhance peripheral nerve regeneration after injury. In equal groups of animals, two types of pulsing electromagnetic field treatment were compared with untreated controls. All animals underwent quantitative electrophysiologic and morphologic assessment at the area of injury. In addition, muscle fiber sizing in the periphery and retrograde labeling of anterior horn motoneurons with horseradish peroxidase were studied. Results have shown no statistical differences between the groups in electrophysiologic or morphologic parameters. However, in animals treated with a pulse-burst electromagnetic field there was a statistically significant improvement in the labeling and localization of anterior horn cells in the central nervous system. These results indicate that pulse-burst electromagnetic radiation can increase the numbers of motor neurons that reestablish appropriate connections to the periphery after nerve injury. It remains to be seen if this improved spinal cord organization can translate to improved peripheral functional return.

PMID: 6695016 [PubMed – indexed for MEDLINE]

Clin Orthop. 1983 Dec;(181):283-90.
Effect of weak, pulsing electromagnetic fields on neural regeneration in the rat.
Ito H, Bassett CA.

The short- and long-term effects of pulsed electromagnetic fields (PEMFs) on the rate and quality of peripheral nerve regeneration were studied. High bilateral transections of rat sciatic nerves were surgically approximated (a 1-mm gap was left) and shielded with a Silastic sleeve. Animals were exposed to PEMFs for two to 14 weeks after operation. Three groups of 20 rats each (control rats and rats undergoing 12- and 24-hour/day PEMF exposure) were killed at two weeks.Histologically, regenerating axons had penetrated the distal stump nearly twice as far in the PEMF-exposed animals as in the control animals. Return of motor function was judged two to 14 weeks after operation by the load cell-measured, plantar-flexion force produced by neural stimulation proximal to the transection site. Motor function returned earlier in experimental rats and to significantly higher load levels than in control rats. Nerves from animals functioning 12-14 weeks after operation had less interaxonal collagen, more fiber-containing axis cylinders, and larger fiber diameters in the PEMF-exposed group than in the control rats. Histologic and functional data indicate that PEMFs improve the rate and quality of peripheral nerve regeneration in the severed rat sciatic nerve by a factor of approximately two.

PMID: 6641063 [PubMed – indexed for MEDLINE]

J Hand Surg [Br]. 1984 Jun;9(2):105-12.
An experimental study of the effects of pulsed electromagnetic field (Diapulse) on nerve repair.
Raji AM.

This study investigates the effects of a pulsed electromagnetic field (PEMF) (Diapulse) on experimentally divided and sutured common peroneal nerves in rats. Evidence is presented to show that PEMF accelerates recovery of use of the injured limb and enhances regeneration of damaged nerves.

PMID: 6747406 [PubMed – indexed for MEDLINE]

J Bone Joint Surg Br. 1983 Aug;65(4):478-92.
Effects of high-peak pulsed electromagnetic field on the degeneration and regeneration of the common peroneal nerve in rats.
Raji AR, Bowden RE.

Apart from preliminary notices of present work, previous reports of experimental and clinical trials of the effects of a high-peak pulsed electromagnetic field (PEMF) on degeneration and regeneration of peripheral nerves lacked statistical analysis. Therefore, we designed experiments with standardised operative, histological, cytological and morphometric techniques to assess the effect of PEMF on lesions of the common peroneal nerves in paired male rats matched for age, environmental conditions and level and type of lesion. One of two types of lesion was induced in the left common peroneal nerve: in 12 pairs of rats the nerve was crushed just above the knee and in the remaining 12 pairs the nerve was cut and immediately sutured at the same level. The right common peroneal nerve of each rat served as a control. Animals received 15 minutes of PEMF produced by a Diapulse machine or sham treatment daily for periods ranging from three and a half days to eight weeks after injury. Healthy nerves were unaffected, but after damage there were statistically significant differences between PEMF treated and sham treated rats. PEMF accelerated the recovery of injured limbs and the degeneration, regeneration and maturation of myelinated axons; epineural, perineural and intraneural fibrosis was reduced; and the luminal cross-sectional area of intraneural vessels increased after both types of lesion. Findings are discussed and the need for clinical trials is stressed.

PMID: 6603461 [PubMed – indexed for MEDLINE]

Nippon Ika Daigaku Zasshi. 1986 Aug;53(4):321-31.
[Nerve regeneration with pulsing electromagnetic field stimulation, with special reference to nerve conduction velocity]
[Article in Japanese]
Narita T.

PMID: 3760123 [PubMed – indexed for MEDLINE]

Paraplegia. 1976 May;14(1):12-20.
Experimental regeneration in peripheral nerves and the spinal cord in laboratory animals exposed to a pulsed electromagnetic field.
Wilson DH, Jagadeesh P.

Peripheral nerve section and suture was performed in 132 rats. Postoperatively half the animals were exposed to a pulsed electromagnetic field each day and half were kept as controls. Nerve conduction studies, histology and nerve fibre counts all indicated an increased rate of regeneration in the treated animals. A similar controlled study of spinal cord regeneration following hemicordotomy in cats has been started, and preliminary results indicate that when the animals are sacrificed three months after

the hemicordotomy, the pulsed electromagnetic therapy has induced nerve fibre regeneration across the region of the scar.

PMID: 180476 [PubMed – indexed for MEDLINE]

Plast Reconstr Surg. 1989 Feb;83(2):301-8.
Effect of a high-intensity static magnetic field on sciatic nerve regeneration in the rat.
Cordeiro PG, Seckel BR, Miller CD, Gross PT, Wise RE.
Department of Plastic and Reconstructive Surgery, Lahey Clinic Medical Center, Burlington, Mass.

The effect of a high-intensity static magnetic field on peripheral nerve regeneration is evaluated in rat sciatic nerve. Forty-four rats underwent sciatic nerve repair using polyethylene nerve guides. Postoperatively, the animals were exposed to a 1-tesla magnetic field for 12 hours per day for 4 weeks with appropriate controls. Our results demonstrate that a 1-tesla static magnetic field has no statistically significant effect on nerve regeneration as determined by myelinated axon counts and electrophysiologic studies. Also, the specific orientation of the sciatic nerve with respect to the magnetic field has no influence on axonal growth or nerve conduction. Periods of restraint of 12 hours per day for 4 weeks significantly inhibit weight gain but have no effect on peripheral nerve regeneration.

PMID: 2911629 [PubMed – indexed for MEDLINE]

Plast Reconstr Surg. 1991 Jan;87(1):122-9.
A multivariate approach to the treatment of peripheral nerve transection injury: the role of electromagnetic field therapy.
Zienowicz RJ, Thomas BA, Kurtz WH, Orgel MG.
University of Massachusetts Medical School, Berkshire Medical Center, Pittsfield.

A multivariate approach to the treatment of peripheral nerve transection injury has been used in a rat model. A pilot study (48 animals, 8 groups) examined variables associated with the method and timing of surgical repair, the arrest of wallerian degeneration, and the role of pulsing electromagnetic field therapy (PEMF) in functional recovery. A second phase (90 animals, 6 groups) then studied the timing and duration of pulsing electromagnetic field therapy as the only variable in larger groups of animals. The pilot study revealed that a vein-graft conduit did not improve functional recovery compared with standard
epineurial repair. Additionally, delayed repair compared favorably with immediate repair. The use of chlorpromazine to inhibit the toxic effects of calcium influx appeared to enhance early functional recovery, and the combination of delayed nerve repair and pulsing electromagnetic field
therapy seemed to consistently improve function. The second phase of the study has demonstrated (for the first time) statistical improvement in ambulation in animals treated with delayed surgical repair and prolonged pulsing electromagnetic field therapy. We postulate that future treatment of
nerve transection injuries will involve a combined treatment regimen consisting of the immediate arrest of wallerian degeneration, delayed surgery, and pulsing
electromagnetic field therapy.

PMID: 1984256 [PubMed – indexed for MEDLINE]

Lancet. 1982 Aug 21;2(8295):444-5.
Effects of high peak pulsed electromagnetic fields on degeneration and regeneration of the common peroneal nerve in rate.
Raji AR, Bowden RE.

Publication Types:
Letter

PMID: 6124837 [PubMed – indexed for MEDLINE]

Equine Vet J. 1983 Oct;15(4):354-60.
Review of pulsing electromagnetic field therapy and its possible application to horses.
Auer JA, Burch GE, Hall P.
The relevant literature on electrostimulation in general, and pulsing electromagnetic fields in particular, is reviewed. DC current influences cell behaviour by affecting transmembrane ion transport, which is often under enzymatic control. Pulsing electromagnetic fields influence cell functions through adsorption of ions or dipole formation at the cell membrane. Invasive and non-invasive DC current stimulation is compared to pulsing electromagnetic fields. The mode of application of pulsing electromagnetic fields to the equine limb and suggested treatment times are briefly discussed. Two case reports are
used to illustrate the effect of pulsing electromagnetic fields in equine fracture treatment.

Publication Types:
Case Reports
PMID: 6641683 [PubMed – indexed for MEDLINE]

Bioelectromagnetics. 1993;14(4):353-9.
Pretreatment of rats with pulsed electromagnetic fields enhances regeneration of the sciatic nerve.
Kanje M, Rusovan A, Sisken B, Lundborg G.
Department of Animal Physiology, University of Lund, Sweden.

Regeneration of the sciatic nerve was studied in rats pretreated in a pulsed electromagnetic field (PEMF). The rats were exposed between a pair of Helmholtz coils at a pulse repetition rate of 2 pps at a field density of 60 or 300 microT. The PEMF treatment was then discontinued. After an interval of recovery, regeneration of the sciatic nerve was initiated by a crush lesion. Regeneration of sensory fibers was measured by the “pinch test” after an additional 3-6 days.
A variety of PEMF pre-treatments including 4 h/day for 1-4 days or exposure for 15 min/day during 2 days resulted in an increased regeneration distance,measured 3 days after the crush lesion. This effect could be demonstrated even after a 14-day recovery period. In contrast, pretreatment for 4 h/day for 2 days at 60 microT did not affect the regeneration distance. The results showed that PEMF pretreatment conditioned the rat sciatic nerve in a manner similar to that which occurs after a crush lesion, which

indicates that PEMF affects the neuronal cell body. However, the mechanism of this effect remains obscure.

PMID: 8216387 [PubMed – indexed for MEDLINE]

Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 1999 Mar;13(2):114-8.
[Morphological changes and electrophysiological study of motor neuron of spinal cord following delayed repair of peripheral nerve injury]
[Article in Chinese]
Zhu JY, Huang YT, Lu R.
Institute of Orthopaedics, Xijing Hospital, Fourth Military Medical University, Xi'an Shanxi, P. R. China 710032.

OBJECTIVE: Following the delayed repair of peripheral nerve injury, the cell number of anterior horn of the spinal cord and its ultrastructural changes, motorneuron and its electrophysiological changes were investigated.

METHODS: In 16 rabbits the common peroneal nerves of both sides being transected one year later were divided into four groups randomly: the degeneration group and regeneration of 1, 3 and 5 months groups. Another 4 rabbits were used for control. All transected common peroneal nerves underwent epineural suture except for the degeneration group the electrophysiological examination was carried out at 1, 3 and 5 months postoperatively. Retrograde labelling of the anterior horn cells was demonstrated and the cells were observed under light and electronmicroscope.

RESULTS: 1. The number of labelled anterior horn cell in the spinal cord was 45% of the normal population after denervation for one year ($P < 0.01$). The number of labelled cells increased steadily from 48% to 57% and 68% of normal values at 1, 3 and 5 months following delayed nerve repair ($P < 0.01$).
2. The ultrastructure of the anterior horn cells of the recover gradually after repair.
3. With the progress of regeneration the latency become shortened, the conduction velocity was increased, the amplitude of action potential was increased.

CONCLUSION: Following delayed repair of injury of peripheral nerve,the morphology of anterior horn cells of spinal cord and electrophysiological display all revealed evidence of regeneration, thus the late repair of injury of peripheral nerve was valid.

PMID: 12080765 [PubMed – indexed for MEDLINE]

ASAIO Trans. 1988 Oct-Dec;34(4):947-51.
The use of DC electric fields to promote regeneration in the mammalian nervous system.
Zanakis MF.
American Biointerface Corporation, New York, New York.

Publication Types:
Review
Review, Tutorial

PMID: 3064792 [PubMed – indexed for MEDLINE]

J UOEH. 1988 Mar 1;10(1):31-45.
The effect of long-term pulsing electromagnetic field stimulation on experimental osteoporosis of rats.
Mishima S.
Department of Orthopedic Surgery, School of Medicine, University of Occupational and Environmental Health, Kitakyushu, Japan.

The author performed experiments in order to investigate what biological effect on the bone would be produced by long-term pulsing electromagnetic field (PEMF) systemic stimulation. In some of the mature female rats used as experimental animals, bilateral ovariectomy and right sciatic neurectomy were performed in order to make a model osteoporosis. PEMF stimulation was produced by repetitive pulse burst (RPB) waves at a positive amplitude of 25 mV, negative amplitude of 62.5 mV, burst width of 4.2 ms, pulse width of 230 microseconds and 12 Hz, with the magnetic field strength within a cage being set at 3-10 Gauss. PEMF stimulation over 6 months did not produce any effects on the physiologically aged bones. PEMF stimulation also did not produce any effects on losed cortical one in osteoporotic hindlegs. On the other hand, an increase of bone volume and bone formation activity was observed in the cancellous bone of osteoporotic hindlegs. These findings suggested that PEMF stimulation exerted a preventive effect against bone loss of osteoporotic hindlegs. Furthermore, an observed increase in bone marrow blood flow seemed to be related with this increase of bone volume and bone formation activity.

Publication Types:
Review
Review, Tutorial

PMID: 3285429 [PubMed – indexed for MEDLINE]

Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 1997 Jan;11(1):14-8.
[Influence of low energy He-Ne laser on regeneration of peripheral nerve]
[Article in Chinese]
Shi K, Lu R, Xu X.

Institute of Orthopedics of PLA, Fourth Military Medical University, Xi'an. The purpose of this experiment was to elucidate the influence of the low-energy
He-Ne laser on the function of regeneration of peripheral nerve. Forty-four rabbits about 2.5 kg body weight were used in the experiment. The animals were
divided into 4, 8, 12, 16 weeks groups according to the observation period. Six animals were used in each irradiated group and in the control group 5 rabbits were used in each observation period. Regeneration of the axon and myelinc sheath, the latent rate of the common peroneal nerve, the conditions of the anterior tibital muscle and the toe expansion test were all observed systematically in

both groups. The experimental results was: A few thin regenerated axon was seen at 4 weeks in the irradiated group, while in the control group it might be seen at 8 weeks, the P value was < 0.01. A low amplitude latent rate of the common peroneal nerve is determined at the peroneal side of the anterior tibial muscle in a few animal at 4 weeks of the irradiated
group, and it is not observed in the control group, from 12 to 16 weeks. THe latent rate of the common peroneal nerve was the irradiated group than in the controlled, the P value was < 0.01. The regeneration of the myeline sheath was evident in the irradiated group, and also the slstion of the muscle
fibers anterior tibial muscle was clearly visible than the controlled. 16 weeks postoperatively, the toe expansion test was normal in the irradiated group,while in the control group it was the same as seen at 12 weeks after operation in the irradiated group. Now it was certain that the low-energy He-Ne laser could promole the function of the spinal motor nerve cells and accelerate the axonal regeneration.

PMID: 9867943 [PubMed – indexed for MEDLINE]

Clin Orthop. 1983 Dec;(181):277-82.
Effects of pulsing electromagnetic fields on bone growth and articular cartilage.
Smith RL, Nagel DA.

Observations made during treatment of juvenile pseudarthrosis by pulsing electromagnetic fields (PEMF) suggested that bone growth might be altered. PEMF applied to immature rabbits under conditions of continuous stimulation (24 hours/day for 8 weeks) produced no major changes in bone growth. Continuous stimulation by PEMF induced a statistically significant increase (22%) in femoral articular cartilage glycosaminoglycan. Intermittent PEMF stimulation (12 hours with stimulation/12 hours without stimulation) for 18 weeks produced no significant change in bone growth or time of epiphyseal plate closure. No
significant changes in the physical characteristics of growing bone were observed with any treatment.

PMID: 6641061 [PubMed – indexed for MEDLINE]

J Reconstr Microsurg. 1999 Aug;15(6):427-31.
Using a direct current electrical field to promote spinal-cord regeneration.
Shen NJ, Wang SC.
Department of Orthopedics, People's Hospital of Hainan Province, Haikou, China.

The authors used a direct current electrical field to promote spinal-cord regeneration in a canine model. Thirty-two dogs were randomly divided into four groups. Complete spinal-cord injury was induced, and electrical stimulators were then placed in the animals. Group 1 served as controls; Groups 2 to 4 were experimental groups, with varying stimulator voltages: 0V in Group 1, 12V in Groups 2 and 4, and 6V in Group 3, with the stimulator implanted 6 hr after spinal-cord injury in Group 4. Functional, electrophysiologic and morphometric assessments were carried out 1 to 3 months postoperatively. Results showed that
spinal-cord function, cortical somatosensory evoked potentials, number of neurons, sectional area of neurons, and Nissl body density in the experimental groups were much better than those in the control group. In addition, all the indices in Group 2 were better than those in Groups 3 and 4. This indicated

that direct current electrical stimulation could effectively promote spinal-cord regeneration and functional recovery in this model. The 12V voltage was safe for the animals. The stimulator was not rejected by the host for a relatively long period of time.

PMID: 10480562 [PubMed – indexed for MEDLINE]

Brain Res. 1985 Nov 25;348(1):159-62.
Regeneration of gamma-fusimotor axons after nerve-freeze injury in the cat.
Scott JJ.

Nerve injury was produced by application of dry ice to the common peroneal nerve. After 20 weeks, muscle-spindle primary endings responded normally to stretch and the spindles were found to have a fully functional fusimotor innervation.

PMID: 4063820 [PubMed – indexed for MEDLINE]

Muscle Nerve. 2001 May;24(5):662-6.
Partial peripheral motor nerve lesions induce changes in the conduction properties of remaining intact motoneurons.
Havton LA, Hotson JR, Kellerth JO.
Department of Neurology, University of California, Los Angeles, and Reed Neurological Research Center, 710 Westwood Plaza, Los Angeles, California
90095-1769, USA. LHavton@mednet.ucla.edu

A partial injury or loss of peripheral motor axons is followed by compensatory sprouting of remaining intact motor axons in order to reinnervate muscle. Little is known, however, about the electrophysiologic properties proximally of these intact motoneurons and their axons following injury of neighboring motor axons. We studied the conduction properties of intact cat motor axons and motoneurons proximal to the site of a partial peripheral nerve section. Twelve weeks after the partial transection of the cat medial gastrocnemius motor nerve, there was a significant (7%) reduction in conduction velocity and a 13% prolongation in
afterhyperpolarization half-decay time in the remaining intact motoneurons, compared with controls. Partial injury to motor nerves thus induces reactive electrophysiologic changes in the remaining intact motoneurons and their axons, perhaps associated with compensatory sprouting within partially denervated muscle.

PMID: 11317276 [PubMed – indexed for MEDLINE]

J Hand Surg [Am]. 1983 May;8(3):248-53.
Specificity of muscle reinnervation after epineurial and individual fascicular
suture of the rat sciatic nerve.
Brushart TM, Tarlov EC, Mesulam MM.

We experimentally analyzed the specificity of muscle reinnervation after suture and regeneration of rat sciatic nerve. We used a horseradish peroxidase (HRP) technique of axon tracing to compare the number and location of motoneurons that innervate muscle via the peroneal nerve after epineurial and individual fascicular suture of the parent sciatic nerve. These motoneurons are significantly reduced in number from control levels and are often in spinal cord locations that indicate previous innervation of antagonistic muscle via the tibial nerve. This inappropriate reinnervation of peroneal muscle by tibial motoneurons is minimized by individual fascicular suture without compromise of overall reinnervation. Our findings thus support the hypothesis that individual fascicular suture may avoid distortion of the central connections of peripheral units.

PMID: 6348148 [PubMed – indexed for MEDLINE]

Science. 1980 May 9;208(4444):603-5.
Alteration in connections between muscle and anterior horn motoneurons after peripheral nerve repair.
Brushart TM, Mesulam MM.

The connections between the spinal cord and lower leg muscles of the rat are significantly altered by repair of the intervening sciatric nerve. Muscles supplied by the peroneal branch of the sciatic are innervated by fewer motoneurons after sciatic repair. Many of these neurons originally innervated the peroneal muscles, and others formerly served the antagonistic tibial muscles. Perikarya in the size range of alpha motoneurons regained peripheral connections with greater frequency than those in the gamma range. There are thus postoperative defects in the extent and specificity of alpha reinnervation as well as in the degree of gamma control.

PMID: 7367884 [PubMed – indexed for MEDLINE]

Spine. 1984 Apr;9(3):273-9.
The effect of postoperative electromagnetic pulsing on canine posterior spinal fusions.
Kahanovitz N, Arnoczky SP, Hulse D, Shires PK.

An experimental canine study was devised to evaluate the efficacy of a noninvasive adjunct to improve the rate and quality of the posterior fusion mass over the standard surgical technique. Ten large adult mongrel dogs underwent a three-level lumbar spinal fusion. Bone excised from the spinous processes was packed in removed facet joints and over the decorticated laminae. To insure rigid internal fixation, custom-made distraction instrumentation was placed bilaterally under the laminae of the vertebrae above and below the three fused vertebrae. Five dogs underwent electromagnetic pulsing, and five dogs acted as
controls. Two dogs were sacrificed at 4, 6, 9, 12, and 15 weeks to assess the radiographic and histologic status of the fusion mass. Preoperative and preautopsy hematologic studies as well as gross and histologic autopsy specimens revealed no abnormalities attributable to the electromagnetic pulsing. High-resolution radiography and histologic studies showed earlier incorporation of the graft, improved new bone formation, and better organization of the fusion mass in the 4-, 6-, and 9-week stimulated specimens. However, by 12 and 15 weeks there did not appear to be any histologic or radiographic differences between the stimulated and control dogs. Although electromagnetic pulsing appears to

produce an early accelerated osteogenic response, it does not appear to improve the overall results of primary canine spinal fusions.

PMID: 6729593 [PubMed – indexed for MEDLINE]

Exp Neurol. 1983 May;80(2):418-26.
Reinnervation of the gastrocnemius muscle by the contralateral S1 nerve root.
Shonnard N, Wakefield C.

Functional regeneration after transposition of a ventral nerve root was established in the adult cat. Reconstruction of the ventral root, using microsurgical methods, directed the right S1 ventral nerve root to innervate the left gastrocnemius muscle. Stimulus-induced unit responses were recorded from the left gastrocnemius muscle 5 to 8 months after the root cross, demonstrating the reestablishment of neuromuscular connections. The innervation of the left gastrocnemius muscle by neurons in the right ventral horn of the spinal cord was verified by injecting horseradish peroxidase into the muscle. Horseradish peroxidase reaction product was located in alpha and gamma motor neurons in the right S1 segment of the spinal cord. Computer-assisted determination of the soma area of the labeled neurons was compared with a normal S1 innervation of the gastrocnemius muscle. Analysis of the percentage of cells of a given soma area demonstrated an overall decrease in soma area in the operated animals. Because ventral root reconstruction can result in innervation of a foreign muscle, studies such as this may encourage repair or reconstruction of nerve roots to gain some functional recovery after spinal cord or nerve root injuries.

PMID: 6840247 [PubMed – indexed for MEDLINE]

Bioelectromagnetics. 1996;17(1):44-7.
Effect of low-intensity millimeter wave electromagnetic radiation on regeneration of the sciatic nerve in rats.
Kolosova LI, Akoev GN, Avelev VD, Riabchikova OV, Babu KS.
Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg.

The effect of low-intensity millimeter wave electromagnetic radiation (MWR) on regeneration of the rat sciatic nerve after transection and microsurgical reapproximation was examined. Rats were exposed to 54 GHz MWR at a power density of 4 mW/cm2. It was found that MWR treatment of the femoral skin in the area of suture accelerated the regeneration of nerve fibers. At the twentieth postoperative day, the MWR-treated animals had a 32% increase in the regeneration distance compared to the control animals. The conduction velocity showed a 26% increase in the MWR-treated animals.

PMID: 8742755 [PubMed – indexed for MEDLINE]

J Neurosci Res. 1995 Dec;42(5):692-9.
Acute treatment with pulsed electromagnetic fields and its effect on fast axonal transport in normal and regenerating nerve.

Sisken BF, Jacob JM, Walker JL.
Department of Anatomy and Neurobiology, University of Kentucky, Lexington 40506, USA.

The mechanism whereby low-frequency electromagnetic fields accelerate axonal regrowth and regeneration of peripheral nerve after crush lesion is not known. One candidate is an alteration in axonal transport. In this study we exposed unoperated rats for 15 min/day, and rats that had undergone a crush lesion of the sciatic nerve, for 1 hr/day for 2 days, to 2-Hz pulsed electromagnetic fields. To label fast transported proteins, [3H]-proline was microinjected into the spinal cord, and the sciatic nerves were removed 2, 3.5, and 5 hr later. The rates of fast axonal transport were obtained for animals in all groups by
counting sequential 2-mm segments of nerves. The following transport rates were found: in unoperated normal sciatic nerve not exposed to PEMF, 373 +/- 14 mm/day; in unoperated normal nerve exposed to PEMF, 383 +/- 14 mm/day; in sham crush nerves not exposed to PEMF, 379 +/- 19 mm/day; in sham crush nerve exposed to PEMF, 385 +/- 17 mm/day; in crushed nerves not exposed to PEMF, 393 +/- 16 mm/day. and in crushed nerves exposed to PEMF, 392 +/- 15 mm/day. The results of these experiments indicate that 1) a crush injury to the sciatic nerve does not alter the rate of fast axonal transport, and 2) low-frequency pulsed electromagnetic fields do not alter fast axonal transport rates in operated (crush) or unoperated sciatic nerves.

PMID: 8600302 [PubMed – indexed for MEDLINE]

Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 1997 Jan;11(1):10-3.
[Influence of low energy He-Ne laser on spinal motor nerve cell]
[Article in Chinese]
Shi K, Lu R, Xu X.
Institute of Orthopedics of PLA, Fourth Military Medical University, Xi'an.

The object of this experimental study was to investigate the influence of low-energy He-Ne laser on the motor nerve cells of the spinal cord. The experimental study included as follows:
(1) Four rabbits were used in this experiment. The L5-6 spinal cord segment was irradiated by He-Ne laser percutaneously, the nerve velocity of the comon peroneal nerve was measured in order to determine the function of the spinal motor nerve cells when theperipheral nerve was intact.
(2) The common peroneal nerve was transected on one side wothout repair, two weeks after laser irradiation, the grey mater of the spinal cord of L5-6 segment was procured for electronic microscopic examination.
(3) The common peroneal nerve on the contralateral side was transected and followed by end-to-end anastomosis, and laser irradiation was done on the same spinal cord segment. Two weeks after irradiation, the nerve velocity of the common peroneal nerve and the toe expanding test were investigated.

The results were:
(1) The He-Ne laser can influence the spinal motor nerve cells function as expressed by latent rate when the peripherial nerve is intact. i.e. the nerve velocity is slower than mormal, and the amplitude is markedly decreared.
(2) the change of the microstructure of the spinal motor nerve cells is comparatively slight in the 10 and

15 minutes groups.
(3) the recovery of the nerve velocity and the toe expansion are more earlier in the 15 min. group. In short, the low-energy He-Ne laser can influence the function of the spinal motor nerve cells.

PMID: 9867942 [PubMed – indexed for MEDLINE]

J Bone Joint Surg Am. 1982 Jul;64(6):888-95.
Modification of fracture repair with selected pulsing electromagnetic fields.
Bassett CA, Valdes MG, Hernandez E.

We assayed different pulsing electromagnetic fields for their effects on the mechanical and histological repair properties of an osteotomy of the radius of the rat fourteen days postoperatively. Highly significant differences were found in the control and experimental initial load values and their decay as a function of time. These results correlate well with the histological pattern in the bridging callus. A pulse that produces an increase (above the control level) in initial load by a factor of 2.4 and a slower decay was characterized by more extensive calcification of fibrocartilage and its replacement by fibrous bone at this early, but important, stage in fracture-healing.

PMID: 7085716 [PubMed – indexed for MEDLINE]

J Neurosurg. 1995 Apr;82(4):623-9.
The fate of motoneurons in the spinal cord after peripheral nerve repair: a quantitative study using the neural tracer horseradish peroxidase.
Gilmour JA, Myles LM, Glasby MA.
Department of Anatomy, University of Edinburgh, Medical School, Scotland.

This study assessed the changes that occurred in the spinal motoneuron pool after the repair of a specific peripheral nerve by means of several clinically appropriate surgical techniques: nerve graft, muscle graft, and epineurial suture. The motoneuron pool relating to a single muscle was assessed at 50, 100, 200, and 300 days after repair via retrograde axonal transport of the neural tracer horseradish peroxidase. The results indicate that although a small portion of the motoneuron population dies following peripheral nerve surgery, this is not a significant number. The majority of the anterior horn cells appear to have the ability to both survive nerve transection and form new functional connections with the regenerated nerve after repair. The degree of cell loss is influenced by the nature of the injury and the method of repair implemented. Injuries involving neurotmesis result in the loss of a greater proportion of the cell population than less severe injuries involving axonotmesis. A greater proportion of the motoneuron population is preserved when the severed nerve has been repaired using a direct epineurial suture than when repair is achieved by means of a graft. The two methods of grafting produced comparable results, although the muscle graft tended to result in the preservation of a greater number of cells than the nerve graft, making it an acceptable alternative method
for the surgical repair of short gaps in peripheral nerves.

PMID: 7897525 [PubMed – indexed for MEDLINE]

Exp Mol Med. 2002 Mar 31;34(1):53-9.
Enhanced expression of neuronal nitric oxide synthase and phospholipase C-gamma1 in regenerating murine neuronal cells by pulsed electromagnetic field.
Kim SS, Shin HJ, Eom DW, Huh JR, Woo Y, Kim H, Ryu SH, Suh PG, Kim MJ, Kim JY,
Koo TW, Cho YH, Chung SM.
Department of Pathology, Ulsan University College of Medicine, Korea.

Pulsed electromagnetic field (PEMF) has been shown to improve the rate of peripheral nerve regeneration. In the present study we investigated the expression of neuronal nitric oxide synthase (nNOS) and phospholipase C-gamma1 (PLC-gamma1) in regenerating rat laryngeal nerves during the exposure to PEMF after surgical transection and reanastomosis. Axons were found to regenerate into the distal stump nearly twice faster in PEMF-exposed animals than in the control. Consistently, motor function was better recovered in PEMF-treated rats. The expression of nNOS and PLC-gamma1 was highly enhanced in the regenerated nerves.

PMID: 11989979 [PubMed – indexed for MEDLINE]

Spine. 2003 Dec 15;28(24):2660-6.
Exposure to pulsed magnetic fields enhances motor recovery in cats after spinal cord injury.
Crowe MJ, Sun ZP, Battocletti JH, Macias MY, Pintar FA, Maiman DJ.
Neuroscience Research Laboratories, The Clement J. Zablocki VA Medical Center, Milwaukee, WI 53295, USA. mcrowe@mcw.edu

STUDY DESIGN: Animal model study of eight healthy commercial cats was conducted.

OBJECTIVE: To determine whether pulsed electromagnetic field (PMF) stimulation results in improvement of function after contusive spinal cord injury in cats.

SUMMARY OF BACKGROUND DATA: PMF stimulation has been shown to enhance nerve growth, regeneration, and functional recovery of peripheral nerves. Little research has been performed examining the effects of PMF stimulation on the central nervous system and no studies of PMF effects on in vivo spinal cord injury (SCI) models have been reported.

MATERIALS AND METHODS: PMF stimulation was noninvasively applied for up to 12 weeks to the midthoracic spine of cats
with acute contusive spinal cord injury. The injury was produced using a weight-drop apparatus. Motor functions were evaluated with the modified Tarlov assessment scale. Morphologic analyses of the injury sites and somatosensory-evoked potential measurements were conducted to compare results between PMF-stimulated and control groups.

RESULTS: There was a significant difference in locomotor recovery between the PMF-stimulated and control groups.
Although not statistically significant, PMF-stimulated spinal cords demonstrated greater sparing of peripheral white matter and smaller lesion volumes compared to controls. Somatosensory-evoked potential measurements indicated that the PMF-stimulated group had better recovery of preinjury

waveforms than the control group; however, this observation also was not statistically significant because of the small sample size.

CONCLUSIONS: This preliminary study indicates that pulsed magnetic fields may have beneficial effects on motor function recovery and lesion volume size after acute spinal cord injury.

PMID: 14673366 [PubMed – in process]

Exp Neurol. 1994 Feb;125(2):302-5.
Enhancement of functional recovery following a crush lesion to the rat sciatic nerve by exposure to pulsed electromagnetic fields.
Walker JL, Evans JM, Resig P, Guarnieri S, Meade P, Sisken BS.
Division of Orthopaedic Surgery, University of Kentucky College of Medicine, Shriners Hospitals for Crippled Children, Lexington.

Previous studies showed that exposure to pulsed electromagnetic fields (PEMF) produced a 22% increase in the axonal regeneration rate during the first 6 days after crush injury in the rat sciatic nerve. We used the same injury model to assess the effect on functional recovery. The animals were treated with whole body exposure to PEMF (0.3 mT, repetition rate 2 Hz) for 4 h/day during Days 1-5 while held in plastic restrainers. Functional recovery was serially assessed up to Postinjury Day 43 using recently described video imaging of the 1-5 toe spread and the gait-stance duration. Footprint analysis was also used with
calculation of a sciatic function index. Those animals treated with PEMF had improved functional recovery, as compared to sham controls, using the tests for video 1-5 toe spread and gait-stance duration ($P = 0.001$ and $P = 0.081$, respectively). This effect was found throughout the 43-day recovery period. No effect was found using the sciatic function index. This study confirms that functional recovery after nerve crush lesion is accelerated by PEMF and has broad implications for the clinical use of these fields in the management of nerve injuries.

PMID: 8313945 [PubMed – indexed for MEDLINE]

J Neurosurg. 1996 Feb;84(2):234-43.
Reinnervation of avulsed and reimplanted ventral rootlets in the cervical spinal cord of the cat.
Hoffmann CF, Marani E, van Dijk JG, vd Kamp W, Thomeer RT.
Department of Neurosurgery, University of Leiden, The Netherlands.

Spinal nerve root avulsions frequently occur in brachial plexus injuries caused by traction. Such lesions are considered to afflict the central nervous system (CNS) and are, therefore, believed to be beyond surgical repair. The present experimental study was initiated to challenge this hypothesis. The ventral rootlets of C-7 were avulsed from the spinal cord in 28 cats via an anterior approach and subsequently reimplanted into the cord at the site of origin. In nonoperated control cats and cats undergoing reimplantation, electrophysiological experiments were performed and horseradish peroxidase was administered to the spinal nerve on the reimplanted side after survival times ranging from 6 to 293 days. Spinal cord sections in all cats were stained for

neurofilament, acetylcholinesterase (AChE), Nissl, and glial fibrillary acidic protein. Horseradish peroxidase-labeled ventral horn motoneurons were found as early as 14 days after reimplantation and their number increased with time. On Days 209 and 293, the number of labeled neurons equaled the number of labeled ventral horn neurons in the two control cats that did not undergo surgery. Starting on Day 6 after reimplantation, the appearance of the ventral horn and the white matter in the neurofilament, AChE, and Nissl-stained sections changed as a result of the CNS response to the injury. A return to their normal appearance could be observed in these stainings from Day 209 onward. Glial fibrillary acidic protein-positive astrocytic tissue was consistently found in the ventral horn and in the white matter reimplantation area. From Day 69 onward, electrophysiological stimulation of the spinal nerve C-7 on the reimplanted side elicited an electromyogram response in the spinodeltoid muscle. The latency and threshold intensity of the C-7 responses were initially increased but equalized to match the nonoperated controls between 98 and 122 days after reimplantation. The results of this study show that functional regeneration of ventral horn neurons after root avulsion and subsequent reimplantation in the cat is possible.

PMID: 8592226 [PubMed – indexed for MEDLINE]

Lancet. 1984 Mar 31;1(8379):695-8.
Pulsed electromagnetic field therapy of persistent rotator cuff tendinitis. A double-blind controlled assessment.
Binder A, Parr G, Hazleman B, Fitton-Jackson S.

The value of pulsed electromagnetic fields (PEMF) for the treatment of persistent rotator cuff tendinitis was tested in a double-blind controlled study in 29 patients whose symptoms were refractory to steroid injection and other conventional conservative measures. The treated group (15 patients) had a significant benefit compared with the control group (14 patients) during the first 4 weeks of the study, when the control group received a placebo. In the second 4 weeks, when all patients were on active coils, no significant differences were noted between the groups. This lack of difference persisted over the third phase, when neither group received any treatment for 8 weeks. At the end of the study 19 (65%) of the 29 patients were symptomless and 5 others much improved. PEMF therapy may thus be useful in the treatment of severe and persistent rotator cuff and possibly other chronic tendon lesions.

Publication Types:
Clinical Trial
Randomized Controlled Trial

PMID: 6143039 [PubMed – indexed for MEDLINE]

J Bone Joint Surg Am. 1982 Oct;64(8):1214-20.
Treatment of therapeutically resistant non-unions with bone grafts and pulsing electromagnetic fields.
Bassett CA, Mitchell SN, Schink MM.

This study reviews the cases of eighty-three adults with ununited fractures who were treated concomitantly with bone-grafting and pulsed electromagnetic fields. An average of 1.5 years had elapsed since fracture and the use of this combined approach. Nearly one-third of the patients had a history of infection, and an average of 2.4 prior operations had failed to produce bone union. Thirty-eight patients who were initially treated with grafts and pulsed electromagnetic fields for ununited fractures with wide gaps, synovial pseudarthrosis, and malalignment achieved a rate of successful healing of 87 per cent. Forty-five
patients who had initially been treated unsuccessfully with pulsing electromagnetic fields alone had bone-grafting and were re-treated with pulsing electromagnetic fields. Ninety-three per cent of these fractures healed. The residual failure rate after two therapeutic attempts, one of which was operative, was 1.5 per cent. The median time to union for both groups of patients was four months.

PMID: 6752151 [PubMed – indexed for MEDLINE]

Prog Clin Biol Res. 1986;210:251-60.
Effects of applied DC fields on sensory nerve sprouting and motor-nerve regeneration in adult rats.
Pomeranz B.

PMID: 3960914 [PubMed – indexed for MEDLINE]

JAMA. 1982 Aug 27;248(8):921.
Pulsing electromagnetic field treatment.
Irvine RD.
Publication Types:
Letter
PMID: 7097952 [PubMed – indexed for MEDLINE]

Clin Exp Rheumatol. 1985 Oct-Dec;3(4):333-6.
Chronic lateral humeral epicondylitis–a double-blind controlled assessment of pulsed electromagnetic field therapy.
Devereaux MD, Hazleman BL, Thomas PP.

Pulsed electromagnetic fields (PEMF) have been shown to be beneficial in the treatment of rotator cuff tendinitis. As lateral humeral epicondylitis (tennis elbow) is a similar chronic tendon lesion, 30 patients with both clinical and thermographic evidence of tennis elbow were randomly allocated to receive either active or inactive PEMF therapy. Treatment was continued for a minimum period of eight weeks. At this time there was no statistical difference between the two groups.

Publication Types:
Clinical Trial
Randomized Controlled Trial

PMID: 4085165 [PubMed – indexed for MEDLINE]

Electromyogr Clin Neurophysiol. 1994 Jul-Aug;34(5):259-64.
Electrophysiological study of regenerated rabbit tibial and peroneal nerves: autologous versus non-neural grafts.
Wessel K, Muller H, Deseniss V, Dombert T.
Department of Neurology, Medical University of Lubeck, Germany.

In recent years, successful experimental nerve regeneration using extracellular matrix as implants has been reported. In the present study, we compared peripheral nerve regeneration through implants of amnion membrane matrix (AMM) and umbilical cord membrane matrix (UCMM) versus autologous nerve transplantation, bridging gaps 8-12 mm in length in rabbit tibial and peroneal nerves. The data are based on direct nerve stimulation and recording of somatosensory evoked potentials (SEPs) and muscle action potentials (MAPs) to measure functional recovery after these different types of neuroplastic bridging. Incomplete regeneration was demonstrable as missing SEPs (15-22%), missing MAPs (17-42%), a mean delay of SEPs and distal motor latencies of approximately 40-50% compared with a normal control group, and slowed motor conduction velocities by approximately 50%. There were no significant differences between the three different types of neuroplastic bridging. Most of the AMM and UCMM implants (80-100%), but none of the autologous nerve transplants, caused inadequate connections with peripheral targets. We conclude that extracellular matrix implantation represents a useful experimental model for studying the biological basis of nerve regeneration, but does not yet serve as a tool for therapeutic applications.

PMID: 7956874 [PubMed – indexed for MEDLINE]

J Neurosurg. 2001 Jan;94(1 Suppl):82-90.
Innervation of the caudal denervated ventral roots and their target muscles by the rostral spinal motoneurons after implanting a nerve autograft in spinal cord-injured adult marmosets.
Liu S, Aghakhani N, Boisset N, Said G, Tadie M.
Laboratory of Experimental Neurosurgery, Faculte de M ecine Paris-Sud, University of Paris XI, France.

OBJECT: The authors conducted a study to determine the effects of using a nerve autograft (NAG) to promote and guide axonal regrowth from the rostral spinal cord to the caudal lumbar ventral nerve roots to restore hindlimb motor function in adult marmosets after lower thoracic cord injury.

METHODS: Nine animals underwent a left-sided hemisection of the spinal cord at T-12 via left-sided T9-L3 hemilaminectomy, with section of all ipsilateral lumbrosacral ventral nerve roots. In the experimental group (five animals), an NAG obtained from the right peroneal nerve was anastomosed with the sectioned and electrophysiologically selected lumbar ventral roots (left L-3 and L-4) controlling the left quadriceps muscle and then implanted into the left ventrolateral T-10 cord. In the control group (four animals), the sectioned/selected lumbar ventral roots were only ligated. After surgery, all marmosets immediately suffered from complete paralysis of their left hindlimb. Five months later, some clinical signs of reinnervation such as tension and
resistance began to appear in the paralyzed quadriceps of all experimental animals that received autografts. Nine months postoperatively, three of the five experimental marmosets could maintain their

lesioned hindlimb in hip flexion. Muscle action potentials and motor evoked potentials were recorded from the target quadriceps in all experimental marmosets, but these potentials were absent in the control animals. Horseradish peroxidase retrograde labeling from the distal sectioned/reconnected lumbar ventral roots traced 234+/-178 labeled neurons in the ipsilateral T8-10 ventral horn, mainly close to the NAG tip.
Histological analysis showed numerous regenerating axons in this denervated/reconnected nerve root pathway, as well as newly formed motor endplates in the denervated/reinnervated quadriceps. No axonal regeneration was detected in the control animals.

CONCLUSIONS: These data indicate that the rostral spinal neurons can regrow into the caudal ventral roots through an NAG, thereby innervating the target muscle in adult marmosets after spinal cord injury.

PMID: 11147873 [PubMed – indexed for MEDLINE]

Exp Neurol. 1998 Jul;152(1):95-100.
Motoneuron survival after neonatal peroneal nerve injury in the rat-evidence for the sparing effect of reciprocal inhibition.
Waters HJ, Barnett G, O'Hanlon GM, Lowrie MB.
Division of Biomedical Sciences, Imperial College School of Medicine, Norfolk Place, London, W2 1PG, United Kingdom.

Sciatic nerve crush at birth results in the death of most of the motoneurons in the sciatic motor pool. It has been proposed that these cells die through excessive activation which can be explained partly by an increased susceptibility to NMDA. However, it is also possible that decreased inhibitory mechanisms resulting from nerve injury may contribute to overactivation of the motoneurons. In this study we compared the survival of motoneurons innervating two muscles in the peroneal motor pool, tibialis anterior and extensor digitorum longus, after either sciatic or common peroneal nerve crush. These two procedures both axotomize the motoneurons but differ in their effects on afferent input. Sciatic nerve crush severely reduces the afferent input from the antagonist muscles innervated via the tibial nerve, whereas common peroneal nerve crush preserves them. Using retrograde labeling with horseradish peroxidase, we found that almost twice as many motoneurons survived common peroneal nerve crush than sciatic nerve crush and that muscle weight showed a corresponding significant improvement. A control experiment excluded the possible involvement of increased stretch of the muscles as a result of common peroneal nerve crush alone as an explanation for the improvement. We therefore suggest that the increased survival of motoneurons after peroneal nerve crush was due to the preservation of their reciprocal inhibitory input. However, since even with this improvement the majority of motoneurons still died, loss of reciprocal inhibition probably does not play a major role in the death of motoneurons induced by overactivation.

PMID: 9682016 [PubMed – indexed for MEDLINE]

Zh Nevropatol Psikhiatr Im S S Korsakova. 1989;89(5):41-4.
[Characteristics of the effect of a constant electromagnetic field on reparative processes in spinal cord injuries]

[Article in Russian]
Tkach EV, Abilova AN, Gazalieva ShM.

In 171 white rats the spinal cord was completely sectioned in the upper thoracic region. In 46 control rats an early crude spinal cord scar was identified which precluded the growth of nervous fibers. On the contrary, in animals exposed to constant magnetic field a smooth spinal cord scar was found with collaterals of anterior spinal arteria, recrease of the destruction zone and nervous fiber growth across the scar, This resulted in restored hind paw motility by 56 +/- 4.8% as related to control rats in which motility did not restore. Magnet therapy applied as a part in combined restitutional therapy in 104 patients in early restitution period yielded a 46.15 +/- 4.89% to 76.32 +/- 4.87% increase in the rate of restoration of motor and sensory functions. With the therapy
applied in late periods, the restitution was 48.1 +/- 5.6% and 78.1 +/- 3.9%, respectively. The magnetic field is considered as a reparation booster in spinal cord trauma applicable in any stage of the disease.

PMID: 2781918 [PubMed – indexed for MEDLINE]

Am J Otolaryngol. 1993 Jan-Feb;14(1):43-8.
Misdirected regeneration of injured recurrent laryngeal nerve in the cat.
Nahm I, Shin T, Watanabe H, Maeyama T.
Department of Otolaryngology, Saga Medical School, Japan.

INTRODUCTION: Misdirected regeneration (MR) frequently occurs following injury to the recurrent laryngeal nerve (RLN) resulting in neurotmesis or axonotmesis. Physiological and anatomic parameters involved in the functional recovery of the larynx following freezing injury or neurorrhaphy of the RLN were studied. A multi-facilitated approach is undertaken to clarify the functional abnormalities caused by the MR after recurrent laryngeal nerve injury.

MATERIALS AND METHODS: Three groups of adult cats were studied. These included controls, cats with recurrent laryngeal neurorrhaphy, and cats with recurrent laryngeal nerve freeze injuries. From 2 weeks to 9 months after the nerve injury, the animals were studied endoscopically and with electromyography (EMG). Using the same animal, the number and location of motoneurons supplying the ipsilateral posterior cricoarytenoid (PCA) muscle were examined with horseradish peroxidase (HRP). Animals were subsequently sacrificed to study the pattern of reinnervation.

RESULTS: Following neurorrhaphy all cats had vocal cord paralysis. After neurorrhaphy, effective motion function did not return in the affected vocal cord and it remained fixed in the paramedian position. Although EMG of the laryngeal muscles of the affected side showed interference voltage, the pattern of activities was markedly different from that of the unaffected side, and reciprocity among the laryngeal muscles was not restored. The number of PCA motoneurons recovered to the normal range, but a considerable number of neuronal bodies were dispersed outside the normal PCA area. This indicates misdirected reinnervation to the PCA muscle by motoneurons that originally served other laryngeal muscles. In the freezing injury, effective vocal cord movement finally recovered after 6 months. At this time, EMG showed a normal pattern, although a relatively small amount of misdirected neurons was observed.

DISCUSSION: Functional recovery of vocal cord motion does not occur following neurorrhaphy. Prominently disorganized arrangement of laryngeal motor neurons was observed in the horseradish peroxidase study. This suggests that inappropriate reinnervation develops in spite of reapproximation and suturing. Altered central organization of the motor nucleus is a significant pathogenic factor in the loss of laryngeal muscular coordination following recurrent laryngeal nerve lesions. The degree of recovery is related to the mechanism of injury.

PMID: 8434719 [PubMed – indexed for MEDLINE]

Arch Otolaryngol Head Neck Surg. 1998 Apr;124(4):383-9.
Effect of pulsed electromagnetic stimulation on facial nerve regeneration.
Byers JM, Clark KF, Thompson GC.
Department of Otorhinolaryngology, University of Oklahoma Health Sciences Center, Oklahoma City, USA.

OBJECTIVE: To determine if exposure to electromagnetic fields influences regeneration of the transected facial nerve in the rat.

DESIGN AND METHODS: The left facial nerve was transected in the tympanic section of the fallopian canal in 24 rats randomly assigned to 2 groups. The cut ends of the facial nerve were reapproximated without sutures within the fallopian canal to maximize the potential for regeneration. Rats in the experimental group (n= 12) were then exposed to pulsed electromagnetic stimulation (0.4 millitesla at 120 Hz) for 4 hours per day, 5 days per week, for 8 weeks. Rats in the control group (n=12) were handled in an identical manner without pulsed electromagnetic stimulation. Four other rats were given sham operations in which all surgical procedures were carried out except for the actual nerve transection. Two of these rats were placed in each group. Nerve regeneration was evaluated using electroneurography (compound action potentials), force of whisker and eyelid movements, and voluntary facial movements before and at 2-week intervals after transection. Histological evaluation was performed at 10 weeks after transection. Each dependent variable was analyzed using a 2-way analysis of variance with 1 between variable (groups) and 1 within repeated measures variable (days after transection).

RESULTS: Statistical analysis indicated that N1 (the negative deflection of depolarization phase of the muscle and/or nerve fibers) area, N1 amplitude, and N1 duration, as well as absolute amplitude of the compound action potentials, were all significantly greater 2 weeks after transection in the experimental than in the control group of rats. The force of eye and whisker
movements after electrical stimulation was statistically greater in the experimental group of rats 4 weeks after transection. Voluntary eye movements in the experimental group were significantly better at 5 and 10 weeks, while whisker movements were better at 3 and 10 weeks. There was no statistical difference between the 2 groups for any histological variable.

CONCLUSION: Results of this study indicate that pulsed electromagnetic stimulation enhances early regeneration of the transected facial nerve in rats.

PMID: 9559684 [PubMed – indexed for MEDLINE]

Tierarztl Prax. 1983;11(4):483-6.
[Treatment of a navicular bone fracture in a horse with pulsing electromagnetic field (MF therapy)]
[Article in German]
Boening KJ.
Publication Types:
Case Reports
PMID: 6658771 [PubMed – indexed for MEDLINE]

Brain Res. 1983 Jan 17;259(1):31-9.
Changes in the somatotopic organization of the cat lumbar spinal cord following peripheral nerve transection and regeneration.
Lisney SJ.

Glass microelectrodes were used to record the activity of neurones in the left dorsal horn of the L6 segment of the spinal cord of normal cats and cats in which the left sciatic and saphenous nerves had been cut 1 or 9 months previously. In the normal animals the receptive fields of L6 dorsal horn neurons excited by tactile stimulation of the leg were somatotopically organized, with neurones in the medial and central dorsal horn having receptive fields on the distal parts of the leg, particularly the toes, and neurones in the lateral dorsal horn having receptive fields on the proximal parts of the leg, buttock and lower back. This somatotopy has been shown before. One month after nerve section no cells responded to tactile stimulation of the distal leg and cells in the medial and central parts of the dorsal horn now had receptive fields on the proximal leg, buttock and back. There did not appear to be any somatotopic organization of these new receptive fields. Lateral dorsal horn neurones had normal receptive fields. Nine months after nerve section neurones in the medial and central parts of the lumbar dorsal horn had receptive fields on the distal leg but they showed several abnormal features and there was no evidence of a return of the somatotopic organization seen in normal animals. Lateral dorsal horn cells still had normal receptive fields.

PMID: 6824934 [PubMed – indexed for MEDLINE]

Ann N Y Acad Sci. 1974;238:575-85.
The effects of pulsed electromagnetic energy on peripheral nerve regeneration.
Wilson DH, Jagadeesh P, Newman PP, Harriman DG.
PMID: 4548339 [PubMed – indexed for MEDLINE]

Otolaryngol Head Neck Surg. 1996 Mar;114(3):424-34.
Hyperbaric oxygen treatment after rat peroneal nerve transection and entubulation.
Santos PM, Zamboni WA, Williams SL, Covey JF, Kienstra MA.
Division of Otolaryngology, Southern Illinois University, Springfield, IL 62794, USA.

Rat peroneal nerves were transected and entubulated with a Silastic channel. The experimental group was treated with hyperbaric oxygen to evaluate changes in
acute edema, functional recovery, and histology. Hyperbaric oxygen was administered with 100% O2 at 2.5 atmospheres absolute for 90 minutes twice a day for 1 week and then four times a day for 1 week. Acute edema changes based on nerve water weight and transfascicular area measurements were greater in injured than in uninjured nerves but demonstrated no differences between hyperbaric oxygen-treated and -untreated groups 2, 8 and 16 days after surgery. Functional evaluation with gait analysis demonstrated significant changes between injured and uninjured group 1, 3, 7, and 13 weeks after injury but no differences between hyperbaric oxygen-treated and -untreated groups. Thirteen weeks after the initial injury, elicited muscle force measurements demonstrated no significant improvement from hyperbaric oxygen treatment of injured nerves. Histologic evaluation of nerve area, myelinated axon number, myelinated axon area, myelin thickness, and blood vessel number and area revealed no significant differences between hyperbaric oxygen-treated and -untreated groups. Hyperbaric oxygen was not associated with improvement of nerve regeneration with any of the outcome variables in this model.

PMID: 8649877 [PubMed – indexed for MEDLINE]

J Neurosci Res. 1998 Mar 15;51(6):723-34.
Axonal regrowth through a collagen guidance channel bridging spinal cord to the avulsed C6 roots: functional recovery in primates with brachial plexus injury.
Liu S, Bodjarian N, Langlois O, Bonnard AS, Boisset N, Peulve P, Said G, Tadie M.
Department of Neurosurgery, Hospital of Bicetre, Le Kremlin-Bicetre, France.

Intraspinal implantation of a collagen guidance channel (CGC) to promote axon regeneration was investigated in marmosets with brachial plexus injury. After avulsion of the right C5, C6 and C7 spinal roots, a CGC containing (group B) or not (group A) a nerve segment, or a nerve graft (group C), was ventro-laterally implanted into the cord to bridge the ventral horn and the avulsed C6 roots. No spinal cord dysfunction was observed following surgery. Two months later, the postoperative flaccid paralysis of the lesioned arm improved. In five months, a normal electromyogram of the affected biceps muscle was recorded in all repaired animals. Motor evoked potentials were obtained with a mean amplitude of 13.37 +/- 13.66 microV in group A, 13.21 +/- 5.16 microV in group B and 37.14 +/- 35.16 microV in group C. The force of biceps muscle contraction was 27.33 +/- 20.03 g (group A), 24.33 +/- 17.03 g (group B) and 37.38 +/- 21.70 g (group C). Retrograde tracing by horseradish peroxidase showed labelled motoneurons ipsilaterally located in the C5 and C6 ventral horn, nearby the implantation site. The mean labelled neurons was 32.33 +/- 21.13, 219.33 +/- 176.29 and 64.33 +/- 23.54 in group A, B and C respectively. Histological analysis presented numerous myelinated and unmyelinated regenerating axons in the implant of these animals. Statistical analysis did not show significant difference among the three repaired groups. Our results indicate that spinal neurons can regenerate through a CGC to avulsed nerve roots and induce motor recovery in primates.

PMID: 9545086 [PubMed – indexed for MEDLINE]

Plast Reconstr Surg. 1998 Nov;102(6):2072-81; discussion 2082-4.
Long-term observation of the effect of peripheral nerve injury in neonatal and young rats.
Watanabe O, Mackinnon SE, Tarasidis G, Hunter DA, Ball DJ.
Department of Surgery, Washington University School of Medicine, St. Louis, MO, USA.

The purpose of this study was to observe functional recovery and motoneuron death after nerve transection-and-repair in neonatal versus young animals. One hundred nine Lewis rats underwent posterior tibial nerve transection-and-repair at 6 or 22 days of age. Fifty-two and fifty-seven nerves at the 6- and 22-day times were used for endpoint analysis at 1, 3, 10, and 14 months. These assessments included serial functional walking track analysis, electrophysiologic studies, muscle mass evaluation, motoneuron counts with retrograde horseradish peroxidase tracing, and histologic and morphometric nerve analysis. Walking track analysis and nerve conduction velocity indicated significantly poorer functional regeneration in the 6-day-old group than in the 22-day-old group. Muscle mass in the 6-day-old group did not recover as well as in the 22-day-old group. Motoneuron numbers stained with horseradish peroxidase were less in the 6-day-old group than in the 22-day-old group. In contrast, morphometric analysis did not reach significance. This study suggests that the same nerve injury sustained in a neonatal rat is less likely to demonstrate functional recovery than one sustained in a young rat.

PMID: 9811005 [PubMed – indexed for MEDLINE]

J Reconstr Microsurg. 1997 Jan;13(1):31-7.
Nerve regeneration after terminolateral neurorrhaphy: experimental study in rats.
Zhao JZ, Chen ZW, Chen TY.
Zhong Shan Hospital, Shanghai Medical University, People's Republic of China.

Four methods of nerve terminolateral neurorrhaphy (TLN) were studied in rat experimental model.
In Group A, the distal end of a severed peroneal nerve was sutured end-to-side with an intact tibial nerve trunk, without removal of the tibial epineurium at the suture site.
In Group B, the distal end of a severed peroneal nerve was sutured end-to-side with the intact tibial nerve trunk, with removal of the tibial epineurium at the suture site.
In Group C, a nerve segment was bridged between the distal part of the severed peroneal nerve and the intact tibial nerve with two end-to-side sutures.
In Group D, the proximal end of a severed tibial nerve was sutured end-to-side with the peroneal nerve trunk.

Through electrophysiologic, histologic, and ultrastructural examinations, the following conclusions were drawn:
1. Nerve regeneration is possible after TLN.
2. The regenerating fibers after TLN have the ability to penetrate the endoneurium, perineurium, and epineurium.
3. After different methods of TLN, the regenerating fibers grow in both a flowing-out and a filling-in fashion.

PMID: 9120840 [PubMed – indexed for MEDLINE]

J Peripher Nerv Syst. 2003 Mar;8(1):17-22.
Repair of ventral root avulsion using autologous nerve grafts in cats.
Holtzer CA, Marani E, van Dijk GJ, Thomeer RT.
Neuroregulation Group, Department of Neurosurgery, Leiden University Medical Center, Leiden, The Netherlands.

This study focuses on the capacity of motor axons to elongate from the spinal cord through an autologous nerve graft into a spinal nerve. Applying a ventral surgical approach, C7 ventral roots were avulsed from the cord in 12 cats. Autologous saphenous nerve grafts were implanted into the cord at the ventral root outlet site and coaptated to the spinal nerve. Outgrowth of axons was studied at survival times 7, 14, 30, 60 and 120 days, respectively. The results showed horseradish peroxidase positive motoneurons in the C7 ventral horn after retrograde labeling, as well as neurofilament and acetylcholinesterase positive
axons in the entire trajectory from spinal cord to spinal nerve. Neurotization of the C7 spinal nerve started between 14 and 30 days after graft implantation. In addition electrophysiology provided evidence that outgrowing axons had re-established functional contact with the spinodeltoid muscle at 120 days after implantation.

PMID: 12678550 [PubMed – indexed for MEDLINE]

J Anat. 1997 Jan;190 (Pt 1):51-6.
Nerve fibre regeneration across the peripheral-central transitional zone.
Carlstedt T.
Department of Orthopaedics, Karolinska Hospital, Stockholm, Sweden.

Neurons cannot negotiate an elongation across the peripheral (PNS)-central nervous system (CNS) transitional zone and grow into or out of the spinal cord in the mature mammal. The astrocytic rich CNS part of the spinal nerve root is most effective in preventing regeneration even of nerve fibres from transplanted embryonic ganglion cells. Regeneration of severed nerve fibres into the spinal cord occurs when the transition zone is absent as in the immature animal. Before the establishment of a transition zone there is also new growth of neuronal processes from dorsal horn neurons distally to the injured dorsal root. Thus the experimental strategy to reestablish spinal cord to peripheral nerve connectivity has been to delete the transitional region and implant severed ventral or dorsal roots into the spinal cord. Dorsal root implantation resulted in reestablished afferent connectivity by new neuronal processes from secondary sensory neurons in the dorsal horn of the spinal cord extending into the PNS. The ability for plasticity in these cells allowed for a concurrent retention of their original rostral projection. Ventral root implantation into the spinal cord corrected deficit motor function. In a long series of experiments performed in different species, the functional restitution was demonstrated to depend on an initial regrowth of motor neuron axons through spinal cord tissue (CNS). These findings have led to the design of a new surgical strategy in cases of traumatic spinal nerve root injuries.

Publication Types:
Review
Review, Tutorial

PMID: 9034881 [PubMed – indexed for MEDLINE]

J Reconstr Microsurg. 2001 Nov;17(8):631-6.
Direct neurotization of muscles by presynaptic motoneurons.
Brunelli GA.
Department of Orthopaedics, University of Brescia, Italy.

The spinal cord cannot heal after severance because the central nervous system is “non-permissive” to the advancement of axons that regrow from presynaptic motoneurons. With the aim of overcoming paraplegia, the author has carried out extensive experimental research since 1980, first in rats and subsequently in monkeys, severing the cord and connecting its cephalad stump with the muscular nerve branches by means of peripheral-nerve grafts, and using various surgical protocols. Functional connections were established, ascertained by physical, electrophysiologic, and histologic examinations. In this reported study, it is demonstrated that presynaptic motoneurons are also able to reconstruct the cytoskeleton of peripheral neurons, as well as motor end-plates. The possibility of elongation of the axons of presynaptic motoneurons into the peripheral nerve up to the muscle had not previously even been hypotheized. This possibility, which has now been validated, can open the door to new surgical techniques for spinal-cord lesions. In addition, the author presents preliminary results from a single human case, utilizing the surgical procedures of the preceding animal experiments.

PMID: 11740660 [PubMed – indexed for MEDLINE]

Fysiatr Revmatol Vestn. 1980 Jun;58(3):137-42.
[The effect of an electromagnetic field on the neuromuscular apparatus]
[Article in Czech]
Rehacek J, Benova H, Straub J.
PMID: 7190118 [PubMed – indexed for MEDLINE]

Brain Res. 1997 Oct 10;771(1):31-6.
Reinnervation of denervated muscle by transplantation of fetal spinal cord to transected sciatic nerve in the rat.
Katsuki M, Atsuta Y, Hirayama T.
Department of Orthopaedic Surgery, Asahikawa Medical College, Nishikagura, Japan.

When motor neurons in the spinal cord are destroyed, regeneration of motor axons and muscle reinnervation cannot be expected. We attempted reinnervation of the denervated muscle, i.e. motor unit reconstruction, using transplantation of the fetal spinal cord to the peripheral nerve. The sciatic nerve of an adult rat was resected for 20 mm, and a cavity was prepared using an autologous femoral vein at the distal stump of the nerve. The fetal spinal cord was then transplanted into the venous cavity.

After 3-6 months, no voluntary muscle contraction was observed due to the absence of communication with the central nervous system. However, reinnervation of the muscles via the sciatic nerve by the transplanted spinal neurons was demonstrated electrophysiologically and histochemically.
This suggested that a motor unit can be reconstructed by fetal spinal cord transplantation even if the original motor neurons in the spinal cord are not available.

PMID: 9383005 [PubMed – indexed for MEDLINE]

Eur J Oral Sci. 1995 Oct;103(5):299-305.
The effects of low level laser treatment on recovery of nerve conduction and motor function after compression injury in the rat sciatic nerve.
Khullar SM, Brodin P, Messelt EB, Haanaes HR.
Dept. of Oral Surgery and Oral Medicine, University of Oslo, Norway.

An animal study is presented examining the effect of low level laser (LLL) treatment on nerve regeneration following axonotmesis. Twenty animals received a standardised injury to the right sciatic nerve using a time, load and length sequence (10 min, 150 N, 5 mm) known to cause extensive axonal degeneration of the rat sciatic nerve. The LLL treatment was administered using a hand-held laser probe in light contact with the skin on the dorsal aspect of the hind leg
overlying the site of the axonotmesis injury to the sciatic nerve. A group of 10 animals were treated with 6J of LLL (GaAlAs 830 nm) daily for a period of 28 d. Ten more animals were treated daily with a sham exposure setting and served as controls. Nerve function was assessed by a recognised method of walking tract print analysis; the “Sciatic Functional Index” (SFI), and nerve regeneration was assessed by recording the evoked compound action potentials (cAP) in the common peroneal nerve. At 21 d post-injury, the laser-treated group had a significantly lower median SFI than the sham laser-treated group, indicating that the real laser treatment had improved functional recovery in the nerve. However, no differences were found between the evoked cAP parameters that were measured in the laser-treated and sham laser-treated groups. Histological examination reiterated the lack of difference between the two groups. Consequently, the effects of LLL on recovery must have occurred more peripherally to the point measured.

PMID: 8521121 [PubMed – indexed for MEDLINE]

J Bone Joint Surg Am. 1981 Apr;63(4):511-23.
Treatment of ununited tibial diaphyseal fractures with pulsing electromagnetic fields.
Bassett CA, Mitchell SN, Gaston SR.

One hundred and twenty-five patients with one hundred and twenty-seven ununited fractures of the tibial diaphysis were treated exclusively with pulsing electromagnetic fields. The over-all success rate in healing of the fracture with this surgically non-invasive out-patient method was 87 per cent. The success rate was not materially affected by the age or sex of the patient, the length of prior disability, the number of previous failed operations, or the presence of infection or metal fixation.
PMID: 7217117 [PubMed – indexed for MEDLINE]

Izv Akad Nauk SSSR Biol. 1981 Sep-Oct;(5):774-80.
[Acute experimental emotional stress in rabbits in a modulated electromagnetic field]
[Article in Russian]
Gorbunova AV, Petrova NV, Portugalov VV, Sudakov SK.
PMID: 7197697 [PubMed – indexed for MEDLINE]

Clin Orthop. 1981 Jan-Feb;(154):136-48.
Congenital "pseudarthroses" of the tibia: treatment with pulsing electromagnetic fields.
Bassett CA, Caulo N, Kort J.

During the past seven years, 34 patients with infantile nonunions associated with congenital "pseudarthroses" completed treatment with pulsing electromagnetic fields (PEMFs). An analysis of results reveals that 17/34 (50%) have achieved complete healing with biomechanically sound union and radiographic demonstration of remedullarization. Union with function, i.e., healing with continued need for protection, was achieved in 7/34 (21%). Failure was the outcome in 10/34 patients (29%). Most of these occurred in males with a history of early fracture (less than 1 year) and with spindled, hypermobile lesions (Type III). During the early period of the study, PEMFs were the sole means of treatment. After a "coil effect" had been demonstrated, surgical realignment, immobilization and grafting were combined with PEMF treatment. Fundamentals of orthopedic management developed by the larger experience with adult nonunions were found to apply equally to infantile nonunions treated with PEMFs. These include effective immobilization of the fracture site and controlled "stress working" during recovery to facilitate gradual remodeling. PEMFs have been demonstrated to be a potentially useful adjunct in the orthopedic surgeon's armamentarium for treating infantile nonunions (congenital "pseudarthroses").

PMID: 6781806 [PubMed – indexed for MEDLINE]

Equine Vet J. 1989 May;21(3):201-5.
A preliminary investigation of the effect of selected electromagnetic field devices on healing of cannon bone osteotomies in horses.
Sanders-Shamis M, Bramlage LR, Weisbrode SE, Gabel AA.
Department of Clinical Sciences, Ohio State University, College of Veterinary Medicine, Columbus 43210, USA.

The effect of electrical stimulation by means of selected electromagnetic field devices on healing of cannon bone osteotomies in horses was examined. The defects were created as 3 cm x 1 mm longitudinal osteotomies through the dorsal cortices of the mid-metacarpi/metatarsi of adult horses. This type of defect would asses bone healing in a situation similar to an acute, stable fracture of the cortex. Three electromagnetic devices of different design were tested in three different groups of horses. Healing was evaluated radiographically and histologically. Results showed that osteotomies treated with the electromagnetic devices healed similarly to untreated controls. Our conclusion is that the electromagnetic devices studied did not have a local effect on the repair process of an acute, stable, osseous defect.

PMID: 2731509 [PubMed – indexed for MEDLINE]

Zh Ushn Nos Gorl Bolezn. 1980 May-Jun;(3):51-3.
[Use of a low-frequency pulsing electromagnetic field in treating inflammatory diseases of the ENT organs]
[Article in Russian]
Ozinkovskii VV.
Publication Types:
Case Reports
PMID: 7385978 [PubMed – indexed for MEDLINE]

JAMA. 1982 Feb 5;247(5):623-8.
Pulsing electromagnetic field treatment in ununited fractures and failed arthrodeses.
Bassett CA, Mitchell SN, Gaston SR.

Pulsing electromagnetic fields (PEMFs) induce weak electric currents in bone by external coils on casts or skin. This surgically noninvasive, outpatient method, approved by the Food and Drug Administration in November 1979, produced confirmed end results in 1,007 ununited fractures and 71 failed arthrodeses, worldwide. Overall success at Columbia-Presbyterian Medical Center was 81%, internationally, 79%; and in other patients in the United States, 76%. Treatment with PEMFs was effective in 75% of 332 patients (a subset) with an average 4.7-year disability duration, an average of 3.4 previous operative failures to
produce union, and a 35% rate of infection. Eighty-four percent of carpal naviculars and 82% of femoral neck-trochanteric nonunions were united. After attempted arthrodeses could not salvage a failed total-knee prosthesis, PEMFs promoted healing in 85% of patients. When coils were unsuccessful
alone, combining them with surgical repair was effective.

PMID: 7054564 [PubMed – indexed for MEDLINE]

J Neurosci Res. 1999 Jan 15;55(2):230-7.
Electromagnetic fields influence NGF activity and levels following sciatic nerve transection.
Longo FM, Yang T, Hamilton S, Hyde JF, Walker J, Jennes L, Stach R, Sisken BF.
Department of Neurology, UCSF/VAMC, San Francisco, California, USA. LFM@itsa.UCSF.edu

Pulsed electromagnetic fields (PEMF) have been shown to increase the rate of nerve regeneration. Transient post-transection loss of target-derived nerve growth factor (NGF) is one mechanism proposed to signal induction of early nerve regenerative events. We tested the hypothesis that PEMF alter levels of NGF activity and protein in injured nerve and/or dorsal root ganglia (DRG) during the first stages of regeneration (6-72 hr). Rats with a transection injury to the midthigh portion of the sciatic nerve on one side were exposed to PEMF or sham control PEMF for 4 hr/day for different time periods. NGF-like activity was
determined in DRG, in 5-mm nerve segments proximal and distal to the transection site and in a

corresponding 5-mm segment of the contralateral nonoperated nerve. NGF-like activity of coded tissue samples was measured in a blinded fashion using the chick DRG sensory neuron bioassay. Overall, PEMF caused a significant decrease in NGF-like activity in nerve tissue ($P < 0.02$, repeated measures analysis of variance, ANOVA) with decreases evident in proximal, distal, and contralateral nonoperated nerve. Unexpectedly, transection was also found to cause a significant ($P=0.001$) 2-fold increase in DRG NGF-like activity between 6 and 24 hr postinjury in contralateral but not ipsilateral DRG. PEMF also reduced NGF-like activity in DRG, although this decrease did not reach statistical significance. Assessment of the same nerve and DRG samples using ELISA and NGF-specific antibodies confirmed an overall significant ($P < 0.001$) decrease in NGF levels in PEMF-treated nerve tissue, while no decrease was detected in DRG or in nerve samples harvested from PEMF-treated uninjured rats.

These findings demonstrate that PEMF can affect growth factor activity and levels, and raise the possibility that PEMF might promote nerve regeneration by amplifying the early postinjury decline in NGF activity.

PMID: 9972825 [PubMed – indexed for MEDLINE

Exp Physiol. 1991 Jul;76(4):473-94.
Electrical fields, nerve growth and nerve regeneration.
McCaig CD, Rajnicek AM.
School of Biomedical Sciences, Division of Physiology, Marischal College, University of Aberdeen.

The presence of voltage gradients within developing and damaged tissues led to the notion that the resultant electrical fields provide instructional cues to cells. Field effects on avian and amphibian neurones in vitro include increased differentiation, turning of neurites towards the cathode, increased rate of growth towards the cathode, resorption of anodefacing neurites, increased branching and increased filopodial activity. Electric fields enhance regeneration of damaged PNS and CNS neurones in animals as diverse as lampreys, frogs, rats and guinea-pigs, but the mechanisms by which fields produce their effects are not understood. Further examination of the interaction of fields with intracellular elements, such as the cytoskeleton and second messenger systems, may offer some insight.

Publication Types:
Review
Review, Academic

PMID: 1910756 [PubMed – indexed for MEDLINE]

J R Coll Surg Edinb. 1982 Mar;27(2):102-7.
Pulsing electromagnetic fields in the treatment of non-union of fractures.
Caullay JM, Mann TS.
Publication Types:
Case Reports
PMID: 7086715 [PubMed – indexed for MEDLINE]

Am J Orthod Dentofacial Orthop. 1987 Feb;91(2):91-104.
Effect of pulsed electromagnetic fields on orthodontic tooth movement.
Stark TM, Sinclair PM.

The purpose of this study was to determine whether the application of a simple surgically noninvasive, pulsed electromagnetic field could increase both the rate and amount of orthodontic tooth movement observed in guinea pigs. In addition, the objective was to evaluate the electromagnetic field's effects on bony physiology and metabolism and to search for possible systemic side effects. Laterally directed orthodontic force was applied to the maxillary central incisors of a sample of 40 young male, Hartley guinea pigs (20 experimental, 20 control) by means of a standardized intraoral coil spring inserted under constricting pressure into holes drilled in the guinea pigs' two maxillary central incisors. During the experimental period, the guinea pigs were placed in specially constructed, plastic animal holders with their heads positioned in an area of uniform electromagnetic field. Control animals were placed in similar plastic holders that did not carry the electrical apparatus. The application of a pulsed electromagnetic field to the experimental animals significantly increased both the rate and final amount of orthodontic tooth movement observed over the 10-day experimental period. The experimental animals also demonstrated histologic evidence of significantly greater amounts of bone and matrix deposited in the area of tension between the orthodontically moved maxillary incisors. This increase in cellular activity was also reflected by the presence of significantly greater numbers of osteoclasts in the alveolar bone surrounding the maxillary incisors of the experimental animals. After a 10-day exposure to pulsed electromagnetic field, minor changes in serologic parameters relating to protein metabolism and muscle activity were noted. The results of this study suggest that it is possible to increase the rate of orthodontic tooth movement and bone deposition through the application of a noninvasive, pulsed electromagnetic field.

PMID: 3468800 [PubMed – indexed for MEDLINE]

Nippon Ika Daigaku Zasshi. 1997 Feb;64(1):69-70.
An electron microscopic study of peripheral nerve regeneration with pulsing electromagnetic fields.
Ito H, Shirai Y, Narita T.
Department of Orthopaedic Surgery, Nippon Medical School, Tokyo, Japan.
PMID: 9119957 [PubMed – indexed for MEDLINE]

J Cell Biochem. 1993 Apr;51(4):404-9.
Prospects on clinical applications of electrical stimulation for nerve regeneration.
Sisken BF, Walker J, Orgel M.
Center for Biomedical Engineering, University of Kentucky, Lexington 40506, USA.

Regenerative capability is limited in higher vertebrates but present in organ systems such as skin, liver, bone, and to some extent, the nervous system. Peripheral nerves in particular have a relatively high potential for regeneration following injury. However, delay in regrowth or growth, blockage, or misdirection at the injury site, and growth to inappropriate end organs may compromise successful regeneration, leading to poor clinical results. Recent studies indicate that low-intensity electrical

stimulation is equivalent to various growth factors, offering avenues to improve these outcomes. We present a review of studies using electric and electromagnetic fields that provide evidence for the enhancement of regeneration following nerve injury. Electric and electromagnetic fields (EMFs) have been used to heal fracture non-unions. This technology emerged as a consequence of basic studies [Yasuda, 1953; Fukada and Yasuda, 1957] demonstrating the piezoelectric properties of (dry) bone. The principle for using electrical stimulation for bone healing originated from the work of Bassett and Becker [1962], who described asymmetric voltage wave forms from mechanically deformed live bone. These changes were presumed to occur in bone during normal physical activity as a result of mechanical forces, and it was postulated that these forces were linked to modifications in bone structure. Endogenous currents present in normal tissue and those that occur after injury were proposed to modify bone structure [Bassett, 1989]. These investigators proposed that tissue integrity and function could be restored by applying electrical and/or mechanical energy to the area of injury. They successfully applied electrical currents to nonhealing fractures (using surgically implanted electrodes or pulsed currents using surface electrodes) to aid endogenous currents in the healing process.

Publication Types:
Review
Review, Tutorial

PMID: 8496243 [PubMed – indexed for MEDLINE]

Microsurgery. 1996;17(11):589-96.
The value of continuous electrical muscle stimulation using a completely implantable system in the preservation of muscle function following motor nerve injury and repair: an experimental study.
Williams HB.
Department of Plastic and Reconstructive Surgery, McGill University, Montreal Children's Hospital, Quebec, Canada.

Functional recovery following motor nerve injury and repair is directly related to the degree of muscle atrophy that takes place during the period of nerve regeneration. The extent of this muscle atrophy is related to a number of factors including the accuracy of nerve repair; the distance through which the nerve must regenerate; the age of the patient; and the type of nerve injury and other associated tendon and soft tissue and bony damage. Atrophy of muscle that is always associated with nerve injury is a combination of disuse and degeneration. Our hypothesis proposed the following question: "Would continuous
electrical stimulation of the denervated muscle during the period of nerve regeneration maintain the integrity of the muscle fibers and hence their potential functional capacity?" We have completed a series of animal studies (rabbit and canine models) in our laboratory using a completely implantable system to provide continuous muscle stimulation following nerve injury and microsurgical repair. In several different experiments, the nerves under study were cut and repaired at 4 and 12 cm from the muscles to study the effects of short- and long-term recovery. In all experiments, a beneficial effect was demonstrated with improved morphology and functional capacity of the reinnervated stimulated muscles when compared with nonstimulated controls. In addition, electrical stimulation using this implantable system could be applied for extended periods without evidence of discomfort in the experimental animals.

PMID: 9514517 [PubMed – indexed for MEDLINE]

Handchirurgie. 1979;11(1):31-5.
[Nerve regeneration by means of the effect of an intermittent electromagnetic field. Experimental study on a rabbit]
[Article in German]
Meissl G.

An experiment on healing of transected nerves of rabbits was carried out. Under microsurgical techniques continuity of the nerve was reestablished by end-to-end coaptation without creating a defect, so only the elasticity of the nerve tissue had to be overcome, and by nerve grafting. In both cases treatment with intermittent high frequency magnetic field was applied continuously. Histologic studies revealed that the scar at the suture site matured more quickly than usually and that distal to the site of transection the normal calibre of regenerated axons was reached within a shorter time than previously.

PMID: 393577 [PubMed – indexed for MEDLINE]

J Bone Joint Surg Am. 1989 Mar;71(3):411-7.
Prevention of osteoporosis by pulsed electromagnetic fields.
Rubin CT, McLeod KJ, Lanyon LE.
Musculo-Skeletal Research Laboratory, Department of Orthopaedics, State University of New York, Stony Brook 11794.

Using an animal model, we examined the use of pulsed electromagnetic fields, induced at a physiological frequency and intensity, to prevent the osteoporosis that is concomitant with disuse. By protecting the left ulnae of turkeys from functional loading, we noted a loss of bone of 13.0 per cent compared with the intact contralateral control ulnae over an eight-week experimental period. Using a treatment regimen of one hour per day of pulsed electromagnetic fields, we observed an osteogenic dose-response to induced electrical power, with a maximum osteogenic effect between 0.01 and 0.04 tesla per second. Pulse power levels of more or less than these levels were less effective. The maximum osteogenic response was obtained by a decrease in the level of intracortical remodeling, inhibition of endosteal resorption, and stimulation of both periosteal and endosteal new-bone formation. These data suggest that short daily periods of exposure to appropriate electromagnetic fields can beneficially influence the behavior of the cell populations that are responsible for bone-remodeling, and that there is an effective window of induced electrical power in which bone mass can be controlled in the absence of mechanical loading.

PMID: 2925715 [PubMed – indexed for MEDLINE]

Srp Arh Celok Lek. 1993 Aug-Dec;121(8-12):124-6.
[Use of pulsating high-frequency electromagnetic fields in patients with diabetic neuropathies and angiopathies]
[Article in Serbian]

Vesovic-Potic V, Conic S.
Belgrade Institute of Rehabilitation.

High-frequency pulsating electromagnetic field therapy was carried out in 22 patients with diabetic polyneuropathy and angiopathy manifested on lower extremities (18 men, 4 women, aged 48.2 +/- 6.3 years; 10 insulin-dependent persons, and 12 on oral antidiabetic treatment). The aim of the study was to verify the effect of this therapy on symptoms, neurophysiological findings and peripheral circulation. The diagnose of diabetic polyneuropathy was based on the electromyographic examination of foot and calf muscles, measurement of motor nerve conduction velocity of peroneal and tibial nerve, and sensory nerve
conduction velocity of sural nerve. Diagnosis of diabetic polyneuropathy was based on electromyographic examination of the foot and calf muscles, measurement of the motor nerve conduction velocity of peroneal and tibial nerves, and the sensory nerve conduction velocity of the sural nerve. Diagnosis of diabetic angiopathy was established by oscillometric examination, measurement of skin temperature and claudication distance. The same methods were used for the evaluation of the therapeutical effect of electromagnetic field. Significant improvement of symptoms, and of all registered parameters of peripheral
circulation was established after the therapy, but there were no significant changes of neurophysiological parameters. Therefore, high-frequency pulsating electromagnetic field is recommended for the treatment of diabetic angiopathy. In patients with neuropathic changes it can be used as an introduction procedure, or as an additional procedure to physical agents which are commonly used in the treatment of peripheral nerve lesion.

PMID: 7725151 [PubMed – indexed for MEDLINE]

J Reconstr Microsurg. 1995 May;11(3):189-93.
Experimental study using a direct current electrical field to promote peripheral nerve regeneration.
Shen N, Zhu J.
Department of Orthopedics, People's Hospital of Hainan Province, Haikou, People's Republic of China.

A direct current (DC) electrical field was used to stimulate transected and sutured rat sciatic nerve. Electrophysiologic, morphometric, and functional assessments were carried out on days 10, 20, 30, and 60 postoperatively. The results showed that the electrophysiologic index, the diameter and myelin-sheath thickness of regenerating nerve fibers, the sciatic functional index (SFI), and the strength of the triceps surae muscle in the experimental group were much better than those in the control group. This indicated that DC electrical stimulation could effectively promote peripheral nerve regeneration and produce positive effects after 3 weeks, and that the stimulator was not rejected by the host for a relatively long period of time.

PMID: 7650644 [PubMed – indexed for MEDLINE]

Rev Chir Orthop Reparatrice Appar Mot. 1981;67(1):11-23.
[Acceleration of repair of non-unions by electromagnetic fields (author's transl)]

[Article in French]
Sedel L, Christel P, Duriez J, Duriez R, Evrard J, Ficat C, Cauchoix J, Witvoet J.

This work deals with the results obtained by four French orthopaedic departments using the electromagnetic field stimulation for non union treatment. This is the method established by A. Bassett. 37 cases are studied, the results are known for 35 of them with 6 failures and 29 successes. The failures can be explained for four of them by a bad application of the device. Concerning the 29 successful cases, the role of the stimulation is discussed. Discarding those who have been treated a short time after a surgical procedure, those who have been immobilized more than 6 months and those where the non union could have been a
delayed union, it remains 14 successful cases apparently undisputable. For them the role of the electromagnetic field stimulation seems real.

Publication Types:
Case Reports

PMID: 6453392 [PubMed – indexed for MEDLINE]

Science. 1983 Jun 17;220(4603):1283-5.
Pulsing electromagnetic fields induce cellular transcription.
Goodman R, Bassett CA, Henderson AS.

Weak, pulsing electromagnetic fields can modify biological processes. The hypothesis that responses to such induced currents depend on pulse characteristics was evaluated by using transcription as the target process. Two pulses in clinical use, the repetitive single pulse and the repetitive pulse train, were tested. These pulses produced different results from each other and from controls when transcription in dipteran salivary gland cells was monitored with tritiated uridine in transcription autoradiography, cytological nick translation, and analysis of isolated RNA fractions. The single pulse increased the specific activity of messenger RNA after 15 and 45 minutes of exposure. The pulse train increased specific activity only after 45 minutes of exposure.

PMID: 6857248 [PubMed – indexed for MEDLINE]

Clin Orthop. 1977 May;(124):128-43.
A non-operative salvage of surgically-resistant pseudarthroses and non-unions by pulsing electromagnetic fields. A preliminary report.
Bassett CA, Pilla AA, Pawluk RJ.

This report documents, for the first time, to the authors' knowledge, the therapeutic use in humans of low energy, electromagnetic fields pulsing in the extremely low frequency (E.L.F.) range. These fields, established outside the body, were used to treat congenital and acquired pseudarthroses and non-unions. Energy of this type appears to affect biological processes, not through heat production, but through electrically-induced changes in the environment of cells
within the organism. Of the 29 patients included in the study, 17 had experienced at least one failure of surgical repair and, in each of these, amputation had been recommended. The overall success rate,

including those patients treated with inadequate pulse characteristics and those who failed to follow the protocol, was in excess of 70 per cent. Improvements in the specificity of pulse characteristics hold promise for increasing the rate of success. The simple, clinical methodology, which is conducted on an out-patient basis, appears to be both safe and effective. It can be applied with or without surgery. This approach requires additional controlled investigations before it is ready for general use in the orthopaedic community. The indications for
amputation of surgically-resistant pseudarthroses, however, should be reassessed. The principles and technology, which have been established during this endeavor, may have physiologic and practical significance for processes other than pseudarthrosis and non-union.

PMID: 598067 [PubMed – indexed for MEDLINE]

Prog Clin Biol Res. 1986;210:239-50.
The role of natural and applied electric fields in neuronal regeneration and development.
Borgens RB.
PMID: 3960913 [PubMed – indexed for MEDLINE]

Fiziol Zh. 2003;49(2):85-90.
[Use of low-power electromagnetic therapy in diabetic polyneuropathy]
[Article in Ukrainian]
Chebotar'ova LL, Chebotar'ov HIe.

The clinical-electroneuromyography investigations were performed for objective evaluation of low-power electromagnetic therapy effectiveness in 12 patients
with diabetic polyneuropaties. It is established that combination of low-power electromagnetic therapy using "ANET-UHF", "ANET-SHF" apparatus (Ukraine) and low-power variable magnetic field using AMT apparatus (Ukraine) give the stable positive effects. The positive changes were confirmed by following: the decrease of neurological deficit and required insulin daily dose, nerve conduction velocity increase, increase of the muscle compound action potentials (muscle
power) and peripheral outflow in some patients.

Publication Types:
Evaluation Studies

PMID: 12945120 [PubMed – indexed for MEDLINE]

J Orthop Res. 1991 Nov;9(6):908-17.
Electromagnetic stimulation of bone repair: a histomorphometric study.
Cane V, Botti P, Farneti D, Soana S.
Institutes of Human Anatomy, University of Modena, Italy.

The effect of pulsing electromagnetic fields (PEMFs) on bone repair was studied in principal metacarpal bones of eight adult male horses: Six horses were treated with PEMFs, and two horses were untreated.

In treated horses, Helmholtz coils were applied during a 60-day period to the left metacarpal bones, bored with eight holes of equal diameter and depth, from the middiaphysis toward the distal metaphysis. Eight equal holes bored in the right metacarpal, surrounded by unactivated Helmholtz coils, were taken as controls. The two untreated horses were taken as additional control. The results of computer-assisted histomorphometric analysis indicate that (a) in diaphyseal levels, the amount of bone formed during 60 days is significantly greater (p less than 0.01) in PEMF-treated holes than in contralateral ones and those in control horses; (b) in metaphyseal levels, PEMF-treated holes are sometimes more closed, sometimes less, as compared with contralateral holes and those in control horses; in any case the statistical analysis indicates that the symmetry in the rate of hole repair, found between the two antimeres of control horses, is not appreciable at metaphyseal levels also; (c) there was no statistically significant difference between untreated holes in PEMF-treated horses and holes in control horses, neither at diaphyseal nor at metaphyseal levels. These preliminary findings indicate that PEMFs at low frequency influence the process of bone repair on both diaphysis and metaphysis, and seem to improve the process of bone repair in skeletal regions normally having a lower osteogenetic activity, i.e., in diaphyses as against metaphyses.

PMID: 1919855 [PubMed – indexed for MEDLINE]

Exp Brain Res. 1988;71(1):223-6.
Treatment of the damaged rat hippocampus with a locally applied electric field.
Politis MJ, Zanakis MF.
Department of Anatomy, University of Saskatchewan, Saskatoon, Canada.

Previous studies have indicated that axons may be directed to regenerate toward the cathodal source of a locally applied D.C. electric field. In the present studies, similar galvanotropic effects were tested after partial denervation of the rat hippocampus. Following unilateral fimbrial lesions, 1.5 microA of direct current was applied locally to the tissue for 4 weeks. In the experimental group, the distal (temporal) portion of the hippocampus was located near the cathodal electrode, while the proximal (nasal) portion was located near the anode. In two control groups, either the current was reversed, or there was not current delivered to the tissue. Spontaneous alternation behavior 4 weeks post-operatively in the “cathode distal” rats provided results comparable to those in unoperated (normal) animals, whereas the control animals exhibited statistically significantly greater deficits in memory. The ability to learn the location of a submerged platform in a water tank was evident in unoperated and “cathode distal” animals, but not in either of the control groups. Hippocampal acetylcholinesterase activity in “cathode distal” animals was lower than in unoperated animals, but statistically significantly greater than in the other control animals. Results are consistent with the contention that locally applied weak direct current can modulate long term sequellae of hippocampal injury.

PMID: 3416955 [PubMed – indexed for MEDLINE]

Vopr Kurortol Fizioter Lech Fiz Kult. 1984 May-Jun;(3):19-23.
[Effect of interference current and low-frequency magnetic field on tissue regeneration]
[Article in Russian]

Nikolova L, Popov A, Klouchek E.
PMID: 6332416 [PubMed – indexed for MEDLINE]

Equine Vet J. 1987 Mar;19(2):120-4.
Preliminary study of quantitative aspects and the effect of pulsed electromagnetic field treatment on the incorporation of equine cancellous bone
grafts.
Kold SE, Hickman J, Meisen F.

The quantitative aspects of equine cancellous bone graft incorporation and the possibility of influencing graft incorporation by daily exposure to a pulsed electromagnetic field (PEMF) was studied in eight yearling ponies. In order to be able to quantify formative aspects of graft remodelling, a double and treble tetracycline intravital labelling technique was used. Intravital radiographs were obtained at regular intervals throughout the trial, but were found to be of little assistance in assessing any differences between stimulated and non-stimulated grafts. The ponies were humanely destroyed at regular intervals
between nine and 241 days after installation of the graft. Light microscopy and fluorescent light microscopy were used to evaluate quantitative aspects of graft incorporation and to compare PEMF-stimulated grafts with control grafts. There was a small but statistically significant effect of PEMF-stimulation on cancellous bone graft incorporation. In view of this, these observations can only be considered as indicative of a possible trend, but should encourage further studies using different signal modalities.

PMID: 3552658 [PubMed – indexed for MEDLINE]

Chir Narzadow Ruchu Ortop Pol. 1987;52(6):463-8.
[Morphological and morphometric studies of the healing of an experimental musculo-cutaneous wound after its exposure to a constant electromagnetic field]
[Article in Polish]
Szram S, Bielnik K, Sondej J.
PMID: 3452501 [PubMed – indexed for MEDLINE]

Vestn Otorinolaringol. 1988 May-Jun;(3):42-7.
[Use of a low-frequency alternating magnetic field in the complex treatment of patients with functional diseases of the larynx]
[Article in Russian]
Demchenko EV.
PMID: 3212866 [PubMed – indexed for MEDLINE]

Biofizika. 1985 Nov-Dec;30(6):1046-9.
[Effect of weak alternating ultra-low frequency magnetic fields on the development of the

hypercoagulation syndrome in immobilized rats]
[Article in Russian]
Temuriants NA, Mikhailov AV.

The experimental results are given concerning the effect of variable magnetic field (VMF) with the frequency of 8 Hz and intensity 4 A/m on some parameters of rat haemocoagulation system under standard mobile regime as well as under prolonged hypokinesia. It is stated that repeated daily exposition of VMF causes hypocoagulational blood shift in intact animals. Under the effect of simultaneous VMF and hypokinesia the correction of hypercoagulational shift induced by animal hypokinesia was detected. The highest VMF effect was observed in prolonged experiments. A conclusion is drawn concerning the ability of VMF with the given parameters to limit the development of rat blood hypercoagulation under hypokinesia.

PMID: 4074760 [PubMed – indexed for MEDLINE]

Biull Eksp Biol Med. 1983 May;95(5):62-4.
[Effect of an electromagnetic field on conditioned reflex maintenance and the nucleic acid content of brain tissues during carotid artery constriction]
[Article in Russian]
Rutsai SV, Surkova IS.

It has been discovered in chronic experiments on 54 rats that during ligation of the carotid artery, the action of the decimetric electromagnetic field (DMB-irradiation) produces in some cases the deterioration of the rats' status that manifests in paroxysms eventuating in lethal outcomes, whereas in other ones, makes the conditioned reflexes return to normal, accompanied by an increase in RNA content in the cortex of the large hemispheres. The mechanisms of an inconclusive action of DMB-irradiation is discussed as is the importance of changes in RNA content in the cortex for the mechanisms of a favourable action of irradiation on the recovery of brain function in circulatory disorders. The possibilities of using DMB-irradiation under the clinical conditions are also discussed.

Panminerva Med. 1989 Oct-Dec;31(4):151-65.
On the electro-magnetic nature of life.
Jacobson JI.

Man has wondered since the dawning of thought about the origin and the meaning of the spark of life. How does life work and what is the difference between life and non-life? This paper wonders about the part that electromagnetism plays in the life process. It proposes a new insight into the relation of in vivo electromagnetic fields and gravitational fields and discusses such manifestations as solitons, the quantum hall effect, gravity waves, biological strings, biologically closed electric circuits, phonos and the piezoelectric nature of living tissue. It proposes a new and fundamental form of resonance, called Jacobson resonance. The system unifies quantum genetic characters and associated structures with electromagnetic field interaction energies. The result is the reorientation of atomic crystal lattice structures of organic molecules critical to the sustenance of life. A new treatment methodology is proposed for genomic, viral and trophic factor disorders essentially in terms of the potential efficacy of

the magnetic force to reorient the spin angular momenta of electrons and protons; to therein rearrange atomic and molecular magnetic domains regulating homeostasis on microscopic, mesosopic and macroscopic levels through biological amplification of quantum interactions.
Finally it proposes that the equation, mc2 = Bvl coulomb, may indeed represent the achievement of fourfold physical unification, the unification of physics and medicine, and resultant production of a thorough understanding of what may be the most fundamental natural law of the universe representing the ultimate goal of Einsteinian equivalence and relativistic field theory.