Scientific and Clinical Studies on Microcurrent

Cell Regeneration and ATP Production

The Effects of Electric Currents on ATP Generation, Protein Synthesis, and Membrane Transport

Summary: Research shows that ATP (adenosine triphosphate) levels increase with the application of microcurrent and diminish with millicurrent (Cheng 1982). The increase of ATP peaked at 500 microamps and decreased rapidly at higher current levels. Cheng also observed that aminoisobutyric acid uptake increased dramatically beginning at 10 microamps and inhibitory effects began at 750 microamps. The uptake of aminoisobutyric acid which is essential for protein synthesis and membrane transport, showed an increase of 30 - 40%.

Mechanism
During electrostimulation, proton gradients are created across the mitochondrial membrane. The current produces a gradient when electrons at the cathode react with water to form hydroxyl ions while producing protons at the anodic side. As a result a proton and voltage gradient are established across the intervening tissues between the electrodes. The influence of the electrical field and the proton concentration difference produce a proton current that moves from anode to cathode. As the migrating protons cross the mitochondrial membrane-bound H+ATPase, ATP is formed. The increased ATP production stimulates amino acid transport, and these two factors both contribute to increased protein synthesis.
(Cheng, 1982)

also see:
The Role of Endogenous Electrical Fields in Limb Regeneration Limb Development and Regeneration
Vanable, Joseph, Part A, pgs. 587-596, Alan Liss Publishing, N.Y., 1983

Osteoarthritis of the Knee
Treatment of Osteoarthritis of the Knee with pulsed Electrical Stimulation
Thomas M. Zizic

Objective: The safety and effectiveness of pulsed electrical stimulation was evaluated for the treatment of osteoarthritis (OA) of the knee.
Methods: A multicenter, double blind, randomized, placebo controlled trial that enrolled 78 patients with OA of the knee incorporated 3 primary efficacy variables of patients' pain, patients' function, and physician global evaluation of patients' condition, and 6 secondary variables that included duration of morning stiffness, range of motion, knee tenderness, joint swelling, joint circumference, and walking time. Measurements were recorded at baseline and during the 4 week treatment period. Results. Patients treated with the active devices showed significantly greater improvement than the placebo group for all primary efficacy variables in comparisons of mean change from baseline to the end of treatment ($p < 0.05$). Improvement of > 50% from baseline was demonstrated in at least one primary efficacy variable in 50% of the active device group, in 2 variables in 32%, and in all 3 variables in 24%. In the placebo group improvement of > 50% occurred in 36% for one, 6% for 2, and 6% for

3 variables. Mean morning stiffness decreased 20 min in the active device group and increased 2 min in the placebo group ($p < 0.05$). No statistically significant differences were observed for tenderness, swelling, or walking time.
Conclusion: The improvements in clinical measures for pain and function found in this study suggest that pulsed electrical stimulation is effective for treating OA of the knee.
Studies for longterm effects are warranted. (J Rheumatol 1995;22:1757-61)

Glycosaminoglycan production
In Vitro Growth of Bovine Articular Cartilage Chondrocytes in Various Capacitively Coupled Electrical Fields

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Summary: Isolated articular cartilage chondrocytes from 1- to 3-week-old male Holstein calf knee joints were formed into pellets containing 4 x 106 isolated cells and were grown in tissue culture medium (minimum essential medium/NCTC 135) containing either 1 or 10% newborn calf serum (NBCS) in plastic Petri dishes in 5% CO2 and air at 37°C in saturation humidity. On the 4th postisolation day either [3~S]sulfate or [3H]thymidine was added to the medium, and the pellets were exposed for 24 h to capacitively coupled electrical fields (10, 100, 250, and 1,000 V peak-to-peak, 60 kHz, sine wave signals). Current Intensity: 37 uA cm\2 The pellets were then harvested, dialyzed, hydrolyzed, and assayed for DNA, protein, [35S]sulfate incorporation, and [3H]thymidine incorporation.
Results indicated that at 250 V peak-to-peak there was a statistically significant increase in [35S]sulfate in 1% NBCS and a statistically significant increase in [3H]thymidine in 10% NBCS. At potentials above, or below 250 V no changes were noted. Thus, articular cartilage chondrocytes grown in pellet form can be stimulated to increase glycosaminoglycan synthesis or to increase cell proliferation by an appropriate capacitively coupled electrical field. The importance of the serum concentration in the medium in evaluation of biosynthesis in vitro is noted.
Key Words: Articular cartilage chondrocyte--Capacitively coupled electrical field--[35S]Sulfate incorporation--Cell proliferation.

Case Studies on Osteoarthritis of the Knee
Case 1.
An 85 year old female with severe OA of the knee had been kept awake at night with pain. Prior treatments with anti-inflammatories and cortisone provided temporary, short term relief. CellStim treatment consisted of an IFC arrangement of pads on the medial/ lateral line and inf/ sup poles of patella. Treatments began at 3 times a week and then diminished. After 14 treatments in 10 weeks at 30 Hz/ 300 uA x 10 minutes and .3 Hz/ 40 uA x 10 minutes. The pain reduction indicated 95 % improvement.

Case 2.
A 70 year old male with moderate OA of the knee reports on occasion for treatment of knee pain. Previous treatment with IFC gave some improvement for short term relief. 20 - 30 minute CellStim treatments at .3 Hz and 40 uA biphasic gave lasting (2 weeks - 1 month) of significant relief (90-95% improvement). Pad placement was the same as case 1.

Case 3.
A 70 year old female with chronic OA of the 1st MTP was treated on 3 occasions with Cellstim at .3 Hz at 30 uA biphasic once per week for 3 weeks. The joint was probed (using Qtip electrode probes) moving the probe location every 3 to 5 seconds. After 3 treatments the patient reported 90% improvement.
Chiropractic College ... Canada

Pain Reduction
Data collection study, Microcurrent Therapy Lynn A. Wallace, PT (1990)

* 94% of the 1531 patients experienced a reduction in pain during the first treatment.
* No side effects or increase in symptoms were reported. The overall results were remarkably similar when comparing the first 200 / 400 and 800 cases to the final total of 1531 cases.
* Pain reduction occurring after the patient left the clinic was not recorded as pain reduction during treatment.
* Patients who discontinued their treatments after significant progress (i.e. pain decrease from 10 to 3) but, before reaching a pain free state, were recorded as failures.
* Similarly, patients whose treatment was discontinued by their physician before reaching a pain free state were recorded as failures.
* 96% response in pain relief.
* 88% pain free within 10 treatments.
* 12 types of acute injuries tested, average pain free = 4 treatments.
* Acute radiating cervical pain, average pain free = 3.5 treatments.
* Acute lower back pain, average pain free = 4.5 treatments

The following list of criteria was followed:
* Patients were asked to rate their pain on a subjective pain scale (0 to 10, with 10 being unbearable pain).
* Decreases in pain that were achieved after patients left the clinic were not included.
* Biphasic current was used almost exclusively (negative current was used on selected cases with referred spinal pain).
* Electrode probes and pads were used.
* Daily treatment was encouraged, therefore, the total treatments rendered represent approximately that many days of treatment.
* Medication was not altered.
* No other modalities (heat, ice, electricity, or mechanical traction) were used.
* Instructions such as positioning and avoidance were presented during the first treatment.

Worker's Compensation Injuries Study (283 patients)

* Control group on conventional therapy (hot, cold packs, massage) avg. # of treatments for back to work =20.7
* Microcurrent only: avg. # of treatments for back to work =8.7
* Microcurrent and conventional therapy: avg. # of treatments back to work =8.6

Result: 237 % accelerated healing response

Sports Injuries

Direct-Current Electrical Stimulation of Tendon Healing in Vitro

Nessler and Mass, Clinical Orthopedics and Related Research, April 1987

Summary: 80 tendons from white rabbits were surgically transected and removed from the animals after being surgically repaired. They were divided into 4 groups of 20, and cultured with 10 of each group being electrically stimulated, and half not. A 1.4 volt direct current connected through a 150 kOhm resistor was used for stimulation, at a current of about 7 uA. It was found that currents any higher than this caused discoloration of the tendons. Healing was measured by proline uptake and bridging of the repair site by the epitenon.
Results: "a continuous direct current causes increased tendon cell activity within seven days and the increased activity may persist as long as 42 days." The researchers suggested that externally applied microcurrents may be preferable in future studies.
Keywords: tendon, Achilles

Electrical Energy and Soft-Tissue Injury Healing Sportcare and Fitness

Stanish and Gunlaughson, Sept/Oct 1988

Summary: This article is a summary of research into tendon healing acceleration, including human injuries of the anterior cruciate ligament and the Achilles tendons: "While the results are subjective, the individuals in both groups appear to have returned to usual activities more quickly, and have greater mobility, than people treated more conventionally".

Low-intensity Pulsed Galvanic Current and the Healing of Tenotomized Rat Achilles Tendons: Preliminary Report Using Load-to-Breaking measurements

Oweye, Spielholz and Nelson, Archives Physical Med Rehab, Vol. 68, July 1987

Summary: 60 rats were divided into three groups of 20. One was unstimulated, one group had their Achilles tendons stimulated with positive (anodal) current, and the third group's tendons were stimulated with negative (cathodal) currents. A current of 75 microamps, at 10 Hz was used. Results: "The group treated with anodal current withstood significantly greater loads ($p<0.001$) than did either the group which healed normally (i.e. without stimulation) or the group treated with cathodal currents".

Bone reunion

Bone Changes Due to Pulses of Direct Electric Microcurrent

Richez, Chamay and Bieler, U. of Geneva:Virchows Arch. Abt. A Path Anat. 357, 11-18 (1972)

Summary: 26 rabbits had platinum electrodes surgically implanted into the medullary cavities of their humerus bones. Microcurrent stimulation was applied at 50 and 250

uA, allowing pause periods of one second between one second treatment bursts. The scientists found that osteogenesis (bone growth) happened more around the cathode (negative polarity), and that slight tissue necrosis occurred around the anode. The tissues stimulated acted as capacitors, discharging 75% of the current absorbed during the rest periods. They concluded that pulsed current is superior to direct current for bone healing acceleration.
Keywords: EEG,

Headaches and Migraines
Comparative Effects of Microcurrent Stimulation on EEG Spectrum and Correlation Dimension
M. Heffernan: Integrative and Behavioural Science, July-September, 1996, Vol. 31, #3

Summary: 30 subjects were selected for a study comparing the effects of microcurrent on smoothing of EEG measurements of the brain. Subjects were randomly assigned to three groups - microcurrent (100uA) applied to earloble, trapezius area of shoulder, and no stimulation. Electrodes were arranged so subjects could not tell which group they were in. Fast Fourier Transform (FFT) and correlation dimension from chaos analysis were used to measure results. The researcher found that microcurrent applied to the shoulders was markedly more effective in smoothing EEG patterns than earlobe or placebo. "This would represent a possible cost-effective alternative to neurofeedback in treating (anxiety and attention deficit disorders), by raising low regions in the FFT."

TMJ
Experimental Studies of Influences on Healing Process of Mandibular Defect Stimulated by Microcurrent
Tomoya Ohno, Shikwa Gakuho, #82 1982
Summary: 50 uA current pulses were applied to one side of the jaws of a group of dogs with lesions in their jaws. The other side was untreated. The dogs were examined at periods of 3, 7, 14, 21, 28, 42 and 56 days.
Results: "It seems likely that direct microcurrent promotes normal bone formation within the defective area and accelerates the osseous healing process. Prolonged application of electrical stimulus promotes a remarkable bone remodeling mechanism."

Trigger Point Identification and Treatment with Microcurrent

DuPont, The Journal of Craniomandibular Practice, October 1999, Vol. 17, #4

Summary: This article gives the author's techniques for locating and stimulating trigger points (TP's) using a microcurrent stimulator, specifically for the treatment of temporomandibular disorders. He states that electrical conductivity is highest over trigger points, and galvanic skin response (GSR) testing can be used to locate such points. He utilizes probe electrodes to treat small TP's, and pad electrodes to treat larger ones. Probe treatment is delivered @ 0.3 Hz, 20 - 40 uA, with treatment time of 10 - 30 seconds per site. He suggests administering treatment in 24-48 intervals,

and states that results should be seen within 2 - 3 treatments. He acknowledges that these protocols are not necessarily the best ones, but work well for his practice.

Clinical Comparative Study of Microcurrent Electrical Stimulation to Mid-Laser and Placebo Treatment in Degenerative Joint Disease of the Temporomandibular Joint

Bertolucci and Grey, Journal of Craniomandibular Practice, 1995

Summary: 48 patients were divided into three groups, some receiving placebo, some microcurrent and some laser to treat pain of TMJ syndrome. Both microcurrent and laser were found to be significantly more effective than placebo, with laser slightly more effective than microcurrent. The author acknowledges that lasers are not legally sold in the United States for this purpose, and that microcurrent's easy accessibility makes it more practical for practitioners here.

Low Back Pain

A double blind comparative study of micro-stimulation and placebo effect in short term treatment of the chronic back patient
Lerner, Kirsch, ACAJ of Chriropractic 15:S101-S106, 1981

Blood Circulation

Effect of High Voltage Stimulation on Blood Flow in the Rat Hind Limb
Thomas Mohr, Thomas K. Akers, and Henry C. Wessman

The purpose of this study was to test the effect of high voltage stimulation (HVS) on blood flow velocity (BFV) in the rat hind limb. A 20-MHz pulsed Doppler device was used to measure BFV changes in the fernoral artery of 20 anesthetized rats after electrical stimulation.
The animals were stimulated under the following conditions:
1) four different pulse rates,
2) changes in stimulus voltage, and
3) changes in polarity.
Blood flow velocity also was measured in the unstimulated hind limb. Although each of the four pulse rates caused significant increases in BFV, the 20-pulse-per-second rate produced BFV increases significantly greater than the other three pulse rates. The BFV changes, on the average, occurred less than 1 minute from the onset of stimulation and lasted up to 14 minutes after the cessation of the stimulation. The BFV increased with increases in voltage intensity. Both the positive and negative poles elicited significant increases in BFV, but the negative pole produced the greatest increases. Blood flow in the unstimulated hind limb was unchanged after stimulation. This study indicates that HVS of muscle does cause significant increases in blood flow to the stimulated rat hind limb.

Edema and Swelling Reduction

Reduction with Subcontraction High-Voltage Stimulation (SC-HVS):
1. Restricts leakage of flourescien labeled dextran from the microvasculature by decreasing permeability to proteins. (Reed B, 1988), (Bettany JA, 1990)
2. When microcurrent is applied to traumatized tissue, charged proteins are put into

motion and migration into the lymphatic channels is accelerated. The lymphatic channels osmotic pressure is thereby increased, hastening the absorption of fluid from the interstitial space. (Alon G, Domenico G., 1987)
3. The movement of charged proteins into the lymphatic channels is accentuated and the contraction of lymphatic smooth muscle is enhanced. Fluid drawn into the vessels by the oncotic force of albumin labeled with blue dye distended the lumen of the lymphatic vessel and caused a subsequent increase in the rate of lymphatic contraction. (Cook HA & Assoc., 1994)

Wound Healing
Polarity reversal of microcurrent reinitiates wound repair processes following plateaus in healing. Blood coagulation and thrombosis occurs in the vessel beneath the anode but not beneath the cathode. When the polarity is reversed the cathode is capable of solubilizing the clot formed beneath the anode.
(Becker R. 1988)

Electrotherapy for Acceleration of Wound Healing: Low Intensity Direct Current

Carley and Wainapel, Archives of Physical Medicine and Rehabilitation, Vol. 66, July 1985

Summary: 30 hospital patients with non healing ulcers were divided into two groups, one treated with conventional wound dressings and one with microcurrent stimulation at 300-700 uA. The latter group was given two two hour stimulation periods per day. After six weeks of such treatments, the group treated with microcurrents showed a 150-250% faster healing rate , with stronger scar formation, less pain and lessened infection of the treated area.

Accelerated Healing of Skin Ulcers by Electrotherapy

Wolcott, Wheeler, Hardwicke, and Rowley Southern Medical Journal, July 1969.

*Summary: R*esearchers applied microcurrent stimulation ranging from 200-800 uA to a wide variety of wounds, using negative polarity over the lesions in the initial phase, and then alternating positive and negative electrodes every three days. The treated group showed 200-350% faster healing rates than control, with stronger tensile strength of scar tissue and antibacterial effects in infected wounds in the treated group.
Keywords: ulcers, polarity, stimulation, quadriplegia, healing

Use of Low Intensity Direct Current in Management Ischemic Skin Ulcers

Gault and Gatens: Physical Therapy, Vol. 56, #3, March 1976.

Summary: 100 patients with skin ulcers were treated with microcurrent stimulation; six of them had bacterial ulcers with one side used as controls. Stimulation of 200-800 uA was applied, with negative polarity used until infection cleared, and then polarity reversed. Patients had diagnosis ranging from quadriplegia, CVA, brain tumor, peripheral vascular disease, burns, diabetes, fracture, and amputation. The lesions with patients treated with currents showed approximately twice as fast a

healing rate.
Keywords: accelerated, wound healing, current, ATP, amino acids, biochemical

Effects of Electrical Microcurrents on Regeneration Processes in Skin Wounds

Sinitsyn, Razvozva, Ortop Travmatol Protez, Feb. 1986

Summary: 68 patients with post burn and post traumatic wounds underwent treatment constant and modulated microcurrent of negative polarity of 1-10 uA/cm2 over a period of 2-20 days. Although both groups showed accelerated regeneration, the modulated electric current group showed more prolonged and marked effect. Better survival of skin grafts was demonstrated compared with untreated patients.

Bacterial inhibition by electrical activation of percutaneous silver implants.

J.A. Spadaro, S.E. Chase, and D.A. Webster:Journal of Biomedical Materials Research, Vol. 20, 565-577 (1986)

Summary: Percutaneous silver wire implants were placed in rats, and the wounds inoculated with Staphylococcus aureus to test how much infection would spread. Microcurrent stimulation was passed through the wires, with + anodal current placed into implanted silver wire, and the - cathodal electrode placed on the rat's belly as a ground. It was found that significant inhibition of infection occurred, with the most marked results at 20uA current level. "Metallic silver can be effectively and efficiently activated to elicit its anti-microbial activity by the application of microampere electrical current."

Inhibitory Effects on Healing with TENS
Lack of effect of transcutaneous electrical nerve stimulation upon experimentally induced delayed onset muscle soreness in humans.

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Summary: The aim of the current study, for which ethical approval was obtained, was to assess the hypoalgesic efficacy of transcutaneous electrical nerve stimulation (TENS) upon acute stage (72 h) experimentally induced delayed onset muscle soreness (DOMS). TENS naive subjects (n = 48; 24 male and 24 female) were recruited, screened for relevant pathology and randomly allocated to one of four experimental groups: control, placebo, low TENS (200/~sec; 4 Hz) or high TENS group (200/~sec; 110 Hz). DOMS was induced in a standardised fashion in the non-dominant elbow flexors of all subjects by repeated eccentric exercise. Subjects attended on three consecutive days for treatment and measurement of elbow flexion, extension and resting angle (Universal goniometer), Mechanical Pain Threshold/tenderness (algometer) and pain (Visual Analogue Scale (VAS)) on a daily basis, plus McGill Pain Questionnaire on the third day only. Measurements were taken before and after treatment under controlled double blinded conditions.

Analysis of results using repeated measures analysis of variance (ANOVA) and post hoc tests showed some inconsistent isolated effects of high TENS (110 Hz) compared to the other conditions upon resting angle and flexion scores; no significant effects were found for any of the other variables. These results provide no convincing evidence for any measurable hypoalgesic effects of TENS upon DOMS-associated pain at the stimulation parameters used here.

Current Pathways and Electrophysiology
Bioelectricity is conducted through five main components that may be found in any vascularized part of the body.

1. Insulating walls of blood vessels
2. Conducting intravascular plasma
3. Insulating tissue matrix (possibly including lymph vessels)
4. Conducting interstitial fluid
5. Transcapillary electrical junctions for redox reactions

A relatively higher electrical resistance is present in the walls of large blood vessels and a relatively lower resistance in plasma and interstitial fluids, giving rise to a voltage gradient. The vessel walls in this bioelectrical circuit act as electrically conducting, insulating cables that carry plasma (the conducting media) and separate it from the surrounding conducting media (the interstitial fluid) except at its transcapillary junctions (the naturally occurring electrodes in the bioelectric circuit). (Nordenstrom B.)

The capillary cell membranes act as naturally charged electrodes that allow ions to move through the cells via gates and vesicles. Additional ions flow between the cells through pores. This local ion flow stops when excess electrons cross enzyme bridges in the capillary walls, closing the pores and gates and thereby closing the local circuit. This occurrence creates a long distance bioelectrical circuit in which the ions flow. The capillary cell membranes, therefore appear to be the key component in switching from local ion flow across the capillary membranes to long distance ion flow down the capillary walls.

An accumulation of charge (excess electrons) can be generated by soft tissue injury or even normal muscle use. The accumulation of charge may constrict arterial capillaries, switching the current on. However, venous capillaries do not constrict in an electrical field; therefore, ions and charged cells (e.g. neutrophils) can migrate through the pores of a leaky venous capillary near the injury. Because the polarity of the electrical potential from an injury changes, charged cells and ions necessary for healing may ebb and flow as changes take place in the electrical insulation properties of the capillary membranes.

A direct current (DC) system operates within the nerve fiber similar to the way a semiconductor functions. In a semiconductor small amounts of electrical current are transmitted via positive and negative charges through a crystal lattice. When a stimulus such as trauma, amputation, anesthesia or microcurrent is applied to living tissue, the surface potentials change. Only two seconds after trauma is invoked, DC potentials progress up the neuraxis to the cranium. This activity suggests that a

biologic model of a semiconductor system transmits data regarding injury and that the change in surface potential is a record of the injury data transmitted.

The DC semiconductor system is composed of Schwann cell sheaths in the periphery, satellite cells in the dorsal root ganglion, and glial cells in the CNS. (Becker R.)

Calcium acts like a semiconductor thus is stimulated with biphasic as well as monophasic current. Traveling wave depolarization where a group of cells stimulate adjacent cells creates a current pathway allowing microcurrent to penetrate through the GSR. Greater effectiveness has been shown with higher voltages ie. +/- 37 volts.