Wound Healing with Electrical Current
Selected Bibliography

1. Carley, P. J. and S. F. Wainapel (1985). "Electrotherapy for acceleration of wound healing: low intensity direct current." Arch Phys Med Rehabil 66(7): 443-6.
Accelerated wound healing has been an observed effect of low intensity direct current (LIDC) in the range of 200 microA to 800 microA, but present electrotherapeutic equipment has been less than optimal in providing this range of stimulation. A small and portable LIDC stimulator was specially constructed and used in a study of the effects of LIDC on wound healing rates among inpatients here. Thirty patients with indolent ulcers located either below the knee or in the sacral area were randomly assigned to the LIDC protocol or to more conventional wound therapy. The patients in each treatment group were matched by age, diagnosis, wound size, and wound etiology. Comparison revealed 1.5 to 2.5 times faster healing in those receiving LIDC, which was statistically significant. The wounds treated with LIDC required less debridement and the healed scars were more resilient. Additionally, no wound infections occurred and patients reported less discomfort at the wound site. Low intensity direct current appears to be a convenient, reproducible, and effective method for improved healing of chronic open wounds and warrants more widespread use in the clinical setting.

2. Feedar, J. A., L. C. Kloth, et al. (1991). "Chronic dermal ulcer healing enhanced with monophasic pulsed electrical stimulation [see comments]." Phys Ther 71(9): 639-49.
The purposes of this randomized, double-blind, multicenter study were to compare healing of chronic dermal ulcers treated with pulsed electrical stimulation with healing of similar wounds treated with sham electrical stimulation and to evaluate patient tolerance to the therapeutic protocol. Forty-seven patients, aged 29 to 91 years, with 50 stage II, III, and IV ulcers were randomly assigned to either a treatment group (n = 26) or a control (sham treatment) group (n = 24). Treated wounds received 30 minutes of pulsed cathodal electrical stimulation twice daily at a pulse frequency of 128 pulses per second (pps) and a peak amplitude of 29.2 mA if the wound contained necrotic tissue or any drainage that was not serosanguinous. A saline-moistened nontreatment electrode was applied 30.5 cm (12 in) cephalad from the wound. This protocol was continued for 3 days after the wound was debrided or exhibited serosanguinous drainage. Thereafter, the polarity of the treatment electrode on the wound was changed every 3 days until the wound progressed to a stage II classification. The pulse frequency was then reduced to 64 pps, and the treatment electrode polarity was changed daily until the wound was healed. Patients in the control group were treated with the same protocol, except they received sham electrical stimulation. After 4 weeks, wounds in the treatment and control groups were 44% and 67% of their initial size, respectively. The healing rates per week for the treatment and control groups were 14% and 8.25%, respectively. The results of this study indicate that pulsed electrical stimulation has a beneficial effect on healing stage II, III, and IV chronic dermal ulcers.

3. Gentzkow, G. D. (1993). "Electrical stimulation to heal dermal wounds." J Dermatol Surg Oncol 19(8): 753-8.
BACKGROUND. Numerous human and animal efficacy studies have demonstrated that electrical stimulation of the correct charge, density and total energy causes dramatically improved healing of dermal wounds. The investigations of biological actions (in vitro, animal, and human) demonstrate several effects that go a long way to explaining why electrical stimulation works. OBJECTIVE. To discuss recent research and advances in electrical stimulation of wound healing. RESULTS. Based on the latest scientific understanding of the wound healing process, one would expect a beneficial outcome from a therapy what decreases edema, debrides necrotic tissue, attracts neutrophils and macrophages, stimulates receptor sites for growth factors, stimulates growth of fibroblasts and granulation tissue, increases blood flow, stimulates neurite growth, induces epidermal cell migration, prevents post-ischemic oxygen radical-mediated damage, inhibits bacteria, and reduces numbers of mast cells. CONCLUSION. Taken together, the efficacy studies and the mechanism of action studies provide compelling, scientific evidence that electrical stimulation is safe and effective for promoting the healing of dermal wounds.

4. Griffin, J. W., R. E. Tooms, et al. (1991). "Efficacy of high voltage pulsed current for healing of pressure ulcers in patients with spinal cord injury." Phys Ther 71(6): 433-42.
The purpose of this study was to assess the efficacy of high voltage pulsed direct current (HVPC) for healing of pressure ulcers in patients with spinal cord injury. Seventeen patients having pressure ulcers in the pelvic region were randomly assigned to either an HVPC group or a placebo HVPC group. Treatments were given for 1 hour a day for 20 consecutive days. The HVPC protocol consisted of an aluminum-foil electrode placed over the ulcer and set at negative polarity in reference to the dispersive electrode placed on the thigh. Stimulator frequency was set at 100 pps, and an intensity of 200 V was used. Measurements of ulcer surface area were conducted before treatment and after treatment days 5, 10, 15, and 20. To measure ulcer area (in square millimeters), slides taken at each measurement time were projected at actual size, traced, and digitized. Percentage of change compared with pretreatment ulcer size was calculated for each measurement time. Ulcers in the HVPC group demonstrated significantly greater percentage-of-change decreases from their pretreatment size than did ulcers in the placebo group at days 5, 15, and 20. The results suggest that HVPC, in conjunction with good nursing care, can significantly increase the healing rate of pelvic ulcers in patients with spinal cord injury.

5. Kloth, L. C. and J. A. Feedar (1988). "Acceleration of wound healing with high voltage, monophasic, pulsed current [published erratum appears in Phys Ther 1989 Aug;69(8):702]." Phys Ther 68(4): 503-8.
The purpose of this study was to determine whether high voltage electrical stimulation accelerates the rate of healing of dermal ulcers. Sixteen patients with stage IV decubitis ulcers, ranging in age from 20 to 89 years, participated in the study. The patients were assigned randomly to either a Treatment Group (n = 9) or a Control Group (n = 7). Patients in the Treatment Group received daily electrical stimulation from a commercial high voltage generator. Patients in the Control Group had the electrodes applied daily but received no stimulation. The ulcers of patients in the Treatment Group healed at a mean rate of 44.8% a week and healed 100% over a mean period of 7.3 weeks. The ulcers of patients in the Control Group increased in area an average of 11.6% a week and increased 28.9% over a mean period of 7.4 weeks. The results of this study suggest that high voltage stimulation accelerates the healing rate of stage IV decubitis ulcers in human subjects.

6. Mulder, G. D. (1991). "Treatment of open-skin wounds with electric stimulation [see comments]." Arch Phys Med Rehabil 72(6): 375-7.
A randomized double blind multi-center study of electric stimulation compared with sham units enrolled 59 patients (67 wounds) with open wounds of pressure, vascular and surgical etiology at nine sites. The 14-week study consisted of a four-week phase, randomized, parallel-group, double blind, sham stimulation controlled group comparing effectiveness and tolerance of electric and sham stimulation of open wounds. Patients with wounds not completely closed at the end of the four weeks were allowed to cross over to actual treatment. After four weeks of treatment, the electric stimulation group showed a 56% decrease in size with only a 33% decrease in size with sham treatment. Available data suggest that pulsed electric stimulation should be considered by health care practitioners as an adjunct for treating open wounds.

7. Page, C. F. and W. R. Gault (1975). "Managing ischemic skin ulcers." Am Fam Physician 11(2): 108-14.
Etiologic elements in ischemic ulcers include physical factors (pressure, shearing forces, friction and heat), nutrition and infection, as well as circulatory, metabolic and neurologic problems. Prevention is the primary objective of the management program. For patients in nursing homes who have already developed ulcers, low-intensity direct electric current (LIDC) has proved to be a useful adjunct to conventional management. The infection was more rapidly controlled and the wound size more quickly reduced. LIDC is readily accepted by the patient.

8. Stromberg, B. V. (1988). "Effects of electrical currents on wound contraction." Ann Plast Surg 21(2): 121-3.
A prospective randomized evaluation of the potential beneficial effects of electrical currents has been studied in 13 wounds in 7 pigs. The effect of electrical current was assessed by evaluation of wound contraction and residual open wound area. A 35 mA unipolar square wave stimulation for one-half hour stimulation periods twice a day showed consistent results in 13 wounds in 7 pigs. Application of negative currents shows no stimulation of wound contracture. In fact, negative currents seemed to retard wound contracture. After two weeks of treatment, the control wound had decreased to 58% of its original size, whereas wounds treated with negative currents were 93% of their original size. On the other hand, negative currents alternating with positive currents increased the rate of wound contraction for the first two to three weeks of treatment. At two weeks these wounds were 18% of their original size and continued to decrease to 5% by three weeks. Wound contraction may be increased by electrical currents. The concept of alternating negative and positive currents has not been previously described and seems to offer some promise in this early study. Further work is underway to define the exact values required for the maximum effects on wound contraction.

9. Weiss, D. S., R. Kirsner, et al. (1990). "Electrical stimulation and wound healing." Arch Dermatol 126(2): 222-5.
Living tissues possess direct current surface electropotentials that regulate, at least in part, the healing process. Following tissue damage, a current of injury is generated that is thought to trigger biological repair. In addition, exogenous electrical stimuli have been shown to enhance the healing of wounds in both human subjects and animal models. Intractable ulcers have demonstrated accelerated healing and skin wounds have resurfaced faster and with better tensile properties following exposure to electrical currents. This article examines the bioelectric properties of living systems and reviews the existing literature on electrical stimulation and wound healing.