Key Words: Electric stimulation, electrotherapy, wound healing, skin ulcer

ACCELERATED HEALING OF SKIN ULCERS BY ELECTRICAL STIMULATION AND THE INTRACELLULAR PHYSIOLOGICAL MECHANISMS INVOLVED

By

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(Received October 14, 1988; accepted with revisions February 23, 1989)

ABSTRACT:

Evidence is reviewed (8 studies involving 215 clinical patients with ischemic skin ulcers and 7 animal tissue culture studies) that electrical stimulation of fibroblast cells accelerates the intracellular biosynthesis necessary to form new granulation tissue in a healing wound, and that both a direct local tissue effect and a circulatory improvement occur.

A model is presented in which transmembrane currents open voltage controlled calcium channels in fibroblast cells, causing ATP resynthesis, activation of protein kinase mechanisms to synthesize new cellular protein, and the DNA replication necessary for mitotic cell division. Stimulation efficacy appears to be determined by a number of basic electrical parameters, and judicious waveform control is desirable.

INTRODUCTION

There now appears to be considerable evidence that electrical stimulation of ischemic skin ulcers and other wounds results in accelerated healing.

Ischemic skin ulcers are usually characterized either by chronic venous stasis, peripheral arterial insufficiency (as in diabetes), or conditions involving spinal cord damage, lower motor neuron damage, or long term immobilization. If the ulcer results primarily from a circulatory impairment, electrical stimulation applied to the skin surface or electro-acupuncture can result in considerable vasodilation and improvement in circulation, thus enabling the wound to heal.

There is evidence that the fibroblast cells which multiply and migrate to form new granulation tissue in a healing wound are sensitive to ligands such as fibroblast growth factor, platelet-derived growth factor, and fibronectin.48, 52 However, in this paper, evidence from clinical, as well as relevant animal and tissue culture studies, will be reviewed that supports the existence of an additional ligand-independent mechanism by which electrical current flowing through a fibroblast cell can also turn on DNA replication and the synthesis of ATP and protein necessary for the formation of new granulation tissue in the healing wound.

PICTURE OF ULCER 1 - BIEDEBACH

CLINICAL STUDIES WHICH SHOW THE RESULTS OF DIRECTLY APPLIED ELECTROSTIMULATION

Alon (using 80Hz, 200 volt, 5-10 usec. duration pulses, applied through a carbon electrode to saline-soaked sterile gauze over the ulcer for one hour, 3 days per week) reported complete healing after a mean treatment period of 2.6 months in 12 out of 15 diabetic ulcer patients whose ulcers had persisted for an average duration of 8.6 months.

PICTURE OF ULCER 2

Assimacopoulos reported accelerated healing and stronger scar tissue (as judged by light microscopic assessment of histological density and the presence of collagen fibers) in three patients with venous stasis ulcers treated with low intensity current (75 to 100 microamperes applied to the skin adjacent to the ulcer). All ulcers had healed after treatment for 42 days or less.

Wolcott reported that the rate of healing increased from a 5% average rate per week (for 8 untreated controls) to a 13.4% average healing rate per week for 75 ischemic skin ulcers in 67 individuals, using 0.2 to 1.0 milliamperes of current applied to the skin adjacent to the wound for six hours per day.

PICTURE OF ULCER 3

Gault treated (200-800 microamperes of current, 6 hours per day for periods of 8 days to 8 weeks) 76 patients with 106 ischemic skin ulcers which included pressure sores, decubitus ulcers, bed sores, and venous stasis ulcers. They found treated ulcers healed more than twice as fast as untreated control ulcers (in six patients with bilateral symmetrical ulcers that were closely matched in size). One hundred ulcers responded with some degree of success with 48 healing completely and 11 others decreasing in size by 95%.

Thirty patients were paired by Carley, according to age, diagnosis, wound etiology, location and approximate indolent ulcer size. Low intensity current (300 to 600 microamperes, 20 hours/week) therapy was used with experimental subjects, and the results compared with controls receiving conventional treatment consisting of whirlpool therapy and solution-soaked dressings. The ulcers of the experimental treatment group showed a healing rate that was 1.5 to 2.5 times faster (and stronger scar tissue) than untreated controls. A progressively increasing difference was noted between the wounds of both groups ($P<.05$ statistical significance was reached at three weeks and $P<.01$ at five weeks, using Wilcoxon's rank sum test).

PICTURE OF ULCER 4

Barron used a device which applied 600 microamperes (0.5Hz biphasic square pulses having an electronically controlled waveform – the Electro-Acuscope) to chronic decubitus ulcers (which showed little or no improvement for periods as long as one year during prior conventional treatment) in six nursing home patients. Five of the ulcers healed completely after nine treatments or less and the sixth ulcer displayed a 55% decrease in area.

Kloth selected 7 control and 9 treatment decubitus ulcers (stage IV -one month to 2.5 years wound duration) which he stimulated using 105Hz high voltage short duration (50microsec.) pulses. The treatment group healed in an average time of 3.7 weeks, while the lesions in the control group continued to increase in size. It is significant that the reported healing effects of DC stimulation all required 20 or more hours per week of treatment, whereas the pulsed stimulation (Alon: high voltage very short duration; Barron: electronic waveform control- Acuscope, Kloth: high voltage very short duration) studies all reported optimal results with treatment periods of 3 to 4 hours per week.

PICTURE OF ULCER 5

Using low pulse repetition rate electro-acupuncture, or electro-acupuncture combined with transcutaneous electrical stimulation through surface electrodes (approximately 1.5 to 2 biphasic pulses/sec., 200 microsec. Pulse duration, 3to 6.5 volts), Omura treated a diabetic patient with small multiple ulcerations on the leg. He reported an arterial blood pressure increase (measured on the big toe at the sitting position) from 60mmHg to 200mmHg, and complete healing of the ulceration two weeks after one 30 minute treatment. Omura found the greatest circulatory improvement and pain relief with 1-3 pulses per second and voltage which caused maximal muscle contraction without creating pain.

Richter reported complete healing of a venous stasis ulcer in nine weeks of 2.5, 5-hour per week treatments using 80Hz stimulation with impedance monitored waveform control (model: Electro-Acuscope 80C). (Linda Richter, Gardena Memorial Hospital, Calif., unpublished.)

The results of published studies are summarized in Table 1.

TABLE 1

Author	No. of Patients	Type & Number of Ulcers	Type of Treatment	Hrs. of Total Treatment Time/Week	Avg. # Weeks for Healing	Healing Rate per Week
Assima-copoulos	3	6 (venous stasis)	Low intensity D.C. (75-100 microamp)	168	4.4	-
Wolcott	67	8: control 75: treatment (ischemic ulcers)	Low intensity D.C. (approx. 600 microamp)	42	9.6	13.4%/ week healing rate vs. 5%/ wk for controls
Gault	76	6: control 100: treatment (ischemic ulcers)	Low intensity D.C. (200-1000 microamp)	42	4.7	30%/ week healing rate vs. 14.7%/ wk for controls
Carley	30	15: control 15: treatment (indolent ulcers)	Low intensity D.C. (300-700 microamp)	20	5	17.9%/ wk healing rate vs. 9%/ wk for controls
Omura	2	Multiple	Biphasic pulses	0.5	2	-

		small ulcers	1.5-2 pulses/sec 3-6.5 volts, 200 microsec. dur.			
Barron	6	6 decubitus ulcers (treat-ment up to 1 year)	Biphasic pulses 600 microamp at 0.5Hz, electronic waveform control	3	4	-
Alon	15	15 diabetic (persisted for avg. 8.6 months)	High voltage short duration pulses (80Hz)	3	11.3	-
Kloth	15	7:control 9:treatment stage IV decubitus ulcers	High voltage short duration (50 microsec. pulses)	3.7	7.3	44.8%/wk