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## Effect of electrical stimulation waveform on healing of ulcers in human beings with spinal cord injury

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Various electrical stimulation waveforms have been used to enhance wound healing, with little consideration for potential differences in their physiologic effect. The present study evaluated the effect of stimulation waveform and electrode placement on wound healing. Eighty patients with spinal cord injury and one or more pressure ulcers were treated. A total of 185 ulcers received 45 minutes of stimulation daily. Each ulcer was subjected to one of four treatment protocols: asymmetric biphasic waveform, symmetric biphasic waveform, microcurrent stimulation, or a sham control protocol. Electrodes were placed outside the wounds, over intact skin and surrounding the area of the ulcer. Data were categorized by ulcers which healed during the protocol and those which did not. Analysis of the "good response" ulcers ( $n = 104$ ) showed significantly better healing rates for those receiving stimulation with the asymmetric biphasic waveform, compared with the control and microcurrent groups. Mean healing rates from the present study were similar to previously reported measures. The waveforms studied possessed minimal polar capabilities, and the electrodes were placed outside the wound. These data show that electrical stimulation clearly enhanced healing of pressure ulcers in a significant number of individuals with spinal cord injury; the physiologic implications of these findings relative to the mechanism(s) by which electrical stimulation enhances wound healing are discussed. However, extrapolation of these results to patients with other types of wounds must await further study. (WOUND REP REG 1996;4:21-8)

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Electrical stimulation has been used to facilitate wound healing for more than 30 years.<sup>1</sup> Although a number of clinical studies have been published reporting the effects of electrical currents on tissue healing,<sup>1-8</sup> the practice remains restricted to a few centers or as a final therapeutic effort. The low incidence of electrical stimulation as a part of standard healing management programs is largely due to ambiguity associated with the stimulation itself and the

types of patients most successfully managed with this adjunct treatment.

Stimulation programs have ranged from the continuous application of direct currents over a wound for several hours a day<sup>1-5</sup> to the use of one or more short sessions of pulsed stimulation 5 days a week.<sup>6-8</sup> Protocols have included polarity changes<sup>1-7,9</sup> when the probability of polar effects from some forms of stimulation appears to be minimal.<sup>6,7,9</sup> A recent study has reported enhanced healing of decubital ulcers with the use of a waveform with minimal polar capabilities.<sup>10,11</sup> In short, the characteristics of stimulation which most affect the healing process are unknown. Although a variety of clinically based procedures have been developed, they lack either a physiologic rationale or experimental support.

At least two aspects of electrical currents have the potential to influence healing tissue. The first of these is the ability of certain types of electrical currents to attract opposite charged particles, thus possibly en-

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1067-1927/96 \$5.00 + 0 36/1/71095*