Efficacy of High Voltage Pulsed Current for Healing of Pressure Ulcers in Patients with Spinal Cord Injury

Judy W Griffin
Robert E Tooms
Ruth A Mendius
Judy K Clifft
Roger Vander Zwaag
Faten El-Zeky

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 pressure ulcers in patients with spinal cord injury. [Griffin JW, Tooms RE, Mendius RA, et al. Efficacy of high voltage pulsed current for healing of pressure ulcers in patients with spinal cord injury. Phys Ther. 1991;71:433–444.]

Key Words: *Electrotherapy, electrical stimulation; Spinal cord injuries; Ulcers; Wound healing.*

Pressure ulcers are a potentially serious complication in patients with spinal cord injury (SCI). Such ulcers are a main cause of lengthened hospitalization, delay of rehabilitation, and hospital readmission for patients with SCI.[1–3] Although theoretically preventable, pressure ulcers develop in 50% to 60% of patients with complete SCI.[4] Mawson et al[5] reported that 59% of patients admitted to the hospital following SCI developed a pressure sore within 30 days, and Richardson and Mayer[4] recorded a 41% incidence of pressure sores in patients with SCI at the time of admission to a rehabilitation facility.

JW Griffin, MS, PT, is Associate Professor, Department of Rehabilitation Sciences, College of Allied Health Sciences, The Health Sciences Center, The University of Tennessee, Memphis, 822 Beale St, Memphis, TN 38163 (USA). Address all correspondence to Ms Griffin.

RE Tooms, MD, is Professor, Department of Orthopaedic Surgery, The University of Tennessee, Memphis.

RA Mendius, MS, CRRN, is Rehabilitation Coordinator, Baptist Memorial Hospital Regional Rehabilitation Center, 1025 E H Crump Blvd, Memphis, TN 38104.

JK Clifft, MS, PT, is Associate Professor, Department of Rehabilitation Sciences, The University of Tennessee, Memphis.

R Vander Zwaag, PhD, is Associate Director of Health Services Research, Baptist Memorial Hospital, 899 Madison Ave, Memphis, TN 38146.

F El-Zeky, PhD, is Research Associate, Health Services Research, Baptist Memorial Hospital.

This study was approved by the Baptist Memorial Hospital Patient Participation Committee.

This study was funded in part by a grant from the Foundation for Physical Therapy Inc.

This article was submitted May 2, 1990, and was accepted January 28, 1991.

Table 1. *Grades of Pressure Ulcer Severity*[a]

Grade I: An acute inflammatory response involving the epidermis; the epidermis remains intact. Healing may occur in several days.
Grade II: A break in or blistering of the epidermis, surrounded by erythema and induration. Healing may require up to 2 weeks.
Grade III: A shallow, irregular defect extending through the dermis to the subcutaneous fat junction. Healing may require months.
Grade IV: The ulcer extends through the full thickness of the skin into the subcutaneous tissue, fascia, or muscle. Undermining may be present. Healing may require months or surgery.
Grade V: Penetration of the ulcer extensively into the underlying bone, with no anatomic limit. The ulcer has exposed bone, joint, muscle, or fascia at its base. Healing usually requires surgery.

[a]Adapted from the DeLisa Classification System.[7]

Pressure ulcers are notoriously slow-healing in patients with SCI,[6] and medical management is expensive. Nursing costs increase 50% when pressure ulcers develop.[7] The projected cost per year of treatment of early-occurring pressure ulcers in patients with SCI is approximately $66 million.[5] The economic effects of pressure ulcers extend beyond direct wound care, however, because the patient is prevented from pursuing gainful employment or participating fully in rehabilitation activities. Methods to speed healing of pressure ulcers in patients with SCI are thus of interest to the patients and their families, physicians and rehabilitation team members, third-party payers, and society.

A *pressure ulcer* is defined as "an ulceration of skin and/or deeper tissues due to unrelieved pressure, shear force(s), and/or frictional force(s)."[8(p63)] Significant etiologic factors in pressure ulcer occurrence after SCI include paralysis and sensory loss.[2,9] Other factors contributing to pressure ulcer occurrence are soft tissue atrophy, increased age, poor diet, smoking, anemia, vitamin deficiency, hypoproteinemia, and skin maceration attributable to incontinence.[2,9-13] Bacterial contamination, although not a direct cause of pressure ulcers, can cause breakdown and prolonged healing of soft tissue.[8]

Pressure ulcers have been classified into stages, according to severity of tissue damage.[7] Expected healing rate is partially related to severity of tissue damage and varies from weeks to months (Tab. 1). Conservative (non-surgical) management of established pressure sores involves control of the causal factors, such as removal of pressure, avoidance of skin maceration, correction of nutritional deficiencies, removal of necrotic tissue, control of infection, and encouragement of soft tissue repair.[2,3,7,12] A plethora of methods for accelerating granulation and reepithelialization of chronic wounds exist in medical practice. Electrical stimulation is one method advocated for facilitation of soft tissue healing.

Electrical Stimulation in Animal and In Vitro Studies

Many controlled studies of soft tissue healing using animal models have indicated that electrical stimulation applied as either low intensity direct current (LIDC)[14-24] or high voltage pulsed direct current (HVPC)[25-28] is effective. Young[28] reported that application of HVPC following a 12-hour period of tourniquet-induced ischemia prevented the gangrene noted in the legs of control dogs. In animal models, HVPC has been found relatively ineffective in accelerating healing of incisional skin wounds,[25,26] but effective in promoting tendon repair.[27] Brown and colleagues[25,26] noted a tendency for beneficial effects to occur when negative polarity was used the first 4 postoperative days, followed by positive polarity for days 4 to 7 after skin wounding. Owoeye et al[27] reported that using positive polarity for the HVPC wound electrode produced significantly stronger tendon repair than did the use of negative polarity.

In in vitro studies, stimulation of biosynthesis using both LIDC[29,30] and HVPC[31] has been reported. Bactericidal effects of LIDC[32,33] and HVPC[34] have also been noted in in vitro studies. Efficacy of electrical stimulation for cellular biosynthesis and bacterial control may have optimal thresholds for intensity, treatment time duration, frequency, and polarity. Bourguignon and Bourguignon[31] found a maximal effect on DNA and protein synthesis in cultured human fibroblasts using an HVPC intensity of 50 to 75 V, a stimulator frequency of 100 pps, and a negative electrode polarity. Maximal bactericidal effects were found using HVPC with an intensity of 250 V at the cathode for a treatment period of 2 hours.[34] Guffey and Asmussen[33] found that a 30-minute application of HVPC produced no bactericidal effect at any intensity and hypothesized that a treatment time greater than 30 minutes may be required to produce a bactericidal effect in vitro with HVPC.

Results of animal and in vitro studies may not be completely applicable to wound-healing problems encountered in clinical practice. In all of the animal experiments we reviewed, with the exception of that of Young,[28] who induced injury by circulatory constriction, the wound studied was created by sharp surgical incision. Furthermore, all of the animals were healthy, except in the study of Smith et al,[22] who studied healing of skin incisions in mice with induced diabetes. In clinical practice, problems with soft tissue healing frequently occur, not in healthy skin that has been recently surgically incised, but in chronic crater-like skin defects of patients having

Unfortunately, soft tissue healing in humans cannot be studied under the same controlled circumstances as in studies involving animal models.

Electrical Stimulation Efficacy for Healing in Human Subjects

Beneficial effects of healing of chronic ulcers in human subjects have been reported for both LIDC[35–40] and HVPC[41–45] stimulation. Thurman and Christian[44] reported healing of an infected plantar ulcer in a diabetic patient after 4 months of HVPC treatment. In two other clinical reports, HVPC was reported successful for healing plantar ulcers in a diabetic population[42] and for healing chronic pressure ulcers in a geriatric population.[45] Kloth and Feedar,[43] in a controlled, randomized study of chronic grade IV ulcers in patients having no neurological impairment, reported complete healing of all ulcers receiving HVPC, whereas control group ulcers increased in size. Akers and Gabrielson[41] studied the healing rate of ulcers in patients having either SCI or denervation and found patients receiving HVPC had a faster healing rate than patients receiving either whirlpool or whirlpool combined with HVPC.

Treatment protocols for application of electrical stimulation to human wounds have varied widely. In all of the studies cited previously, an electrode was placed directly over the ulcer. Some evidence exists that electrical stimulation using alternate electrode placement sites, such as over the base of a skin flap,[46] on the hand,[47] or epidurally,[48] may stimulate healing response. Studies comparing various electrode sites for efficacy of human skin ulcer healing have not appeared in the literature. Protocols have included initiating HVPC treatment with positive[43] or negative[45] electrode polarity and changing polarity after specified time intervals, as well as maintaining positive polarity until healing occurred.[42] Treatment duration for HVPC stimulation was reported as 20 minutes a day,[44] twice a day.[45] Intensity and frequency settings reported for HVPC stimulation have been between 100 to 175 V and 50 to 105 pps, respectively, with no muscle contraction produced.[42,43,45] No studies have yet been conducted, to our knowledge, that identify maximally effective HVPC intensity, frequency, polarity, and treatment time characteristics for healing chronic ulcers of specific etiologies in human subjects.

Electrical stimulation does appear to have a potentially beneficial effect on healing of chronic ulcers in humans, based on the literature reviewed. The majority of publications on the subject, however, are in the form of clinical reports, with few controlled, randomized studies containing a statistical analysis of the results. The ulcers included in each report have been of mixed etiologies and varied locations, and in none of these studies was the study sample exclusively representative of patients with SCI. Some anecdotal evidence indicates patients with SCI or sensory loss respond less well to LIDC than do patients without such neurological impairment.[39,40] Akers and Gabrielson,[41] however, reported that the patients receiving HVPC, who demonstrated the highest healing rate, had either SCI or partial denervation. Considering the reported efficacy of electrical stimulation in accelerating healing of chronic ulcers and the significant medical costs of treatment of pressure ulcers, further controlled, clinical study of the efficacy of HVPC in healing pressure ulcers in patients with SCI seemed warranted.

The objective of this study was to assess the efficacy of HVPC for healing of pressure ulcers in patients with SCI. The null hypothesis was that the average percentage of decrease from pretreatment ulcer size in the HVPC group would be equal to that in the placebo group after 5, 10, 15, and 20 days of treatment. The alternative hypothesis was that the HVPC group would demonstrate a greater percentage of decrease from pretreatment ulcer size than the placebo group.

Subjects

The study sample consisted of inpatients from the Spinal Cord Injury Service at Baptist Memorial Hospital Regional Rehabilitation Center (Memphis, Tenn). Patients were invited to participate in the study at the time of their admission to the unit if they met the following criteria: The patient had to be male, have a diagnosis of complete or incomplete SCI, and have a pelvic pressure ulcer (over either the sacral/coccygeal or gluteal/ischial regions) classified between grades II and IV (DeLisa Classification System, Tab. 1). Only male patients were included in this study, because hospital records indicated that predominately male patients were admitted to this service. We anticipated a small sample size and wanted to control for as many variables as possible. Patients were excluded if they had severe cardiac disease, cardiac arrhythmia, or uncontrolled autonomic dysreflexia or if they used a pacemaker. Participants (patient or legal guardian) signed an informed consent form after a complete explanation of the purpose and procedures of the study. There was no charge to patients for participation in the study, and no remuneration was given. A total of 20 patients met the inclusion criteria and were selected to participate in the study.

Procedure

On entry to the study, patients were stratified into groups according to ulcer classification (grade II, III, or IV) and smoking status (smoker or nonsmoker), because these two factors are known to affect the rate of expected healing.[7,10] If a patient had multiple pelvic ulcers, the largest ulcer in terms of wound surface area (WSA) was selected for study. Patients were then randomly assigned to either an HVPC group or a placebo HVPC group.

Patients received the respective treatment for 1 hour a day, for 20 consecutive days. We set the treatment time at 1 hour a day, so that treatment

could be reasonably fit into the patients' busy rehabilitation schedule. We set the study end point at 20 days because we wanted to compare the effect on healing time for the two groups after a specific time interval and because we estimated the minimal stay for patients would be 20 days. All treatments were administered by one of three persons—two physical therapists (JWG and JKC) and a nursing coordinator (RAM). The nursing staff and patients were kept blinded as to patient treatment group assignment. We used this modified double-blind design as a control for the known placebo effect on healing of pressure ulcers.[49] Patients were dropped from the study if they developed medical complications requiring transfer from the rehabilitation center to the hospital or if surgical closure of the ulcer was performed. Measurements of WSA were conducted before the first treatment and after the 5th, 10th, 15th, and 20th treatment days.

Treatment Protocols

Electrical stimulation was applied using an Intelect 500 HVPC stimulator.* The stimulator produces a twin-peaked pulse, with approximately 75-μs spacing between pulses, and has an adjustable output of 0 to 500 V and an adjustable frequency of 1 to 120 pps. The ulcer was covered with gauze soaked with sterile 0.9% saline; deep ulcers were packed with saline-soaked gauze. A piece of heavy-duty aluminum foil, cut slightly larger than the ulcer perimeter, was attached with an alligator clip to the negative lead of the HVPC unit. The foil electrode was placed over the ulcer on top of the saline-soaked gauze, as described by Unger.[45] The saline-soaked gauze was then covered with a piece of plastic wrap to retard drying, followed by a dry gauze pad, which was taped to the skin. A sandbag was used, if needed, to hold the wound electrode in place. The dispersive electrode (20×25 cm) was strapped over the patient's medial thigh, with a wet cloth placed between the electrode and the patient's skin. The stimulator frequency was set at 100 pps, with a continuous mode. The intensity was slowly increased to 200 V. The ammeter on the HVPC unit was checked to ensure current was flowing, and contact between the patient's skin and the electrodes was adjusted, if necessary, to obtain maximum current flow for the 200-V intensity used. This intensity of stimulation applied did not evoke obvious muscle contractions in any patient, and no patient complained of any discomfort during treatment. The patient remained in the same position for the 60-minute treatment.

The placebo treatment procedure was the same as that described for the HVPC treatments. The electrode lead, however, was taped outside of the alligator-clip receptacle so that no current flowed, although the HVPC unit appeared to be working, because the light, voltmeter, and timer were functioning. Similar taping was used around the junction of the alligator clips for both HVPC and placebo group patients.

The rationale for our electrical stimulation protocol was as follows. We set the ulcer electrode at negative polarity in reference to the dispersive electrode, partially because other investigators[36,37,45] recommended initiating treatment with negative polarity, particularly when infection is suspected.[36,37,45] We anticipated that the pretreatment wound-culture study would indicate some bacterial presence in most cases.[50] Although observations regarding polarity effects in LIDC stimulation may not apply to HVPC stimulation,[33] our impression from the reviewed literature was that negative polarity was more often effective than positive polarity. Although some investigators[40,43,45] recommended changing polarity after 3 to 7 days or when healing plateaus, the rationale for this change was not clear to us, nor was an operational definition of "healing plateau" clear. We therefore maintained the wound electrode at negative polarity for the entire 20 days of study, to investigate the effect on healing when polarity of the wound electrode remains negative for a specific time period. Some evidence exists that patients with denervation may require a higher intensity of stimulation than other patients for maximal healing responses,[36,41] so we sought to produce a total current of approximately 500 μA, based on the reports of Cheng et al[30] and Carley and Wainapel.[36] To achieve this output on the high voltage stimulator used in this study, a pulse rate of 100 pps at 200 V is required.[51] We placed the dispersive electrode over the medial thigh, primarily because of convenience. Many of the patients had corsets or braces on the torso, so placing the dispersive (anode) electrode proximal to the wound electrode, as recommended by Kloth and Feedar,[43] was not always feasible. We therefore selected a dispersive electrode site that would be identical for all patients.

All patients received equivalent nursing care. Cleansing of ulcers was performed twice a day by the nursing staff using Cara-Klenz,† followed by an application of Carrington gel† and a dry dressing. Wounds were mechanically debrided, as necessary; enzymatic debridement was not used. All ulcers were cultured before treatment began. All possible efforts were made to keep pressure off the ulcer. A routine 2-hour turning schedule was followed when patients were in bed. Patients with sacral/coccygeal ulcers were not allowed to lie supine. Patients with gluteal/ischial ulcers were not allowed to sit until their ulcers were well-healed, with the exception of patient 7, who was allowed to sit an average of 9 hours a day during the study period. The type of bed mattress and wheelchair cushion was not changed for any patient during the course of the 20-day study.

Nutritional status of the patients was evaluated by a nutritionist and a physician upon admission to the unit. Nutritional status and dietary intake

*Chattanooga Corp, PO Box 4287, Chattanooga, TN 37405.

†Carrington Laboratories Inc, Dallas, TX 75356-9500.

The regular diet planned for all patients was sufficient to meet caloric, protein, and vitamin requirements. Patients found to have anemia or hypoproteinemia were given a diet or a dietary supplement appropriate to correct the condition.

Measurement Procedures

Measurements of WSA were conducted before the first treatment and after every fifth treatment for 20 days. At each measurement session, three 35-mm color slides were taken at a distance of 27.9 to 30.5 cm (11–12 in), with a metric ruler taped next to the ulcer. The camera used was an Olympus OM-2s[‡] with a 50-mm 3.5 macro lens.

To obtain measurements of WSA, each slide was projected onto paper and the focus adjusted so that the metric ruler measurements on the slide corresponded with a superimposed ruler identical to the one in the slide. The ulcer perimeter was carefully traced and then transferred to a tablet digitizer with a stylus pen[§]; the area (in square millimeters) was calculated by the Generic CADD 3.0 software program[‖] interfaced with an IBM-PC/XT.[#] The WSA values for the three slides from each measurement session were averaged, giving for each patient one average WSA measurement for days 0, 5, 10, 15, and 20. The same person (JWG) conducted all WSA measurements.

This method of WSA measurement, using digitizer analysis of slides, has been described previously.[41,42] To verify the reliability of measurements obtained with this method, we performed a test-retest study of six pressure ulcers before the study began. Three slides were taken of each ulcer, and the procedure was repeated after scribed earlier. An analysis of test-retest measurements was conducted using an intraclass correlation coefficient (ICC[3,1]),[52] with an obtained value of .99. To further verify consistency of the procedure of tracing slides and digitizing, midway through the study, the analysis of 11 patients' slides was repeated on a subsequent day. Comparing measurements between the two days, an ICC(3,1) value of .99 was obtained. We therefore considered the WSA measurements in this study to be reliable.

At each measurement session, a tracing of ulcer perimeter onto a clear transparency was made using a permanent felt-tip pen. The tracings were used for immediate feedback to patients concerning ulcer size. The feedback was conducted in a standardized way to avoid bias.

Results of laboratory blood studies, wound cultures, and other patient information were obtained from the patients' medical records. Wound culture results were classified as either "positive" or "negative." Anemia was defined as having a hematocrit of less than 36%, and hypoproteinemia was defined as having a serum albumin concentration of less than 3.0 g/dl.

Data Reduction and Analysis

For the day-5, -10, -15, and -20 measurements on each patient, absolute change (in square millimeters) from pretreatment ulcer size was calculated. Because pretreatment WSA differed among patients, measurements at days 5, 10, 15, and 20 were calculated as the percentage of change from the pretreatment (baseline) WSA.

The Mann-Whitney *U* Test for two independent samples was used to compare the percentage of change groups at days 5, 10, 15, and 20 (one-sided test). We used a nonparametric test to avoid assuming sizes of ulcers are normally distributed or have equal variances at all times and for both treatments. We performed separate tests for each day rather than a repeated-measures analysis of variance (ANOVA), because each measure was dependent on previous measures. For example, if an ulcer had healed by day 15, the outcome for day 20 was also known. This specific relationship among the repeated measures is not considered in the usual model for a repeated-measures ANOVA and would violate the assumption of independence among observations.

Our reasons for using a one-sided test were as follows. Our objective a priori was to learn whether ulcer healing rate was accelerated by adding HVPC to good nursing care. Appropriate care would be expected to decrease the size of pressure ulcers. Our null hypothesis was that the average decrease in ulcer size in the group given HVPC would be equal to the average decrease in ulcer size in the placebo group. The appropriate alternative hypothesis was that the average decrease in ulcer size would be greater with HVPC than without HVPC. The question of whether HVPC might actually have the opposite effect (ie, slower healing) was not considered because (1) past studies have provided evidence that one might expect faster healing, (2) there is no evidence from past studies that would suggest electrical stimulation delays or slows healing, and (3) that alternative was inconsistent with our research objective and was of no interest to us in this study. Prior to the study, sample size calculations indicated a sample size of 10 in each group was sufficient for 80% power to detect a difference of 20% improvement between groups using a one-sided test, given a standard deviation of 15%.

To assess the significance of differences between groups in continuous variables, the Mann-Whitney *U* Test was used. To assess the significance of differences between groups in charac-

---

‡ Olympus Optical Co, Tokyo, Japan.

§ Hitachi Seiko Ltd, Tokyo 101, Japan.

‖ Generic Software Inc, Redmond, WA 98052.

International Business Machines Corp, Old Orchard Rd, Armonk, NY 10504.

Table 2. *Characteristics of Patients in High Voltage Pulsed Direct Current (HVPC) and Placebo Groups*

Characteristic	Group					
	HVPC (n=8)			Placebo (n=9)		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Age (y)[a]	32.5	17	54	26.0	10	74
Weight (lb)[a,b]	151.5	108	218	191.0	63	218
Duration of SCI[c] (wk)[d]	156.0	4	1,820	4.0	3	35
Ulcer duration (wk)[a]	4.5	2	116	3.0	1	30
Ulcer size-day 0 (mm^2)[a]	234.1	126	1,027	271.8	41	4,067
	n			n		
SCI level[e] (cervical/ thoracolumbar)	4 /4			4 /5		
SCI status[e] (complete/ incomplete)	8 /0			6 /3		
Ulcer location[e] (gluteal-ischial/ sacral-coccygeal)	5 /3			1 /8		
Ulcer grade[e] (II/III/IV)	2/5/1			2/6/1		
Tobacco use[e] (yes/no)	0 /8			1 /8		
Anemia[c] (yes/no)	3 /5			6 /3		
Hypoproteinemia[e] (yes/no)	0 /8			3 /6		
Wound culture growth[e] (yes/no)	5 /3			8 /1		

[a] Mann-Whitney *U* Test result was not significant ($P>.05$).

[b] 1 lb=0.4536 kg.

[c] SCI=spinal cord injury.

[d] Mann-Whitney *U* Test result was significant ($P<.05$).

[e] Fisher's Exact Test result was not significant ($P>.05$).

teristics having a nominal scale, the Fisher's Exact Test was used. A significance level of .05 was used for all statistical tests.

Results

Seventeen of the 20 patients completed the study. Three patients were transferred to the acute care hospital (2 patients developed medical complications, and 1 patient required surgical repair of his ulcer) and thus were eliminated from the study. No significant differences in characteristics between the HVPC and placebo groups existed, except that the HVPC group demonstrated a significantly longer duration of SCI than did the placebo group (Tab. 2).

Percentage-of-change decreases in WSA exhibited by the HVPC group were significantly greater than in the placebo group at day 5 ($P=.03$), day 15 ($P=.05$), and day 20 ($P=.05$). Differences at day 10 did not reach significance ($P=.14$). The null hypothesis was thus rejected for the day-5, -15, and -20 measurements but accepted for the day-10 measurements.

The healing rates of individual patients over the 20 days of treatment, expressed as percentages of change from pretreatment (day 0) WSA, are presented in the Figure. Grade II ulcers in both groups healed completely. All grade III ulcers in the HVPC group showed consistent patterns of decreased WSA over the treatment period; two grade III ulcers in the placebo group demonstrated periods of increased WSA, whereas the other three grade III ulcers in that group demonstrated consistent decreases WSA. The grade IV ulcer receiving HVPC showed a 67% decrease in WSA by the 20th day of treatment. The grade IV ulcer receiving placebo treatment showed little change over the treatment period, with only a 15% decrease from its original size at the 20th day. The median percentage of change from the initial WSA and the minimum and maximum amounts of change in each group at each measurement interval are presented in Table 3. At the end of the 20 days of study, the worst response in the HVPC group was a 52% decrease; the worst

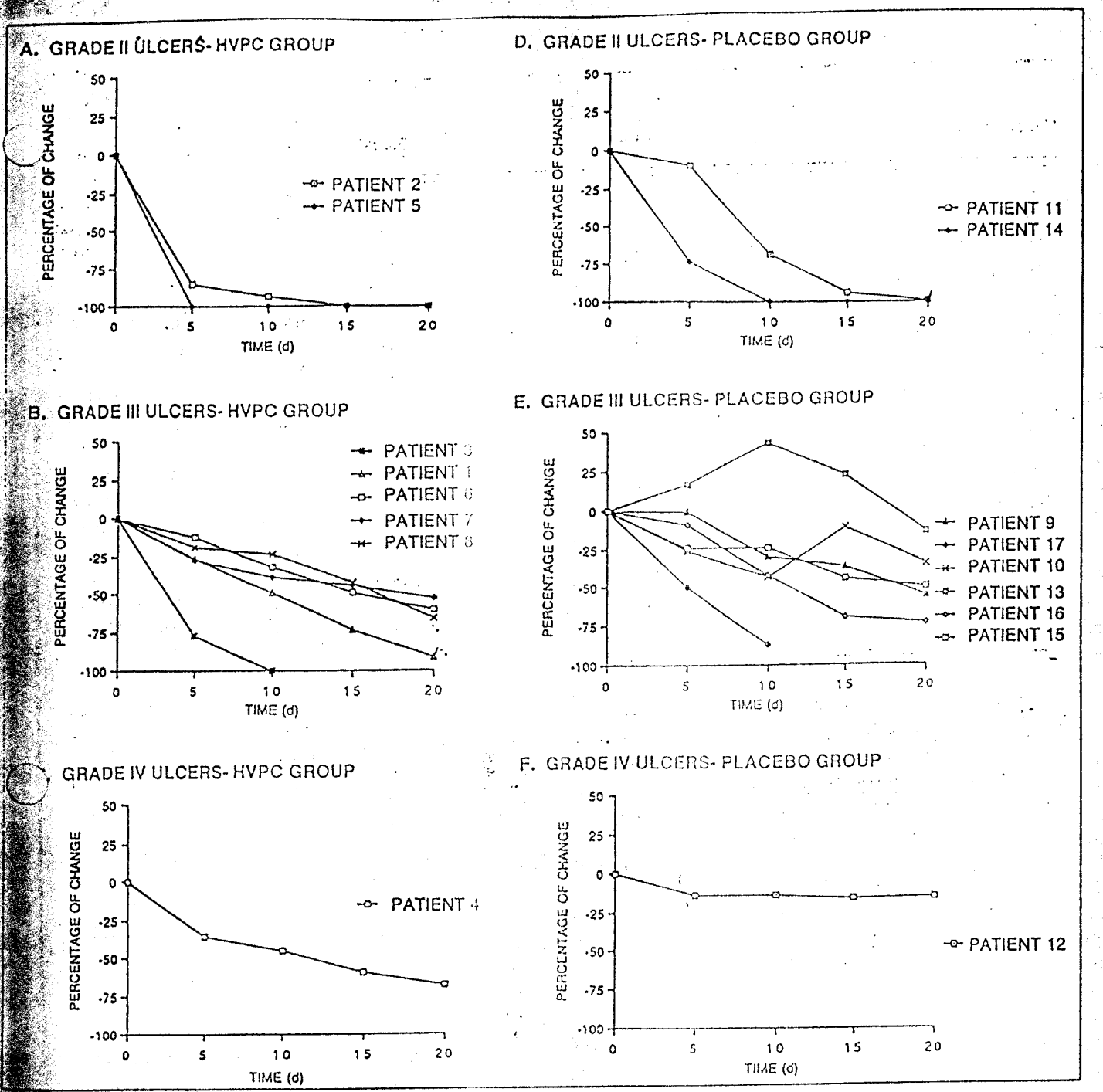

Figure 1. *Percentage of change in ulcer size from pretreatment (day 0) wound surface area at days 5, 10, 15, and 20 for grade II, III, and IV ulcers in high voltage pulsed direct current (HVPC) (A–C) and placebo (D–F) groups.*

response in the placebo group was a 1.9% decrease from pretreatment WSA.

Discussion

In this study, we investigated the efficacy of a specific protocol of HVPC for healing of pelvic pressure ulcers in patients with SCI. Our results indicate that the mean percentage of decrease in WSA in the HVPC group was significantly greater than that of the placebo group at the 5th, 15th, and 20th days of treatment.

Results of this study concerning the efficacy of HVPC for promoting healing of chronic ulcers in humans confirm the observations of other researchers.[4–6,8] Our findings are somewhat difficult to compare with the findings of the two other controlled clinical trials of HVPC efficacy for chronic ulcers. Akers and Gabrielson[11] did not indicate the location of pressure sores studied or the diagnoses of patients studied, although they did indicate that patients in the HVPC group had sensory loss. Kloth and Feedar[13] studied dermal ulcers