Influence of High Voltage Pulsed Galvanic Stimulation on Wound Healing in Children with Burn

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ABSTRACT

Electrical stimulation has long been recommended as adjunct treatment of wound healing. Fourteen children suffering from burn in upper and lower extremities of second-degree type, their ages ranged from 6 to 12 years, were involved in the study. They were divided into two equal groups; treatment group and control group. Treatment group was subjected to high voltage pulsed galvanic stimulation (HVPGS) plus ordinary nursing care. The stimulation frequency was set at 100 pps. and an intensity of 150V. Stimulation was applied under disinfecting procedure for one hour, five days/ week. While the control group was subjected to placebo high voltage pulsed galvanic stimulation plus the ordinary nursing care. Measurements of the wound area were conducted before and after treatment using tracing method. The post treatment results showed that wounds in the treatment group demonstrated significant decrease compared to their pretreatment size than did wounds in the control group. The results suggested that HVPGS in conjunction with good nursing care could significantly increase the healing rate of burn wounds in children.

INTRODUCTION

The skin is the largest organ of the body, ranging from 0.025 square meter (m^2) in the newborn to 1.0 (m^2) in the adult. The survival of the patient with burnt skin depends on careful management of the burn wound[25].

Healing of the skin is a complex biological process that repairs the continuity of the skin[14,30]. The appearance of scar tissue may sometimes be very similar to that of the original skin, but apparently never as smooth, strong, elastic and organized as unwounded skin[7,11]. To stimulate skin healing a variety of drugs and methods has been used. Some improvement on wound healing has been achieved by preventing infections using antibiotics and antiseptics[11,16].

Electrical stimulation has long been recommended, as an adjunct treatment for wound healing. Some investigators[3,36] described the use of low intensity direct current for wound healing by stimulating growth of granulation tissue and by producing bactericidal effect[34].

High voltage galvanic stimulation (HVPGS) has been used to accelerate wound healing in pressure ulcers[17,21] and diabetic ulcers. Kloth and Feedar reported 100% healing of wounds over a mean period of 8 weeks in patients who received HVPGS, compared with a 29% decrease in wound size during a similar time period for a control group of patients. Griffin et al reported a significant reduction in the size of pressure ulcers at 5, 15 and 20 days[17] after initiation of treatment in patient with spinal cord injury who received HVPGC compared with patient who received a placebo.

In an attempt to promote wound healing of an infected diabetic ulcer, HVPGS was used[35] combined with induction of muscle contraction to improve circulation in the area of the wound. In a pilot study[2], a protocol with HVPGS intensity below that at which muscle contraction is induced for healing diabetic ulcer. A total of 12 out of 15 subject s wound were completely healed after $2^1/_2$ months of treatment.

HVPGS[9,10] promotes tendon repair when negative polarity was used at the first 4 postoperative days, followed by positive polarity for 4 to 7 days but ineffective in accelerating healing of incisional wound.

Using positive polarity for the HVPGS, wound electrode produced significantly stronger tendon repair than did the use of negative polarity[29]. In vitro studies stimulation of biosynthesis using both low intensity direct current (LIDC)[26,13] and HVPGS has been reported, bactericidal effects of LIDC, and HVPGS has also been noted in vitro studies[18].

It is found that a maximal effect on DNA and protein synthesis in altered human fibroblasts using HVPGS, intensity of 50-75 V, a stimulator frequency of 100 pps. and a negative electrode polarity[8].

Application of HVPGS[18], for 30 minutes 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 HVPGS. The recent researches and advances in electrical stimulation of wound healing[15] refers a scientific evidence that electrical stimulation is safe and effective for enhancing the healing of dermal wounds.

Why HVPGS was choice

When current passes through circuit containing resistors, voltage drops occur, thereby losing energy. Skin offers impedance (a form of resistance) to the flow of electrical current. This phenomenon occurs in some treatment applications with traditional low voltage unit. A high voltage device produces a spontaneous breakdown in skin impedance. Little voltage drops as current flows through the skin[27].

Procacci and colleagues developed an electrical circuit composed of resistors and capacitors
electrical circuit[31]. When a high voltage stimulus (100 V) passes through a circuit, current flows toward the path of the capacitor. Since crossing a capacitor wastes little energy compared to crossing a resistor, the benefits are two fold: (1) more current density beneath the skin to reach the target tissue, and (2) negligible cutaneous vasodilitation lost energy due to tissue impedance, is converted to heat. This in turn produces direct vasodilitation of cutaneous blood vessels. Since a minimal amount of the high voltage current passes across the resistor side of the circuit, energy loss is minimal. This lessens the occurrence of vasodilitation.

A second important factor to consider for neuromuscular electrical stimulation treatment is that HVPGC produced negligible chemical buildup under the electrode pads. Skin pH was measured[28] for 3 consecutive days before stimulation of 40 subjects. On the treatment day, the active electrode placed on the ventral forearm delivered a 100 V, 80 pps. cathodal stimulation for 30 minute, skin pH measurement followed the treatment, no significant acid or base buildup under the pads occurred.

As a conclusion, HVPGC passes through the skin with negligible thermal and electrochemical effects. Increased current density is available to target tissues, because of the rout undertaken by the current through the skin.

The advantage of the ultrashort pulse duration relates to stimulation of sensory nerve fibers. Li and Bak[23] noted that chronaxia value for A-beta (touch), A-delta (Pain and temperature), and C (pain) sensory axons were 0.20, 0.45, and 1.50 msec, respectively. Since the pulse durations of HVPGC units range up to 200 sec, the chance for stimulating A-delta and C sensory axons decreases, thus increasing patient comfort.

METHODS

Subjects: 14 children of age ranging from 6-12 years old, suffering from burns of the 2nd degree were involved in the study.
They were subdivided randomly into two groups of equal numbers; treatment and control group. The Treatment group received high voltage galvanic stimulation in addition to ordinary nursing care [hydrogel dressing]. While the control group was subjected to treatment by placebo HVGS with ordinary nursing care [hydrogel dressing].

Material: Dynamax II high voltage pulsed galvanic stimulation, Clifton, N.J 07012 was used. Stimulation parameters were set at 100 pps. with intensity of 150 V. (Just below the intensity capable to produce visible muscle contraction).

Procedure: Patient in experimental study group received one hour of HVPGS, applied to burn wound, for 3 weeks (5 days in a week). Patients in control group received a placebo HVPGS, the voltage was maintained at zero. Prior to the use of electrical stimulation on any subject, the electrodes and electrode sponges were disinfected for 20 minutes by immersion in a plastic tube containing betadine solution[19].

After disinfecting the spowere secured to the electrodes using sterile gauzesoaked in 0.9% sterile saline. This served as a sterile barrier between the wound and the sponge surface on the electrode. Electrodes were temporarily placed in a sterile package until application (usually with 2-3 minutes) during this time, any dressings on the wound were removed and the wound was lightly flushed with 0.9% sterile saline on sterile gauze to remove exudate and debris. Disposable face masks and sterile gloves were worn during electrical stimulation to minimize possible contamination from the clinician or experimenters.

Following wound preparation, the treatment electrode was applied directly over the wound. The second electrode was placed on the immediate, opposite surface of the extremity, the electrodes were secured to the extremity via sterile dressing tape. After one hour of stimulation, the electrical stimulator was turned off, the electrodes and gauze were removed under a septic condition.

Primarily treatment was started with wound electrode at negative polarity in reference to the dispersive electrode, particularly when infection is suspected. After one week, polarity was changed at treatment electrode to be a positive polarity as recommended by other studies[9,10].

Measurements: Measurements of a wound area in both groups were conducted before treatment by the method of tracing. Tracing was done by two clinician by placing sterilized transparency film over the wound and tracing the wound s perimeter on the film with a fine tipped transparency marker, placing the tracing over metric graph paper and counting the number of square centimeters and taking the mean of the two measures. Measurement was performed weekly for 3 weeks.

Statistical Analysis: Data will be collected and statistically analyzed using two-way analysis of variance with repeated measurements.

RESULTS

Table 1 shows a general description of the study sample for both groups, treatment and control groups.

Table 2 provides the overall healing for both groups. The children in HVPGS showed a 3.7 times faster healing rate when compared with the control group. No statistical difference between the size of burn wound area in HVPGS and control groups at the start of the study was noticed.

Table (1): (General description of HVPGS and control groups).

Group	Sex M/F	Age (years)	Duration of wound
HVPGS	4/3	1.96±8.60	3 Weeks
Control	4/3	8.80±1.93	2.5 Weeks

Table (2): (Comparison between mean values of wound size in both groups along treatment weeks).

Group	Initial size	1st week	2nd week	3rd week
HVPGS	4.31±1.76	3.53±1.46	2.30±0.65	0.79±0.54
Control	4.50±1.54	4.16±1.38	3.64±1.24	2.95±1.12

In the treatment group (HVPGS) the mean value of burn wound size at the start of the study was 4.31+1.76 cm while it was 0.79±0.54 cm at the end of the third week. Statistically there was significant difference ($P < 0.001$) (Fig. 1).

In control group the mean value of the initial size of the burn wound was 4.5±1.54cm, while it was 2.95+1.12 cm by the end of the third week. There was statistical difference ($P < 0.001$), (Fig. 1 & 2).

On comparison between both groups after treatment protocol along three weeks, There was a significant difference where the mean value of wound area in HVPGS was 0.79 + 0.54 cm, while it was 0.2.95 + 1.12 cm in the control group. ($P < 0.01$), (Fig. 1 & 2).

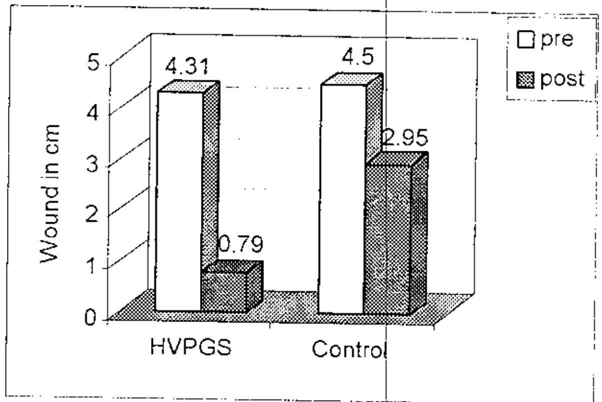

Fig. (1): Comparison between mean values of treatment and control groups pre and post treatment.

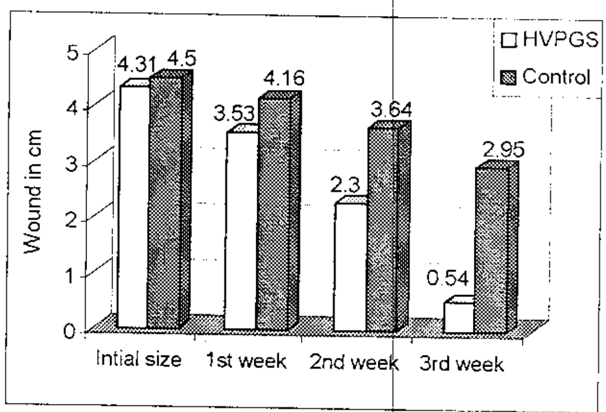

Fig. (2): Comparison between mean values of both groups along treatment weeks.

Comparing the healing rates in both groups along the treatment weeks, it has been found that an increased progressive difference in HVPGS group was, 18.9 %, 46.66 %, and 81.67 % along the first, second and third weeks respectively compared with 7.56 %, 19.0 %, and 34.3 % for control group. The average of healing rate/week were 48.3 % in HVPGS group and 20.32 % in control group (Table 3), (Fig. 3).

Table (3): (comparison between healing rate in both groups along treatment weeks).

Groups	1st week	2nd week	3rd week	Average healing/ week
HVPGS	18.9%	46.66%	81.67%	48.3%
Control	7.56%	19.0%	34.3%	20.32%

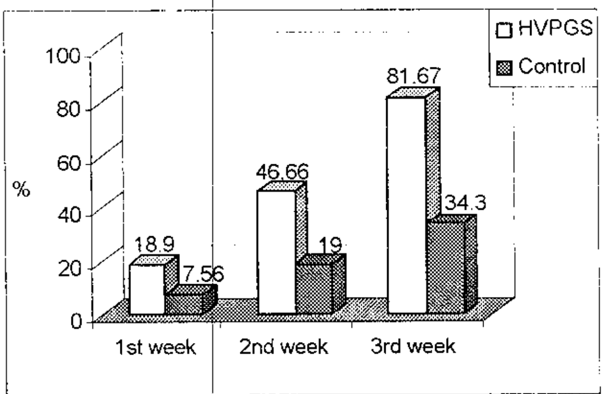

Fig. (3): Comparison between healing rates in both groups along treatment weeks.

DISCUSSION

The results of this study supported our hypothesis and the results of other studies showing that electricity enhances the rate and extent of wound healing[1,4,36].

Comparing findings of this study with other clinical reports that used low intensity direct current (LIDC) and HVPGS for wound healing showed that the HVPG stimulation required to satisfactorily augment tissue healing does not need to exceed 60 minutes, five times per week. The average rate for wound healing was 48.3% per week in this study, compared with 44.8% a week reported by Kloth and Feedar 1988[21], and with 13.4% per week reported by Walcott et al.,[36] This comparison suggested that the protocol of this study is more effective in acceleration of wound healing specially in child burn. Becker[4] suggested that the apparent ability of a nodal direct current to augment healing of dermal ulcers results from the ability of the stimulus to amplify the local positive injury content. By boosting the magnitude of the wound injury potential with the a node, Becker hypothesized that the input signal to the central nervous system may provide a return neuronal signal that activates mechanism for tissue growth and repair.

In this study the polarity of the treatment electrode changed during the course of treatment coming in agreement with other studies because studies have shown that electrode polarity may need to be alternated during treatment to achieve an optimal rate of healing[12,38].

The use of small electrical fields for enhancing wound healing was first reported in connection with the application of gold plates to the injured sites. As early as 1668, the application of gold leaf to smallpox lesions for preventing subsequent scaring was described[33].

Unger[32] reported success in the use of gold foil in healing eardrum perforation. Knof[20] and Wolf and associates[37] separately reported the beneficial effects of gold leaf for healing pressure sores as well as diabetic and ischaemic skin ulcers.

Although the precise mechanism of action was unclear, there was evidence suggesting that an electrostatic and/or electrochemical influence of the gold may have been responsible for enhancement of the tissue healing.

Kloth and McCulloch[22] suggested that the use of electrical stimulation serve to mimic the natural bioelectric currents so that wound healing can proceed through attracting cells carrying either positive or negative charge into wound environment. The charged cells as neutrophils, macrophages, fibroblasts and epidermal are involved in the wound repair.

Becker[5,6] conceptualized the existence of a direct current electrical system controlling tissue healing when the electrical balance of the body is disturbed in an injury, the resulting shift in current flow (referred to as the current of injury) triggers a biological repair system. As healing continues, the direct current potential difference approaches the normal electrical balance relative to the surrounding tissues. These electrical phenomena has been measured by Lund[24] in plants, and by Becker[5] and by Walcott and associates[15] in soft tissue. Based on these concepts, externally applied HVPGS could stimulate biologic homeostasis feedback mechanisms and hence the events which result in tissue repair and replacement.

CONCLUSION

The results of this study indicate that the use of HVPGS is safe, enhance and shorten the length of the treatment and reduce patient suffering. HVPGS decreases edema, debrides necrotic tissue, attracts neutrophils and macrophages, stimulates receptor sites for growth factor, stimulates growth of fibroblasts and granulation tissue, increases blood supply, induces epidermal cell migration and inhibits bacteria. The HVPGS is effective for promoting the healing of burn wound compared with the usual nurse care (Hydrogel dressing).

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الملخص العربي

تأثير الحث الكهربي باستخدام التيار الجلفاني عالي الفولت على التئام الحروق لدى الأطفال

تهدف هذه الدراسة إلى بيان أثر الحث الكهربي باستخدام التيار الجلفاني عالي الفولت على التئام جروح الحروق لدى الأطفـــال . وقد شملت الدراسة أربعة عشر طفلا تتراوح أعمارهم بين ستة وأثنتا عشرة سنة يعانون حروقا من الدرجة الثانية فـــي أطرافـــهم ســـواء الأطراف العليا أو السفلى ، تم تقسيمهم إلى مجموعتين إحداهما تجريبية والأخرى ضابطة .
خضعت المجموعة التجريبية للعلاج باستخدام التيار الجلفاني ذي الفولت العالي بواقع ساعة يوميا لمدة ثلاثة أسابيع إضافة إلـــى العـــلاج التقليدي باستخدام الضمادات المعقمة ، بينما اقتصر العلاج في المجموعة الضابطة على الضمادات المعقمة مع الإيحاء بالحث الكهربي .
وبمقارنة النتائج بعد ثلاثة أسابيع من العلاج لكلا المجموعتين تبين أن هناك فروقا ذات دلالة إحصائية لصالح المجموعة التجريبية حيـــث بلغت نسبة التئام الحروق في المجموعة التجريبية ٨١ % بعد ثلاثة أسابيع من العلاج ، بينما كانت ٣٤ % في المجموعة الضابطة . الأمر الذي يشير إلى فعالية التيار الجلفاني ذي الفولت العالي في التعجيل بالتئام جروح الحروق لدى الأطفال .