CASE STUDY

High voltage pulsed stimulation increases cicatrization of chronic cutaneous ulcers: analysis of six cases

Estimulação elétrica de alta voltagem incrementa a cicatrização de lesões cutâneas crônicas: análise de seis casos

Estimulación eléctrica de alto voltaje incrementa la cicatrización de úlceras cutáneas crónicas: análisis de seis casos

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ABSTRACT | The treatment of cutaneous ulcers by electrical stimulation in clinical practice has grown, however there are few studies investigating the effectiveness of these individual resources in monitoring and complete healing of the lesions. Thus, High Voltage Pulsed Stimulation (HVPS) was used in chronic skin ulcers with the aim of reduce the area of the lesion. Four male subjects with chronic cutaneous ulcers participated in the study. The treatment of the injury consisted on HVPS application (15 microseconds, 100/150 V, 100 Hz) for 30 minutes, 2 times weekly. The electrode with negative polarity was placed on the lesion and positive on vascular path. The ulcers were assessed pre and post-intervention by photogrammetry, and it was calculated the area of the lesion. As a result, we observed the complete healing in the subjects I and II (respectively, area of 4.66 cm^2 to 0 after 21 sessions and 1.74 cm^2 to 0 after 16 sessions). The area of subject III right ulcer obtained reduction of 93% after 100° session (2.02 to 0.14 cm^2) and left ulcer obtained reduction of 80.40% (2.50 to 0.49 cm^2). In subject IV there was a complete healing of the sacral lesion after 75 sessions (10.74 cm^2 to 0) and decrease sciatic lesion of 11.01 to 2.43 cm^2. Thus we conclude that HVPS facilitated the healing process of stimulated ulcers because the areas of all ulcers had decreased more than 78%, and in three of them there was complete healing.

Keywords | electric stimulation; wound healing; photogrammetry; wound closure techniques.

RESUMO | O tratamento de úlceras cutâneas por estimulação elétrica tem crescido na prática clínica, no entanto, faltam estudos que investiguem a efetividade desse recurso em acompanhamento prolongado ou até que ocorra a cicatrização completa das lesões. Assim, a estimulação elétrica de alta voltagem (EEAV) foi aplicada em úlceras cutâneas crônicas com o objetivo de reduzir a área da lesão. Para tanto, participaram do estudo quatro homens que apresentavam seis úlceras cutâneas que receberam a EEAV (fase=15ms; F=100 Hz; T: 100 a 150 V; fases gêmeas), 2 vezes por semana, durante 30 minutos. O eletrodo com polaridade negativa foi colocado sobre a lesão e o positivo no trajeto vascular. As úlceras foram avaliadas pré e pós-intervenção por meio da fotogrametria, sendo calculada a área da lesão. Como resultado, observamos o fechamento completo da lesão nos sujeitos I e II (área de 4,66 cm^2 para 0 após 21 sessões e de 1,74 cm^2 para 0 após 16 sessões, respectivamente). O sujeito III obteve redução de 93% na área da lesão direita (de 2,02 para 0,14 cm^2) e na esquerda de 80,40% (de 2,50 para 0,49 cm^2), após 100 sessões. No sujeito IV ocorreu o fechamento completo da lesão sacral (de 10,74 cm^2 para 0) e a redução da lesão isquiática de 11,01 para 2,43 cm^2, após 75 sessões. Desse modo, concluímos que a EEAV facilitou o processo de cicatrização das úlceras estimuladas, pois as áreas de todas as úlceras apresentaram diminuição superior a 78%, havendo cicatrização completa em três delas.

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Descritores | estimulação elétrica; cicatrização; fotogrametria; técnicas de fechamento de ferimentos.

RESUMEN | El tratamiento de úlceras cutáneas con el uso de estimulación eléctrica tiene crecido en la práctica clínica, pero no hay muchos estudios que investigaron la efectividad de eso recurso en el acompañamiento prolongado o hasta la ocurrencia de la cicatrización completa de las lesiones. Así, la estimulación eléctrica de alto voltaje (EEAV) fue aplicada en úlceras cutáneas crónicas con el objetivo de reducir la área de la lesión. Para eso, cuatro hombres con seis úlceras cutáneas crónicas participaron del estudio, los cuales habían recibido la EEAV (fase=15ms; F=100 Hz; T: el 100 al 150 V; fases), dos veces por semana, por 30 minutos. Lo electrodo con polaridad negativa fue posicionado sobre la lesión y lo positivo en el trayecto vascular. Las úlceras fueron evaluadas antes y después de la intervención por medio de la fotogrametría, y la área de la lesión fue calculada. Se observó, como resultado, el cierre completo de la lesión en los sujetos I y II (área de 4,66 cm^2 para 0 después de 21 sesiones y de 1,74 cm^2 para 0 después de 16 sesiones, respectivamente). El sujeto III obtuvo reducción del 93% en el local de la lesión derecha (de 2,02 para 0,14 cm^2) y en la izquierda del 80,40% (del 2,50 para 0,49 cm^2) después de 100 sesiones. El cierre completo de la lesión del sacro (del 10,74 cm^2 para 0) y la reducción de la isquiática del 11,01 para 2,43 cm^2 ocurrieron en el sujeto IV después de 75 sesiones. Por lo tanto, se concluyo que la EEAV ha facilitado el proceso de cicatrización de las úlceras estimuladas, pues las áreas de todas las úlceras presentaron disminución superior al 78% con cicatrización completa en tres de ellas.

Palabras clave | estimulación eléctrica; cicatrización de heridas; fotogrametría; técnicas de cierre de heridas.

INTRODUCTION

Skin injuries present several etiologies and can become chronic when the tissue formation is interrupted or destroyed by repeated damage or if one or two chemical or cellular elements of the healing process are deficient[1].

In Brazil, the prevention work in general does not happen or it is not properly carried out, therefore the prevalence of pressure ulcers in hospitals is extremely high[2,3]. Difficulty in treatment success is increased due to problems like deficiencies in the patient's nutritional status and in mobility[4].

In 211 assessed risk patients, a 39.8% incidence of pressure ulcers was seen[5]. Also, higher rates of morbidity and mortality were found in these patients[1,6]. These results demonstrate the urgent need to create a program for the prevention and treatment of these wounds.

Not only the wounds of this etiology, but also the chronic injuries, present a relevant repercussion for the health of individuals at risk[7]. The slow healing in vascular ulcers has serious consequences for people, including pain, loss of job, and quality of life decrease[8].

Depending on the injury level and depth in the tissues, the ulcers may bring complications like osteomyelitis, septicemia, or death. Besides the financial losses caused to patients and their relatives, the problem also has psychological disorders and hinders or makes it difficult for the participation of the subject in rehabilitation programs[9,10].

Skin ulcer treatment using electrical stimulation has been growing in the clinical practice[11], because it is a low-cost option and it may accelerate the healing process, reducing treatment expenses[12]. In studies using animals, it has been suggested that electrical stimulation improves wound healing, increasing growth factors in the epidermis and dermis[13].

Regan et al.[14], in a systematic review, presented evidence supporting the use of electrical stimulation to accelerate tissue repair rate in pressure ulcers. Among these resources, the high-voltage pulsed stimulation (HVPS) promotes the acceleration of the healing process in chronic ulcers of several etiologies[7,15-18], due to its significant effects to improve circulation[15].

However, the majority of studies[7,16-19] followed-up the wounds for a short period (4–6 weeks of stimulation)[14], and they did not try to investigate if this resource would lead to the complete lesion healing. Thus, we observed the evolution of the areas of chronic skin ulcers during the treatment with HVPS for 12 months and/or until its complete cicatrization.

METHODOLOGY

Study outline

One case series describing the treatment results of six skin ulcers by HVPS, followed-up for 12 months, is presented in this study.

Participants

Four male subjects (aged 54.75±20.71 years) with chronic skin ulcers were invited to take part in this case

series. The inclusion criterion consisted of skin lesion appearance of any etiology, and infection in the lesion to be treated was the exclusion criterion.

Ethics procedures

This study was carried out according to the resolution 196/96 of the Brazilian National Health Board, approved by the Research Ethics Committee, under protocol 08-3/019. The evaluation and intervention using HVPS was done in the Physical Therapy School Clinic. All subjects were informed about the experimental procedures and signed the free informed consent to take part in this study.

Intervention

The suggested treatment was performed with the Neurodyn High Volt® high-voltage electrical stimulation equipment (IBRAMED®, registration in M.S. 5122).

Intervention consisted of HVPS application (phase=15 ms; F=100 Hz; T: 100–150 V; twin phases) with a similar protocol to that described by Houghton et al.[7], the treatment was carried out twice a week, and each session lasted 30 minutes.

The negative polarity active electrodes were wrapped up in sterilized gauze moistened by saline, being later placed and fixed with an adhesive tape inside the wound. The 10×18 cm self-adhesive dispersive electrode (VALUTRODE® Axelgaard Manufacturing Co., Ltd.) was fixed with positive polarity in the vascular path of the area. After every 5 minutes of treatment, the gauze under the electrodes was humidified with saline using a sterilized syringe as support.

At the end of each session, asepsis of the electrodes was carried out for later use. The polarity of electrodes remained the same throughout the treatment.

It is worth mentioning that each subject had his/her own electrode kit. It was not used with any other medicine treatment in the treated ulcer, it was only necessary to apply, on a daily basis, sunflower oil — essential fatty acids, which are derived from linoleic acid — for skin hydration, and gauze for protection. This procedure was adopted because all patients were already making use of such oil for years.

Evaluation method

The treatment evolution was analyzed by means of standardized photographic records for the wound area analysis, in squared centimeters. Hence, a digital camera was used (Panasonic® Lumix, model FX12; 7.2 megapixels), being placed at 40 cm from the ulcer, perpendicularly, including in the picture a millimeter-scaled ruler touching the skin.

After the recordings, the images were processed in the software used by Davini et al.[19], which calculates the area. A 1-cm distance is marked in the ruler and reported to the software that automatically calculates it in pixels (DPixels).

Data analysis

Data presentation was performed in a descriptive manner to each subject individually. This procedure was adopted because the ulcers have different etiologies and the number of HVPS sessions may vary between the subjects.

RESULTS

Subject I

A 73-year-old patient presenting a superficial venous ulcer, plain crater, in the anterior region of the right tibia, with partial loss of the skin continuity involving epidermis and dermis, since a year. In the initial evaluation, the wound had a 4.66 cm^2 area. After 10 sessions, it reduced to 0.65 cm^2, and the complete healing was obtained after 21 sessions (Figure 1).

Subject II

Twenty-six years old, paraplegic, with pressure ulcer in the sacral area, for 1 year, classified as degree II (plain crater). In the initial photogrammetry, it registered an area of 1.74 cm^2. After 10 sessions, there was a reduction of the injury lesion to 0.75 cm^2, and the complete closure happened after 4 months using HVPS, totaling 26 sessions (Figure 2).

Subject III

Fifty-five years old, quadriplegic, presented two sciatic pressure ulcers since 8 years ago. The right ulcer had a 2.02 cm^2 area in the beginning of the treatment, which in the 44th session diminished to 0.51 cm^2 and in the 100th session to 0.14 cm^2 (93% reduction),

as seen in Figure 3. Also, it should be mentioned that the lesion was classified as degree IV (deep crater with extensive destruction).

The left sciatic pressure ulcer was also a degree IV lesion, which suffered three surgical intervention attempts (graft), with no success. It presented an initial area of 2.50 cm^2 and after the 44th session, this surface reduced to 1.53 cm^2 and in the 100th session to 0.49 cm^2 (80.40% decrease).

It was also seen that there was an increase of the lesion area between the 48th and 50th sessions from 1.53 to 2.07 cm^2. In such a period, the treatment was suspended for 2 months due to an infection in the lesion (Figure 3).

Subject IV

Sixty-six years old, triplegic due to cerebrovascular accident, presents two pressure ulcers being one sacral and the other sciatic to the right, with 4 years of existence. The sacral lesion, degree III (deep crater), had an initial area of 10.74 cm^2, and after 37 sessions it decreased to 3.79 cm^2, reaching complete healing after 75 sessions (Figure 4).

The sciatic ulcer, degree III, presented in the initial evaluation an 11.01 cm^2 area, which, after 34 sessions, decreased to 2.94 cm^2 and by the end of the 75th session, to 2.82 cm^2 (74.38% decrease).

DISCUSSION

In this study, we could notice complete closure of the three wounds and an important reduction of other three lesions treated with HVPS. The ulcers had different etiologies and classifications; therefore, there were distinct responses as to cicatrization speed/time and percentage. Furthermore, the follow-up of these patients for a short period enabled a better comprehension of the lesion reaction to stimulation.

Wound classification comprises stage I–IV with regard to depth of tissue compromising instead of lesion severity[20,21]. Cicatrization happens with the support of granulation tissue, by second intention, and the ulcer improvement or worsening evaluation is carried out by measuring its dimension[22]. Thus, we verified

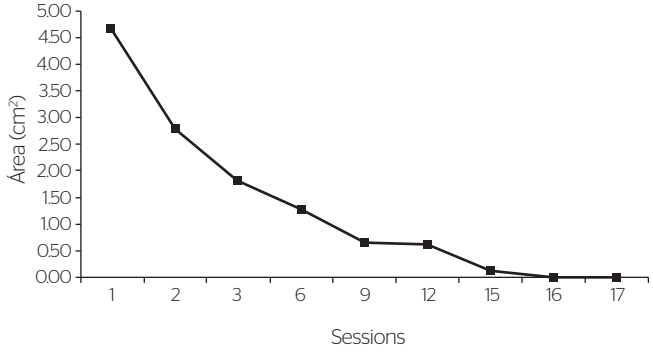

Figure 1. Evolution of the ulcer area (cm^2) from subject I's leg during the high-voltage pulsed stimulation treatment

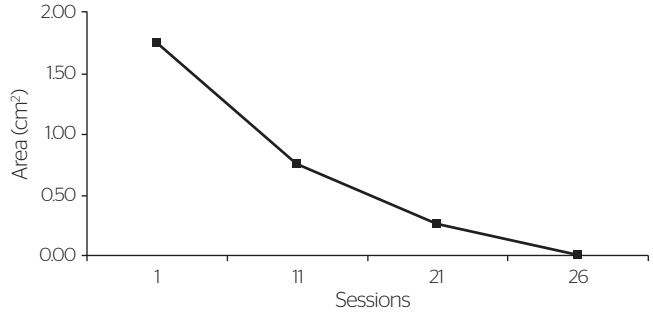

Figure 2. Evolution of the ulcer area (cm^2) of sacral pressure from subject II in the high-voltage pulsed stimulation treatment

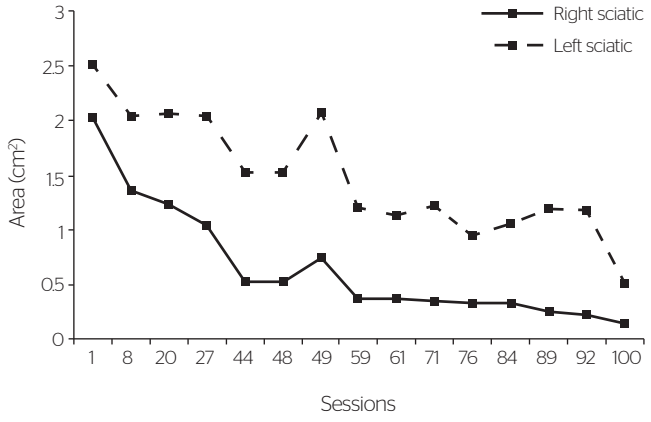

Figure 3. Evolution of the area (cm^2) of right and left sciatic pressure ulcers from subject III in the high-voltage pulsed stimulation treatment

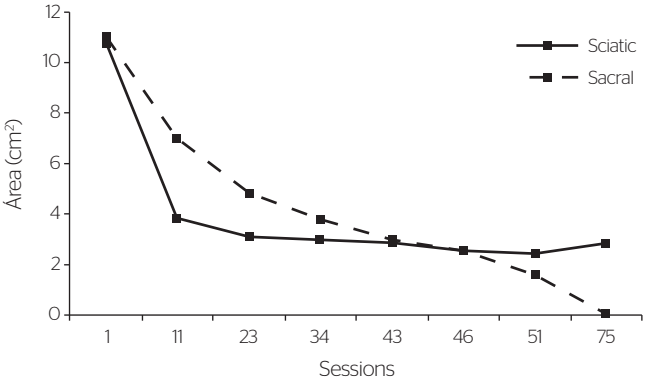

Figure 4. Evolution of the area (cm^2) of right sacral and sciatic pressure ulcers from subject IV in the high-voltage pulsed stimulation treatment

that superficial ulcers presented an accelerated healing speed, because in subjects I and II (degree II) there was complete closure of the lesion after 21 and 26 sessions, respectively, while the sacral lesion healing of subject IV (degree III) was achieved after 75 sessions.

In subjects with degree IV ulcers, there was a decrease from 74 to 93% of the lesions areas; however, it happened more slowly. This reaction is somehow expected, since cicatrization by second intention occurs from inside to outside the ulcer and, due to the fact that these lesions were deep, changes would be seen in depth and not in the lesion area[20]. This fact could be seen by the visualization of the photographed pictures, but it was not measured in this study and, therefore, it is a limitation of this work.

All lesions that did not completely heal were in the gluteal fold, that is, an area with much humidity and contamination and also a constant pressured place, which are caused by shearing and compression strengths.

Studies have indicated an improvement preferentially in pressure ulcers[19]. Griffin et al.[17] observed, after 20 consecutive stimulation days, an 80% decrease of pressure ulcers places and of 52% in the control group. The protocol consisted of negative polarity use in the lesion (60 minutes). Unger et al.[16], however, performed polarity inversion of the electrodes, initiating by negative and after 6 days of treatment, it changed to positive. Eight of the nine stimulated patients had an 88.9% healing, while in the control group three of the eight subjects had a 37.5% improvement. In another study[23], stage II ulcers presented increment of the cicatrization with significant increase in the granulation tissue concerning the control group, after 6 weeks of treatment.

However, HVPS in vascular chronic ulcers in the leg produced a reduction in the size of wounds when compared to those that were considered treated[7]. A similar result was seen in this study, as in one of the subjects who had his/her lesion healed, the etiology was venous. On the other side, in another study[24], nine patients had their venous ulcers healed or reduced, while four had them increased, and the authors reported the reason for this as the incidence time of the lesions. Concerning time of the lesion, it is worth mentioning that the unhealed ulcers were aged between four and eight years old, which is a higher time than those presenting complete cicatrization (one year).

We also saw a fast lowering of the lesion areas in the beginning of treatment, which may be stabilized. This decrease in healing speed may be explained due to the better reaction to the polarity inversion according to the phases in which the tissue repair is found than in the maintenance of the same polarity until the treatment ends[25,26].

Recio et al.[27] started the HVPS treatment with negative polarity and then changed it weekly, thus achieving complete healing of chronic pressure ulcers (existent from 11 to 14 months).

The tissue repair is divided into four phases: hemostasia, inflammation, proliferative, and remodeling[1]; therefore, Sussman and Byl[26] preconized the beginning of the treatment with negative polarity, changing it every 3 days in the proliferation phase, and in the remodeling stage, it was altered every day. It is quite probable that the polarity inversion be necessary in these chronic and deep lesions, in order to not slow the cicatrization process.

The mechanisms for which the HVPS reaches positive healing results have not been well established yet. The current, despite its polarity (single-phase wave)[28,29], passes through the skin with despicable thermal and electrochemical effects and the highest current density is available for target tissues, affecting the cellular level directly[30]. In addition, it can be efficient to contain and absorb acute edemas, to fasten the dermal and sub-dermal tissues repair, and to control pain[31]. Other aspect that should be considered is galvanotaxis, which is the migration of electric-charged cells with regard to an electrical field of opposed polarity. As to skin cicatrization, the electrical fields exogenously applied with the same size as those found in lesions, promote migration of human keratinocytes for the cathode[32], which is the polarity used on the lesion in this study.

Besides its circulatory and regenerative actions, the HVPS presents bactericide action[18], because it leads to local changes in the pH, electrochemical changes in the injured tissue, and recruitment of anti-microbial factors of the organism.

Endogenous electrical fields from a wound may act as an important guide of stimulus for the migration of epidermal stem cells from their niches to the interior of the wound, making healing easer[33]. However, it has been suggested that the cascade of events that happen during and after the cicatrization inflammatory/proliferative process may have suffered an interruption in the chronic wound cases, and electrical stimulation of these wounds produces effects that are able to restart or start the repairing phase[34,35]. In addition, the electrical stimulation can accelerate cicatrization, reducing inflammation, increasing angiogenesis, and advancing to remodeling stages[36].

The increase in microcirculation around the inframalleolar ischemic wounds would explain the quick decay in the area of 11 ulcers stimulated by HVPS[37]. Furthermore, it was verified that there is an increase of the oxygen transcutaneous pressure and capillary perfusion in the edge of venous ulcers, which indicates that HVPS can result in oxygenation and cicatrization due to the increase of tissue perfusion[38,39].

Finally, the efficacy of HVPS treatment may be associated with lesion etiology, occurrence time, wound location, and polarity of electrodes. Therefore, clinical perspectives of our results reinforce the extensive need for multidisciplinary treatment when handling this pathology. Considering the limitations of this outline as to the generalization possibility, the next step should be HVPS intervention use in a randomized and representative sample in patients with skin ulcers, determining the polarity based on cicatrization phase and associating it with conventional treatments.

CONCLUSION

From the experimental conditions that were performed, it could be verified that the areas of all ulcers stimulated by HVPS decreased and there was complete healing in three of them.

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