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Endogenous potentials in two different models of human skin injuries

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Abstract

The present study deals with endogenous potentials of skin injuries in humans and their role in the healing process. Two different models of injured skin were examined: experimental abrasion on forearm and sacral pressure sore. The preliminary results consistently demonstrate positive and markedly higher potentials at the injury sites of both types of wounds (ranging from 22 to 54 mV), compared with the potential of intact skin surface. The effects of electrical stimulation on endogenous potentials of pressure sores were also investigated.

INTRODUCTION

The endogenous electrical properties of living systems and the possible employment of externally applied electricity for influencing natural processes appear to be complementary phenomena which have motivated researchers through the centuries [1].

Chronic wounds are a troublesome problem with complex and not totally understood etiologies which concern numerous patient populations (spinal cord injured (SCI) patients, immobile older people, diabetic patients etc.). Owing to difficulties in preventive treatment, which would remain the best approach to this problem, electrical stimulation modalities seem to offer effective and simple methods for treating chronic wounds [2]. However, because of the lack of knowl-

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edge regarding the mechanisms through which electrotherapy might augment soft-tissue healing, application and confidence in the use of this promising treatment has not increased in line with its merits.

Our search for an explanation of the influence of externally applied electrical current on the healing process led us to the measurement of endogenous electricity [3,4]. Burr et al. [5] found that endogenous electrical potentials of the wounds (after abdominal surgery) were initially positive, but became negative after the fourth day and remained negative until healing was completed. In 1960 Becker [6] theorized that injury causes a localized shift in current flow (current of injury) that triggers biological repair and is generated by the nervous system. Such a role for the nervous system has since been disproved [4]. Barker et al. [3] further investigated the source of these currents in mammalian skin. Measurements showed voltages across the epidermis ("skin batteries") ranging from 30 to 100 mV, where the skin surface was always negative with respect to the dermis. They also suggested that this voltage may subserve epidermal wound healing [3].

Although we are still far from determining the role and significance of bio-electric potentials (endogenous potentials) in the wound-healing process, we present the preliminary results of the endogenous potential measurements of injured human skin. Owing to ethical and practical reasons, measurements of voltage gradient over experimental wounds in humans (volunteers) by means of the progression of injury into deeper tissue planes are not feasible. Therefore, potential measurements were performed on two types of injuries: skin abrasion in healthy volunteers (affected epidermis) and pressure sores in SCI patients (tissue damage down to subdermal space). The purpose of our study was to identify the endogenous potential of the abrasions/pressure sores and the intact surrounding skin, and from the obtained values make an assumption regarding the location of possible sources of endogenous potential. Our intention was also to examine the possible effects of electrical stimulation (ES), used to enhance the wound healing, on the endogenous potential of the pressure sores and the surrounding skin.

METHOD

For the endogenous potential measurement an instrument with a Burr–Brown 3431J electrometer amplifier (differential input impedance greater than $10^{11}\Omega$) was used. In order to ensure low direct current (DC) resistance of the electrode/electrolyte interface and a stable half-cell potential, Ag–AgCl electrodes were chosen. Electrical contact between the sterilized electrodes and the tissue was made through a physiological solution. The electrodes had an electrode potential of less than 2 mV and a drift of less than 0.5 mV h^{-1}. The electrodes were checked before and after each measurement. Positioning of the electrodes was performed by means of a manipulator. Initial transient phenomena lasted for less than 1 min. The readout was carried out after a quasi-stationary (up to ± 3 mV) value was attained for at least 3 min.

The measured voltage (endogenous potential) was the difference between the

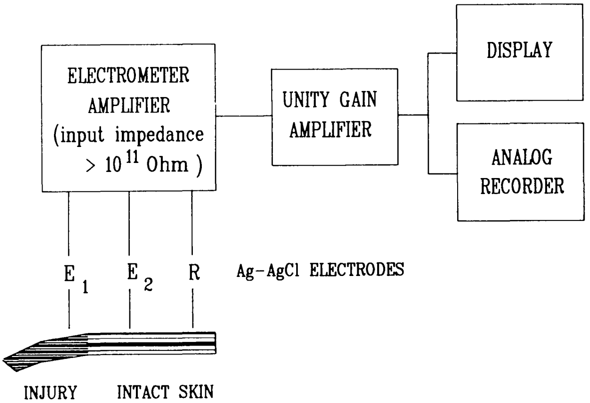

Fig. 1. Measurement setup for endogenous potential measurements.

potentials of the two selected points, with the reference electrode always placed distally on intact skin. The measurement setup is shown in Fig. 1.

Abrasion

In order to identify the endogenous potential of the abrasion, eight healthy volunteers were involved in the study. Electrical measurements were performed on the skin surface of the forearm as follows:

(1) For five successive days on intact skin in order to obtain a baseline value for the two sites on the intact skin.

(2) On skin just before abrasion and immediately after it.

(3) Daily during the healing process (up to nine days) on the abrasion site. The measured voltage was the difference between the potentials of the two selected points on the skin; intact–intact, and then (after the abrasion) intact–injured. The area of abrasion was about 1.5 cm^2.

Pressure sore

Endogenous potential measurements were performed on 7 SCI in-patients having sacral pressure sores with similar initial complexity (tissue damage including subdermal space). The patients were included in the study after receiving particular treatment for a period no less than one month. Preservation of the measurement protocol used in the cases of abrasion was impossible. The measurements of the endogenous potentials of the patient's sacral skin area before development of the pressure sore were not feasible. Also, due to the long-term healing (a few months) required for such sores, it would be difficult to follow the endogenous potentials during the entire healing process. Therefore, the measurements of endogenous potentials were performed on five successive days during the healing.

Endogenous potentials of the sore surrounding (about 1 cm from the sore edge) compared with the intact skin were measured, followed by the endogenous potential measurement of the pressure sores compared with the same intact area. In the case of five patients included in a double-blind study on the effects of ES on wound healing [7], the measurement procedure described above was repeated after 2 h of application of ES.

Two pressure sores were treated conventionally. The treatment included daily application of a new bandage (standard dressing) only.

In the case of two patients, out of five included in the ES program, the placebo effect was examined (sham cases). For these, the electrodes were placed on the intact skin of the sore surrounding but electrical current was not applied. Thus the sores received conventional treatment only. For the remaining three pressure sores 2 h of treatment with a constant direct current of 0.6 mA was added to the conventional wound care. In two sores the ES was delivered through two self-adhering electrodes placed on the intact skin of the sore surrounding. One sore received the same ES treatment but had different electrode placement. The positive electrode (rubber electrode in a gauze soaked in the physiological solution) was placed into the sore cavity and negative electrodes in the sore surrounding.

RESULTS

Abrasion

The measured baseline potential difference between two sites on intact skin were within the range 15 to -10 mV for all volunteers. The endogenous potentials before and immediately after abrasion are shown in Fig. 2. The endogenous potentials of the abrasions were found to be more positive, ranging from 28 to 41 mV, compared with the potential of intact skin. The signs of endogenous potential of abrasions did not change during the healing (Fig. 3), as reported by Burr et al. [5]. The maximal value of endogenous potential amplitude of an abrasion was not

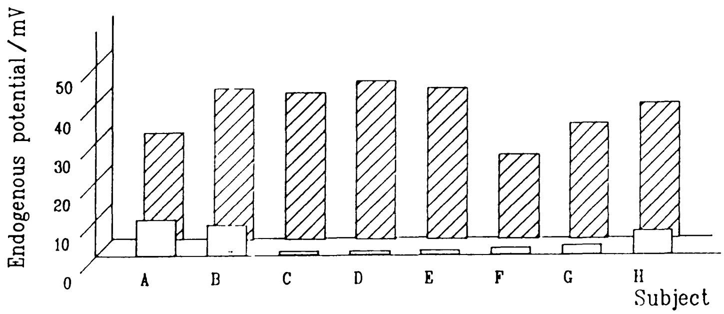

Fig. 2. Endogenous potentials before injury (unshaded) and immediately after the abrasion (shaded area).

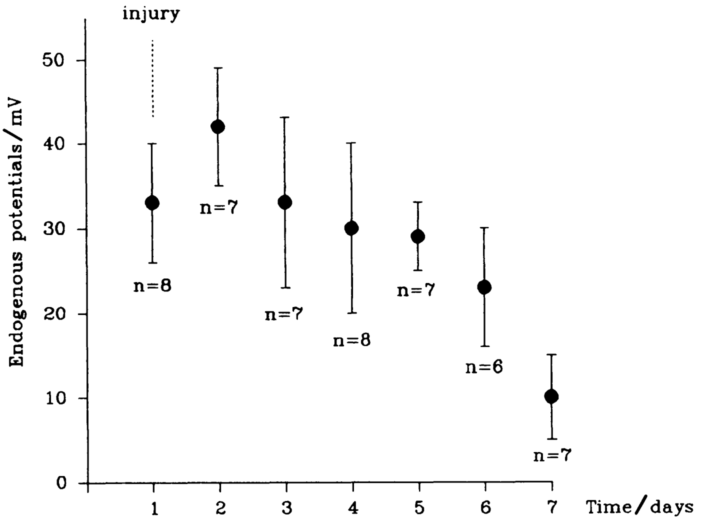

Fig. 3. Endogenous potentials (mean ± standard deviation) during the healing of the abrasions, n = number of subjects.

obtained immediately after the injury but one or two days later. After the healing was almost completed, measured potentials on "scar sites" were within the range of those measured on intact skin (Fig. 4).

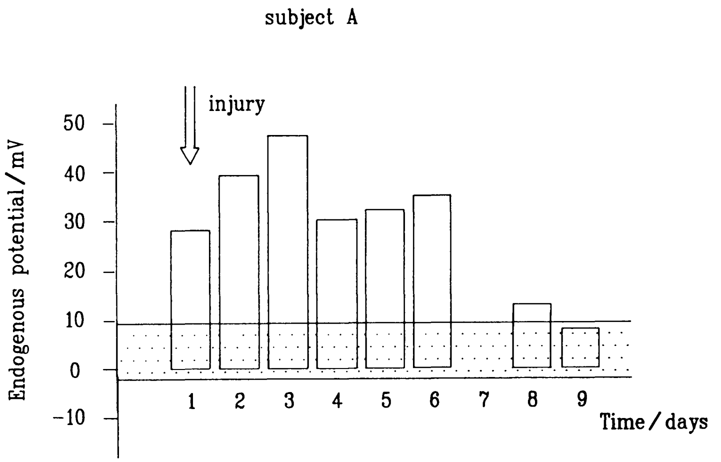

Fig. 4. Endogenous potentials (EP) of the abrasion for case A during the healing process; EP on abrasion site (unshaded), range of EP on intact skin before injury (shaded area).

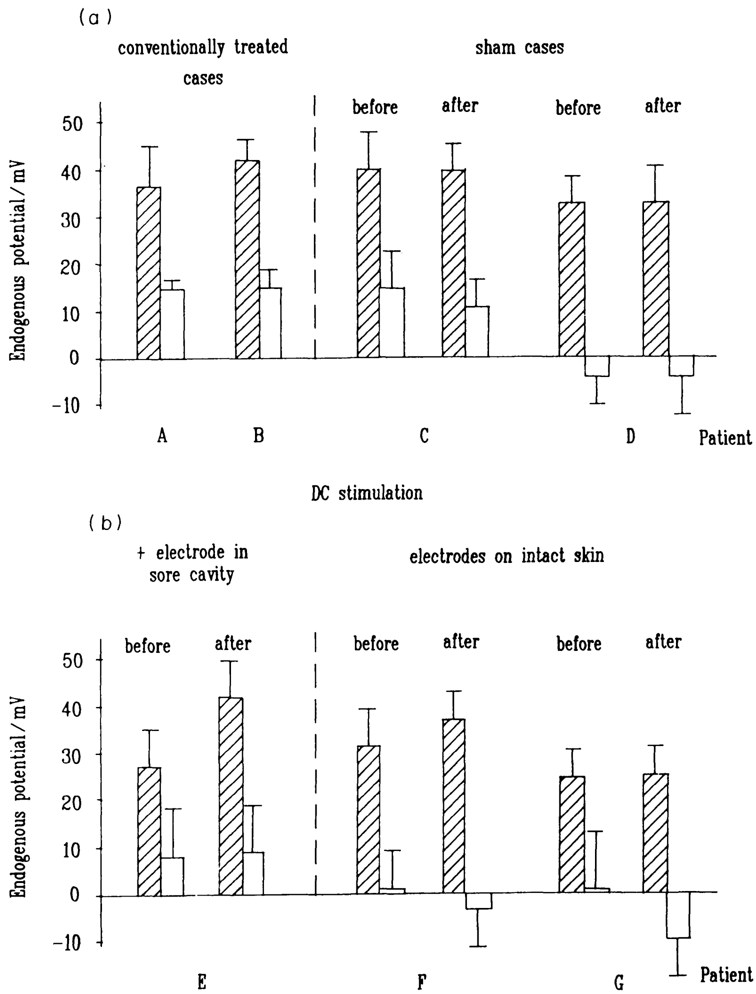

Fig. 5. Endogenous potentials of the pressure sores and their surrounding area (mean ± standard deviation for at least five successive days): (a) conventionally treated sores and sham group, (b) pressure sores treated with DC stimulation. Endogenous potentials in all cases receiving ES were additionally measured before and after 2 h of ES. Pressure sore (shaded area), close to sore surrounding (unshaded).

Pressure sore

The endogenous potentials of the pressure sores (22–54 mV) were markedly higher than those of the sore surrounding, for all measurements, regardless of the sore treatment (conventional, sham or ES), as presented in Fig. 5. In the patients receiving ES, less consistent values of the endogenous potentials of the sore surroundings, varying in sign and amplitude, were observed. The results presented in Fig. 5(b) also suggest an enhancement in the difference between the potential of the sore and its surrounding when influenced by ES. The increase (about 10 mV) of the potential gradient in sore region (sore surrounding–pressure sore) was noticed after 2 h of ES. This was not observed in the two sham cases.

DISCUSSION

The endogenous potentials of injured human skin were found to be positive and significantly higher than the variable baseline value obtained on intact skin surface. The measured voltages of abrasion on the forearm and of pressure sore on the sacral area are within the range of transepithelial potential measured by Barker et al. [3]. Even though direct comparison of endogenous potentials of an abrasion and a pressure sore is not realistic because of differences in skin, underlying tissue and general state of health, it is interesting that the results suggest the injury with a greater degree of affected tissue is not associated with additional endogenous electrical potential values.

The changes in sign of endogenous potential during the healing, reported by Burr et al. [5] were not observed in the abrasion model. As a result of the long period required for pressure sores to heal, the tendency of endogenous potentials during the healing in this model could not be established.

Effects of ES on endogenous potentials of pressure sore area were detected in three sore cases included in the study. ES seems to increase the difference between endogenous potentials of the sore and its surrounding. However, the increase in potential gradient due to ES and the number of sores included in the measurements are too small to draw a conclusion. An extended study is needed to confirm these observations.

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