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Letter to the Editor

Skin Lesions Induced by Transcranial Direct Current Stimulation (tDCS)

For several years, at the Institute Guttmann Neurorehabilitation Hospital (Barcelona, Spain), we have been applying Transcranial direct current stimulation (tDCS) for the management of Neuropathic pain after spinal cord injury. TDCS has been established as useful therapeutic option for patients with neuropathic pain [1]. Several recent studies demonstrate its efficacy, good tolerance and minimal side effects [2,3]. Our accumulated experience spans to having treated more than 100 patients, using always the same standardized protocols. Direct current is delivered with a battery-driven, constant current stimulator (NeuroConn, Ilmenau, Germany) and two surface sponge electrode pads (7 × 5 cm, 35 cm^2) soaked with a saline solution (0.9% NaCl; 308 mosm/l). The anode is placed over C3 or C4 (EEG 10/20 system) aiming to target the motor cortex, and the cathode over the contralateral supraorbital area [4,5]. The electrodes were fastened into position by using two rubber polyester headbands (70 cm × 3 cm). For patients with asymmetric pain, the anode is placed contralateral to the afflicted body part, while for patients with symmetric pain, the anode is placed over the dominant hemisphere. A constant current of 2 mA intensity is applied in daily sessions of 20 min (Current was ramped-up for 15 s until it reached 2 mA; and finally the device was turned-off with a ramp-down of 15 s) during a period of 2 weeks (from Monday to Friday; total of 10 treatment sessions). After each session and patient, the material was replaced and cleaned with soap and water.

Here we report on three cases of skin burns during this tDCS treatment. All three affected patients were men with little hair on their scalp. The three were stimulated with the same parameters getting values of impedance of 3–4.5 kΩ. Their skin's surface was not cleaned with alcohol because the impedance levels were correct. All reported a usual tingling and itching sensation under the electrodes, but none experienced significant discomfort or pain. Following our standard operating procedures, constant electrode's moistness, electrode position and impedance levels were controlled and stable during stimulation sessions.

All patients showed a mild redness of the skin under the central part of the electrodes after the tDCS session but it disappeared after few minutes without discomfort. However, in all three instances, the skin lesions occurred under the cathode (supraorbital region) at the end of the sessions. By separating the electrodes from the skin they presented small skin lesions, which resembled red burns, with small blisters (Fig. 1). The extension of the lesions ranged from 2 to 3 mm up to 1.5 cm. Lesions appeared after the second stimulation session in one patient, while for the other two, they appeared between the eighth and tenth sessions. None of the patients had a skin lesion before the start, skin disease or a history of any pathological skin disorder.

Stimulation sessions were interrupted when the skin lesions appeared and postponed for a week until the lesions disappeared (lesions healed without any scars). Once stimulation sessions with new electrodes were restarted, none of the subjects noted pain or discomfort, and lesions did not reappear.

To our knowledge, these side effects have only been reported twice previously [6,7]. In one instance the skin lesion was under the cathode, while in the second reported case the lesion was under the anode, but in both cases the lesions occurred in the supraorbital region. In both published instances the investigators had used tap water to moisten the electrodes. Tap water can contain metallic particles which can be iontophoretically transferred into the skin and cause heating. However, in our patients the burns occurred despite the use of saline solution.

Palm et al. [6] applied tDCS at the same intensity as in our protocol (2 mA) but Frank et al. [7] used lower intensities (1.5 mA). Frank et al. [7] found skin lesions located in the area where the wire connects with the electrode (forehead), but in our patients we were careful to prevent contact with the wire or the connector with the skin.

Current density must not exceed 14.29 mA/cm^2 to prevent tissue damage [5]. In our patients current densities were approximately 0.057 mA/cm^2 (2 mA/35 cm^2), which is far below safety thresholds. Despite having a good electrode contact with the skin, a homogenous electrode pressure could not be guaranteed because the maximum pressure of the band was centered in the middle of the sponge. In spite of these conditions, we did not observe any effect of considerable heat under surface electrodes, such as redness or sweating. We conclude that the electrodes were not dried out because we kept on moisturizing them whenever they seemed to start drying out (controlled from the impedance values).

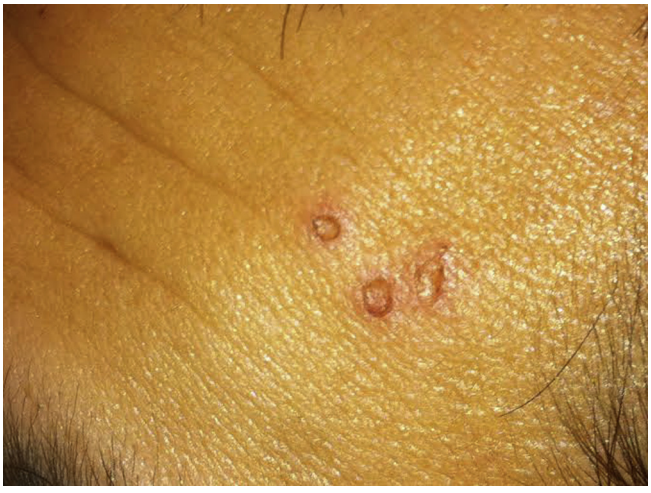

Figure 1. Cathodal skin lesion after tDCS.

In addition to stimulation intensity, several other factors can affect current density, e.g. sponge shape, solution salinity, skin conditions, electrode shape, location, placement and electrode subjection. Several studies simulate the current flow density across the skin in different models [8,9].

Considering our experience and the two previously published cases it seems that the properties of the skin may be the key factor for the risk of burns. However, it is also important to remember electrode characteristics: the shape of the electrodes can determine the potential risk for higher current densities at the edges, and the material integrity of the electrodes which can be lost over time can affect isotropic conductivity.

Based on the above, tDCS electrodes may need to be replaced periodically and round electrodes may offer some advantages over square or rectangular electrodes. Rectangular electrodes are known to cause moderately higher peak concentration of current, comparing to round electrodes, at least at the rectangular electrode corners [10]. Measures to reduce the risk of skin lesions should include a more homogenous subjection of the electrodes thinking of using caps to make it safer and more effective.

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