EFFECTIVENESS OF SELECTED SURFACE ELECTRODES FOR MOTOR STIMULATION

by

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Transcutaneous electric motor stimulation is becoming an increasingly used treatment modality in the management of central nervous system disorders. It may be used to strengthen paretic muscles, actively range joints innervated by paretic muscles to prevent spastic flexion deformities, serve as a permanent means of orthotic substitution, or facilitate neuromuscular recovery.

A common problem encountered in all applications of electrostimulation to achieve a strong motor response has been pain. Different investigators have studied the effect of wave form, pulse duration, frequency and other parameters to minimize the pain response. Relatively little attention has been given to the influence of electrode type.[5]

One of the earliest electrodes was an immersion electrode in which the patient placed his hands or feet. A substantial improvement was made by Duchenne who covered metal plates with cloth soaked in saline solution.[1,3] In recent years, newer types of electrodes have been devised, including silver/silver chloride; carbon-loaded conductive silicon rubber; wire particle-filled rubber and vinyls; solvent-activated current-passing tape; self-adhering disposable pregelled pads; and others.[4] Electrode jellies and pastes have been developed to improve contact between electrode and skin.[2]

The purpose of this study is to compare the relative clinical effectiveness of a variety of selected surface electrodes used for motor stimulation.

METHODOLOGY

Six normal subjects volunteered for study. All were between the ages of 24 and 29 years.

Four types of electrodes were evaluated (Figure 1). The first was a self-adhering, disposable pregelled pad with a current path from a silver/silver chloride snap to electrolyte jelly contained in a sponge rubber pad (surface area 13 cm^2). The second, a solvent-activated current-passing tape activated with acetone before placement on the skin (surface area 34 cm^2). The third, a carbon-loaded silicon conductive rubber pad (surface area 54 cm^2). The fourth, felt-covered metal plates (surface area 54 cm^2). Carbon rubber was tested with two types of commonly used gels: Aquasonic which is a water-soluble transmission agent and Spectra 360 which is a salt-free transmission agent. The felt pads were tested with both saline solution and tap water.

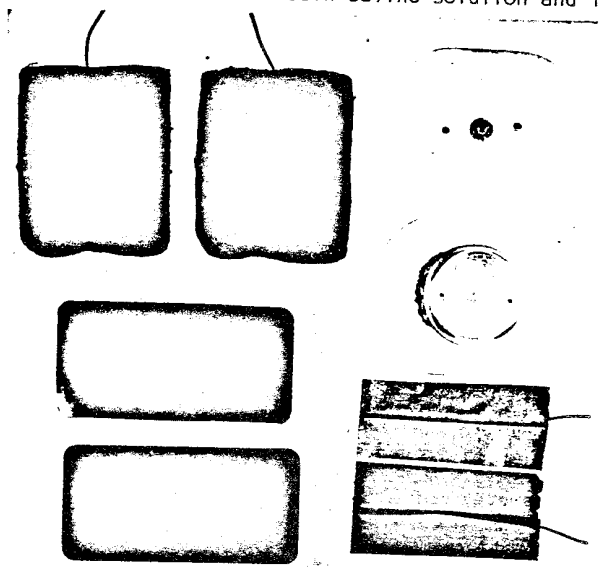

Figure 1
Felt pad electrodes - upper left; Pregelled electrodes - upper right; Carbon rubber - lower left; Conductive tape - lower right

The experiment consisted of a short and long-term test protocol to evaluate the effectiveness of the electrodes during acute and chronic usage.

Short-Term Protocol

Knee extensor torque was measured by tensiometer with the subject placed in a sitting position and the knee flexed 60 degrees. Subjects were asked to exert a maximum voluntary effort.

A randomly selected pair of electrodes was applied over the quadriceps after cleansing of the skin with alcohol. The indifferent electrode was placed 5 cm. above the superior edge of the patella, and the active electrode over the motor point of the rectus femoris. The motor point was marked with silver nitrate to obtain consistency in electrode placement.

Stimulus intensity was increased in incremental amounts until the maximum tolerable limit was attained. Two tests were conducted with each pair of electrodes. The electrical stimulus consisted of a monophasic square wave with a pulse duration of 400 microseconds, a frequency of 35 pulses per second and a duration of one second. Stimulus intensity was increased in increments of approximately 4 volts with at least a 15 second interval between each test.

Long-Term Protocol

Four electrodes were evaluated on five patients over two periods of five consecutive days. The electrodes were left in place after each test session. Felt pad electrodes were excluded because of problems of evaporation of solution. Stimulation was applied daily for 30 minutes at a level of 15 - 20 per cent of the patient's maximum voluntary torque. The average voltage and current for a threshold contraction were recorded before and after each daily session.

RESULTS

Short-Term Study

The average maximum voluntary torque (MVT) achieved by all subjects was 134 foot pounds with a range of 101 - 181 foot pounds. Using electrostimulation, the highest tolerable torques were achieved with the felt pad electrodes soaked in tap water and saline solution. Mean torques were 74 per cent and 70 per cent of the MVT respectively (Figure 2). Carbon rubber with Aquasonic gel reached values of 57 per cent of the MVT. Carbon rubber with Spectra 360 gel achieved 64 per cent of the MVT. Smaller pregelled electrodes attained only 37 per cent of the MVT, while the activated tape produced a torque which was 43 per cent of the MVT.

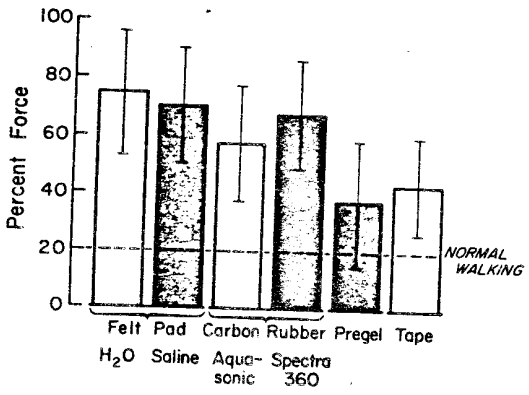

Figure 2

The felt pad electrodes had the lowest impedance (Figure 3). Impedance for carbon electrodes were slightly higher and pregelled electrodes were the highest of the three. The impedance of the activated tape electrodes varied widely. Mean values were slightly higher than the pregelled electrodes. No significant difference was noted in impedance using tap water or saline solution. Similarly, no differences were noted using carbon rubber electrodes with either Aquasonic or Spectra 360 gel.

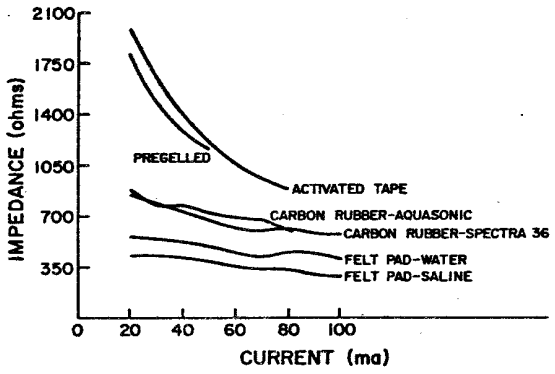

Figure 3

Long-Term Study

A comparison of mean impedance values on the first and fifth days revealed an increase of 5 per cent with carbon rubber electrodes and Spectra 360 gel, an increase of 49 per cent with the carbon rubber-Aquasonic gel (Figure 4). Impedance dropped an average of 24 per cent over the five-day

time period with the pregelled electrode. Mean impedance value of the activated tape electrodes increased 97 per cent the second day.

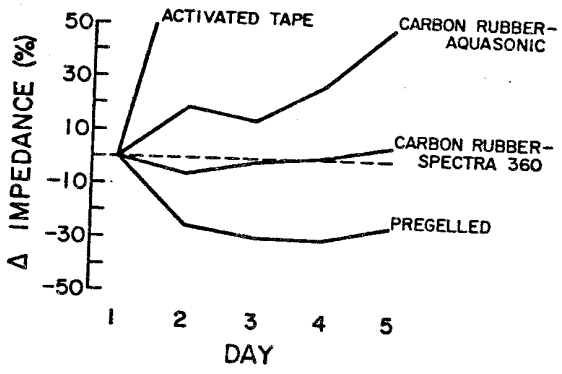

Figure 4

DISCUSSION

Felt pads soaked with either tap water or saline solution provided the highest mean comfortable torque and the lowest impedance. The clinical application of transcutaneous motor stimulation often entails treatments as frequently as two or three times on a daily basis. Because felt pads have problems associated with evaporation and for other reasons, they are unsuitable for chronic usage. The ideal electrode is easy to apply, is durable, and manifests a minimal skin reaction. Based on these criteria and under the conditions of this study, the carbon rubber electrodes in association with

Spectra 360 gel were best suited for long-term use. They produced minimal skin reaction, were easy to apply, and the majority remained intact throughout the five-day study.

Pregelled electrodes produced the lowest mean comfortable torque and had the highest impedances. They were the easiest to apply and were more durable than any other electrodes evaluated. Incorporating a conductive wire mesh inside the pregelled sponge would more evenly disperse the current and allow construction of a larger electrode.

Impedance was variable and unpredictable using the activated tape electrodes. Also, the process of electrode application was involved and the electrodes did not prove durable, making this design the least suitable of all electrodes for chronic motor stimulation.

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