

Use of Electrical Stimulation in Prosthetics for the Control of Pain

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INTRODUCTION

Electrical stimulation as a method of pain control has become increasingly popular because of its rate of success and non-invasive technique. Its use is well accepted in the medical profession, but is limited in the field of prosthetics due primarily to the lack of familiarity and knowledge of the system.

The purpose of this article is to explain the uses and possible applications of electrical stimulation in prosthetics to reduce pain. In particular, the uses of electrical stimulation and its incorporation into definitive prostheses will be discussed. The treatment of one patient will also be reviewed to illustrate some of the results obtained.

PAIN CONTROL

Pain is defined as "a more or less localized sensation of discomfort, distress, or agony resulting from the stimulation of specialized nerve endings." While one is able to define pain in terms of general sensation, knowledge of how it works is still not completely understood. Currently

there are three theories regarding the explanation of pain.

The "specificity theory" holds that pain is the result of stimulation of specific peripheral nerves and once stimulated, transfers itself in much the same way as hot and cold impulses. The impulses are either on or off with no degree of variation. The nerve ends are considered individual "end organs" from which specific impulses are relayed directly to the brain. While this theory does explain the transmission of impulses, it fails to explain the interpretation of pain by the brain in terms of intensity and the existence of pain in unidentifiable locations.

The "pattern theory" on the other hand suggests that pain exists as a stimulus to be interpreted by the brain. This could explain the various degrees of pain. It suggests that pain is not a specific stimulation in a specific area but rather the result of intensity and frequency of non-specific nerve endings.

The "gate control theory" (Melzack & Wall, 1965) suggests that pain is based on the function of the substantia gelatinosa

"T" cells which operate as transmission cells to enable the transfer of pain impulses to the dorsal horn. It is believed that the afferent impulses go through either large or small fibers to be controlled by the substantia gelatinosa as the "T" cell and it is this "T" cell that excites or inhibits pain based on ascending or descending impulses.

It is theorized that electrical stimulation creates an electrical impulse within the nerve fibers to block the pain impulses in the "T" cells. While there are several theories on how this is accomplished, there is no question that electrical stimulation can reduce pain. Since the gate control theory numerous studies have been conducted (Shealy 1968, Hymes 1973, Indeck and Printy 1975) and each resulted in the same conclusion: electrical stimulation reduced or eliminated pain in 60-80% of those patients tested.

TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION

Transcutaneous electrical nerve stimulation (TENS) is a simple form of electrical stimulation. To briefly discuss its use, each unit consists of a small stimulator where wire leads are connected to a pair of flexible carbon electrodes. Electrodes are placed on the patient's skin with gel and an electrical impulse is transmitted through the electrodes by means of the stimulator. The electrical impulse can be controlled by the stimulator unit and the location may be changed by moving the position of the electrodes.

The success of the unit depends on its ability to stimulate large nerve fibers with low strength current. To do this, rate, amplitude and pulse width of the impulse can be adjusted. The most effective impulse pattern is referred to as "square pulse" where the impulse actually pulses by going on and off. Other patterns can be modified to peak in amplitude but while this accomplished the same effect it may result in an unpleasant sensation on the skin.

In addition to impulse control, the system's success depends primarily on the placement of electrodes. The electrodes are to be positioned primarily over the painful area and if no relief is achieved, should be placed over the trigger point or as close to the peripheral nerve as possible. Electrode gel should be used between the skin and electrodes to ensure good conductivity. Electrodes should not touch one another as this eliminates the electrical flow through the body. They should be held in place with tape or self-adhesive backing.

Once the electrodes are placed on the skin, the unit should be turned on slowly until the patient feels a tingling sensation. Caution should be used because of the possibility of discomfort. The unit should be turned up to increase the tingling sensation until it envelopes the area in question to eliminate pain. Again the success or failure of the system usually depends on electrode placement and several attempts may have to be made to find their optimum location. The period of treatment can range from 30 minutes every other day to 24 hours a day depending on the type and location of pain.

PATIENT DATA

The patient, a 41 year old male, sustained a crush injury to the right fifth finger resulting in a rupture of the profundus tendon. The patient was taken to the operating room for a tendon graft. During the procedure, the patient's ulnar neurovascular bundle was lacerated. The patient went on to develop Sudeck's atrophy (neurovascular dystrophy) of the right hand and considerable stiffness secondary to prolonged immobilization. The patient never had neurologic return of the ulnar nerve and developed a chronic pain syndrome of the hand later diagnosed as causalgia (defined as "burning pain often accompanied by trophic skin changes, due primarily to injury of the peripheral nerve"). After a total of five operations, each resulting in a worsening effect, the pain increased with severe burning and cold sensations. Finally, with

total loss of function about the hand and wrist, in combination with causalgic pain, the hand was amputated at the below elbow level to relieve the pain and improve function.

Post operatively, as the wound healed, the patient continued to have a large amount of pain that over subsequent months progressed proximally up the arm into the shoulder and upper neck region. At this point causalgia was diagnosed due to the type of pain and its persistence even after amputation. The patient described the pain as burning, starting in the residual limb and radiating proximally, often accompanied by profuse sweating. It increased with changes in temperature and altitude, and yet remained unpredictable in duration and intensity.

The patient was given multiple medications including narcotics and tranquilizers that only resulted in minimal relief. He underwent a total of eight stellate ganglion blocks and attended pain clinics each with no success. To complicate the situation further, the patient sustained a broken humerus which severely limited his shoulder motion on the prosthetic side. Prosthetic fit was successful because his residual limb was normal and well developed. Due to the increased radiating pain and limited range of motion, the patient's physical and emotional condition declined. Every known form of pain control had been tried with little or no success.

EVALUATION

TENS has been tried before around the shoulder and neck region with little success so it was decided to reexamine the patient concentrating our efforts around the medial distal end of his residual limb from which the pain radiated.

The same procedures were followed on this patient as with the TENS patients. A Medtronic unit and four electrodes were used. The reasoning for using the four electrodes was to surround the residual limb with as much current as possible. Since the patient's pain originated on the medial aspect of his residual limb, 2 large pads (2x3 inches) were placed on the medial and lateral sides and 2 smaller pads

(2x2 inches) on the anterior and posterior sides (Fig. 1). Once the gel and electrodes were in place, the device was turned on and the patient allowed to adjust the intensity of stimulation to a comfortable level. With considerable repositioning of the electrodes, to maximize comfort, the patient soon noticed a marked decrease in the amount of radiating pain. He also noticed when he turned the unit off that within a two to four minute period the pain progressively returned to the level before treatment. During the treatment the only pain remaining was the dull pain about his shoulder, a pain which he said he could easily live with. He stated that this was "the first time I have ever been without pain."

Encouraged by the initial success of the system it was decided to incorporate the electrodes into a prosthesis so that he could wear his prosthesis and still experience the benefits of the TENS unit. To do this, a check socket was fabricated. The electrodes were then incorporated into the socket to check the system to see if it worked (Fig. 2). It was discovered that this



Fig. 1—Initial tests were conducted by temporarily securing the electrodes to the patient's skin.

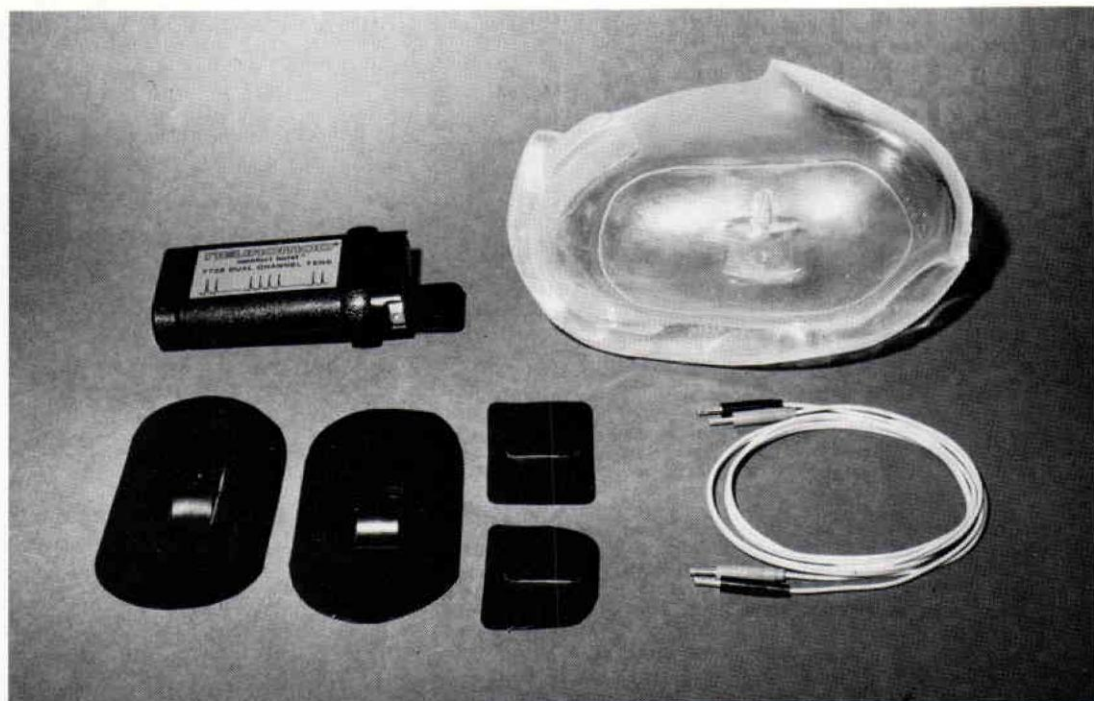


Fig. 2—The system included a medtronic TENS unit, four carbon electrodes, four electrode wires and a clear Surlyn socket.

system was not only possible, but also very successful in reducing the patient's pain; so successful that the electrodes were incorporated into the definitive prosthesis.

FABRICATION

Initially a negative impression was taken for a Muenster type socket. The positive model was modified and a Surlyn check socket fabricated to evaluate initial fit. Once a good fit was established, the existing socket was filled with plaster which was later removed to give a positive model (Fig. 3). The carbon electrodes were trimmed as desired (Figure 4) and glued to the positive model using rubber cement. The model was powdered and Surlyn pulled over the model and electrodes to form a socket (Fig. 5). This clear socket contained built-in recesses for electrode placement. To remove the socket, the plaster was broken out with careful attention not to damage the electrodes. Once removed, the edges of the socket were smoothed and holes drilled so that lead wires could at-

tach to the electrodes on the inside of the socket (Fig. 6).

With the socket and electrode placement complete, electrode gel was placed on the inside of the electrodes to help conduct the electrical impulse and assist the patient in its application by lubricating the skin (Fig. 7 and 8). The electrodes were held against the skin by the socket. Because their location on the residual limb was the same, the unit produced consistent results.

The socket was tested for a period of one week before a final definitive prosthesis was fabricated. During the trial period the patient needed to have the unit on for a 24 hour period because of his pain. Due to this dependency, it was elected to have the patient wear just the socket with embedded electrodes at night, and a definitive prosthesis with electrodes would be made for day use.

The definitive prosthesis was made of acrylic resin to eliminate any allergic reaction. During fabrication, the electrodes were again cemented to the model and a PVA bag was pulled over it. Conventional

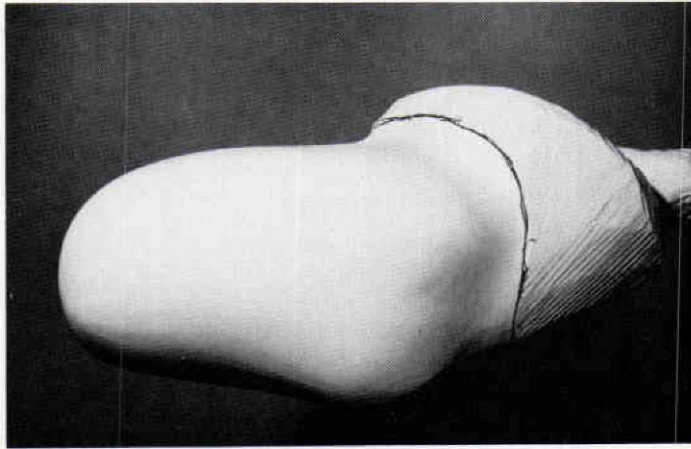


Fig. 3—The positive impression model was modified to obtain a total contact socket.



Fig. 4—The rubber/carbon electrodes were trimmed and cemented to the socket as desired.

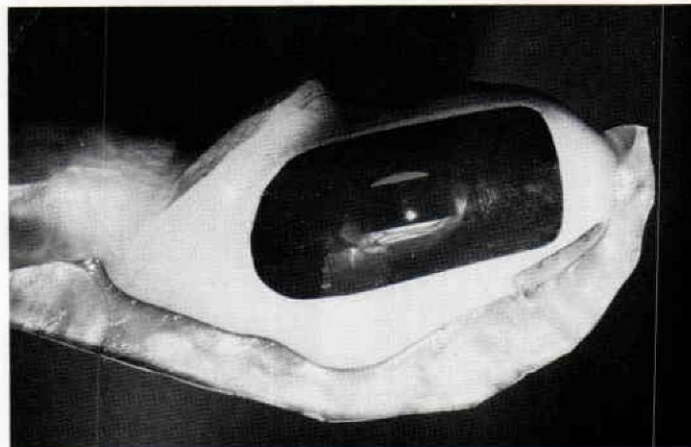


Fig. 5—Surlyn/Thermovac plastic is vacuufomed over the positive impression model and electrodes.

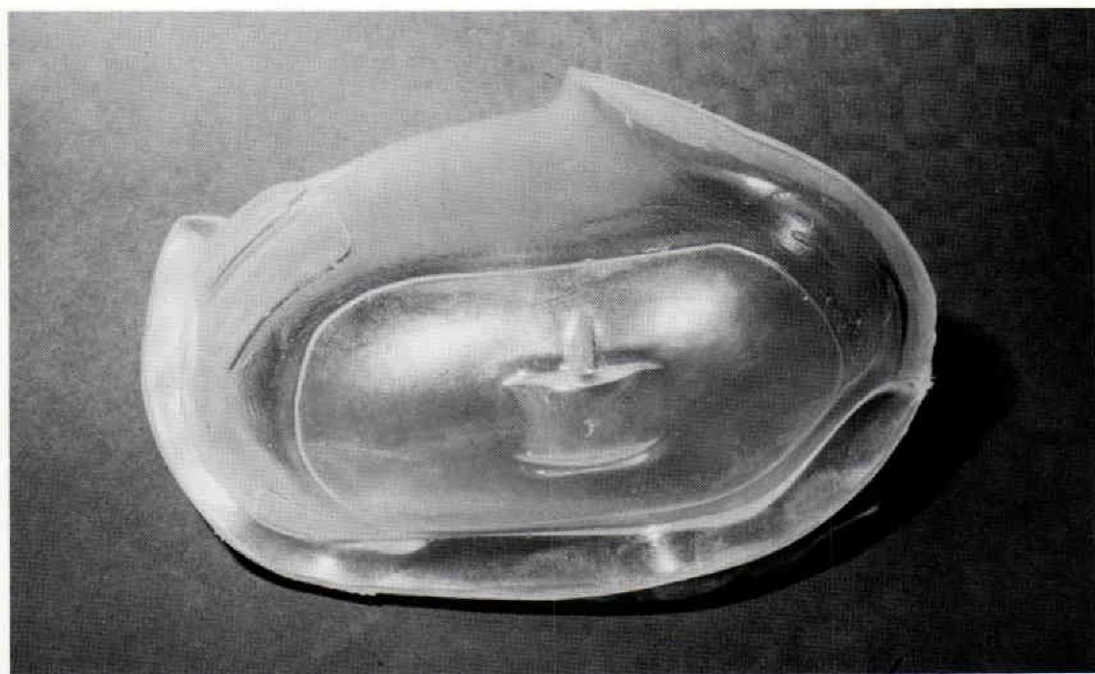


Fig. 6—The positive impression model and electrodes are removed to facilitate the finishing of the socket, and the drilling of electrode wire holes ($\frac{1}{4}$ "').

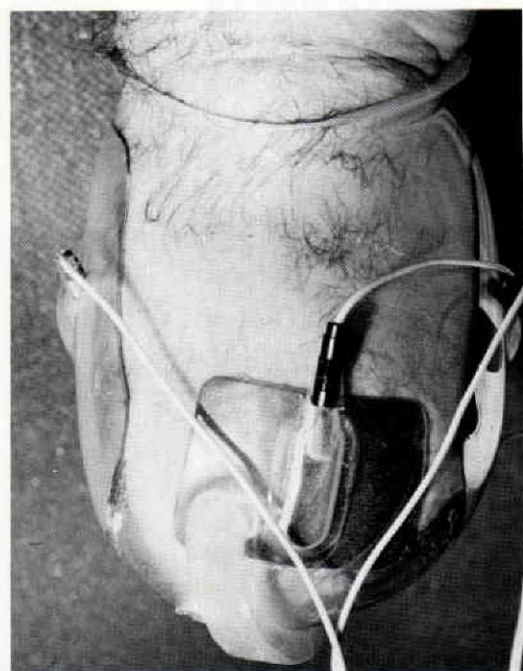


Fig. 7—The carbon electrodes were inserted inside the socket and electrode wires attached.



Fig. 8—Electrode gel was placed on the inside of the electrodes to ensure good conductivity.

laminating and alignment procedures were followed. The cast was broken out, electrodes removed from the socket, and lead wire holes drilled through the socket. The electrodes were reinserted and attached to the wire leads. This system worked as well as before and in combination with the socket at night proved to be an exceptional system for the relief of pain.

CONCLUSION

Incorporating a TENS unit directly into the socket of a prosthesis is a useful tool for decreasing pain. It is a system that can be tested for a predetermined amount of time and, when successful, be incorporated into a definitive prosthesis to produce the same results.

So far it has been used on upper extremity Muenster and above knee suction sockets with a large degree of success, and it is hoped that through continued

development could be used on other types of sockets. With its initial success it is felt the system will find continued applications in prosthetics and give the patient an alternative means of reducing pain.

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