Proof-of-Concept Tremor Suppression Sleeve for Essential Tremor Patients

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Introduction

Essential Tremor (ET) is among the most common movement disorders. It is characterized by involuntary, rhythmic movement in the body, most often in the hands or head. The primary treatment options include deep brain surgery and/or medication, both of which can cause undesired side effects. The Neuromechanics Research Group at BYU is investigating alternative treatments by studying the effect of low-level electrical stimulation of affected extrinsic hand muscles on tremor in ET patients. While the research may prove promising, there are still several obstacles to overcome for this approach to be practical. To apply electrical stimulation, self-adhesive electrodes are placed on the patient’s arm and wired to a transcutaneous electrical nerve stimulator (TENS) unit, which applies a small electrical current. These electrodes are prone to falling off the patient, and the wires can impede the user’s movement. In this project, we sought to find a simple solution to apply electrical current on a patient’s forearm without impeding motion or being uncomfortable. To meet these objectives, we modified a compression sleeve to include adjustable electrodes and a simple, integrated electronics control pack on the upper arm.

Methodology

The design of this tremor suppression device was divided into two subsystems: the sleeve with electrodes and the electronics pack. The sleeve with electrodes was designed first. We hypothesized that a compression sleeve could create enough skin contact pressure that a non-sticky electrode could be used as an alternative to traditional sticky electrodes. This was tested by placing small copper squares inside of a compression sleeve and wiring them to an over-the-counter TENS device. When wearing the sleeve with copper pads tucked inside, it became clear that the sleeve created sufficient contact to allow current to flow into the arm similar to the standard sticky electrodes. We then modified the sleeve so we could mount the electrodes and electronics to the sleeve. We lined the inside of the sleeve with soft Velcro and sewed fabric channels on the outside to organize cabling between the electrodes on the forearm and the electronics pack mounted to the upper arm (Figure 2). We fashioned several copper electrodes using hook-end Velcro backing that could be placed anywhere inside the sleeve.

Once the sleeve and electrode hardware were complete, the electronics pack needed to be designed. Instead of using an off-the-shelf TENS unit, a custom unit was created to simplify the controls and mounting hardware. The circuit was modified from a schematic found on the internet to output two square, biphasic, symmetric voltage signals with short, fixed pulse widths and adjustable frequency and amplitude (Figure 4). A permanent circuit was soldered together with through-hole perforated board (Figure 3). We put the circuit in an enclosure that we modeled in SolidWorks and 3D printed. We also added snaps to the sleeve and enclosure so that the electronics pack could be easily attached. The final sleeve and electronics system can be seen in Figure 1 below.

Results
We were successful at creating a simple device to apply electrical stimulation on the forearm for tremor patients. The sleeve is simple to wear and comfortable to use without impeding typical movement. The electrode placement is fully adjustable to accommodate the needs of different patients. The electronics are small, simple, inexpensive, and easy to control. The TENS unit can stimulate both flexor and extensor sides of the arm with individual amplitude controls for both. It also has an adjustable frequency control that can stimulate between 1-107 Hz, an LED that indicates the stimulation frequency, and a simple On-Off button that is easy to access and press. The TENS unit and electrodes are also easy to remove so the sleeve can be machine washed.

Figure 1 – Overview of tremor suppression sleeve. The control pack mounts on the upper-arm with a large on-off switch (red), three parameter adjustment knobs (black), and an LED indicator (middle).

Figure 2 – Inside of sleeve with electrodes. Soft, comfortable Velcro lines the sleeve so the electrodes can be moved to contact desired muscle locations.
Figure 3 – Inside of finished electronics pack, showing hand-soldered through-hole electronics. Electrodes plug in using 3.5 mm audio jacks.

Figure 4 – Example oscilloscope output of the electronic circuit. This plot shows voltage vs. time, 410V peak-to-peak, 9.25ms period.

Discussion

While this unit met all design objectives, several improvements need to be made to this design before it is ready for clinical use. Because this prototype was hand-built, the build quality and size do not reflect a marketable product yet. Using surface-mount electronics would make the electronics circuit much more compact, but this was beyond the scope of this project. Similarly, the analog controls used in this circuit could be replaced by more stable and robust digital controls, but this would increase circuit complexity. The electrodes also need some improvement. Copper was used for its excellent conductivity and availability. However, copper is highly corrosive and uncomfortable to wear against the skin for prolonged periods. A better electrode material should be investigated to improve durability, comfort, and longevity. While several improvements to the design could be made, the most important question to be addressed is the treatment itself. Preliminary results suggest that this treatment may be promising, but there is still much work to be done in this field before it can be used clinically. Future research efforts should be concentrated on this area before any benefits of the device can be realized, regardless of design improvements.

Conclusion

This project represents a proof-of-concept approach to low-level electrical stimulation treatment for ET patients. The prototype created shows that it is possible to create a device that is comfortable, easy to use and maintain, applies TENS stimulation at desired locations on a patient’s forearm, and allows for natural, unobstructed movement. While the specifics of this device could be improved, and the muscle stimulation research needs to be fully substantiated and fine-tuned, this project is an encouraging step toward alternative options for those who suffer from ET.

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